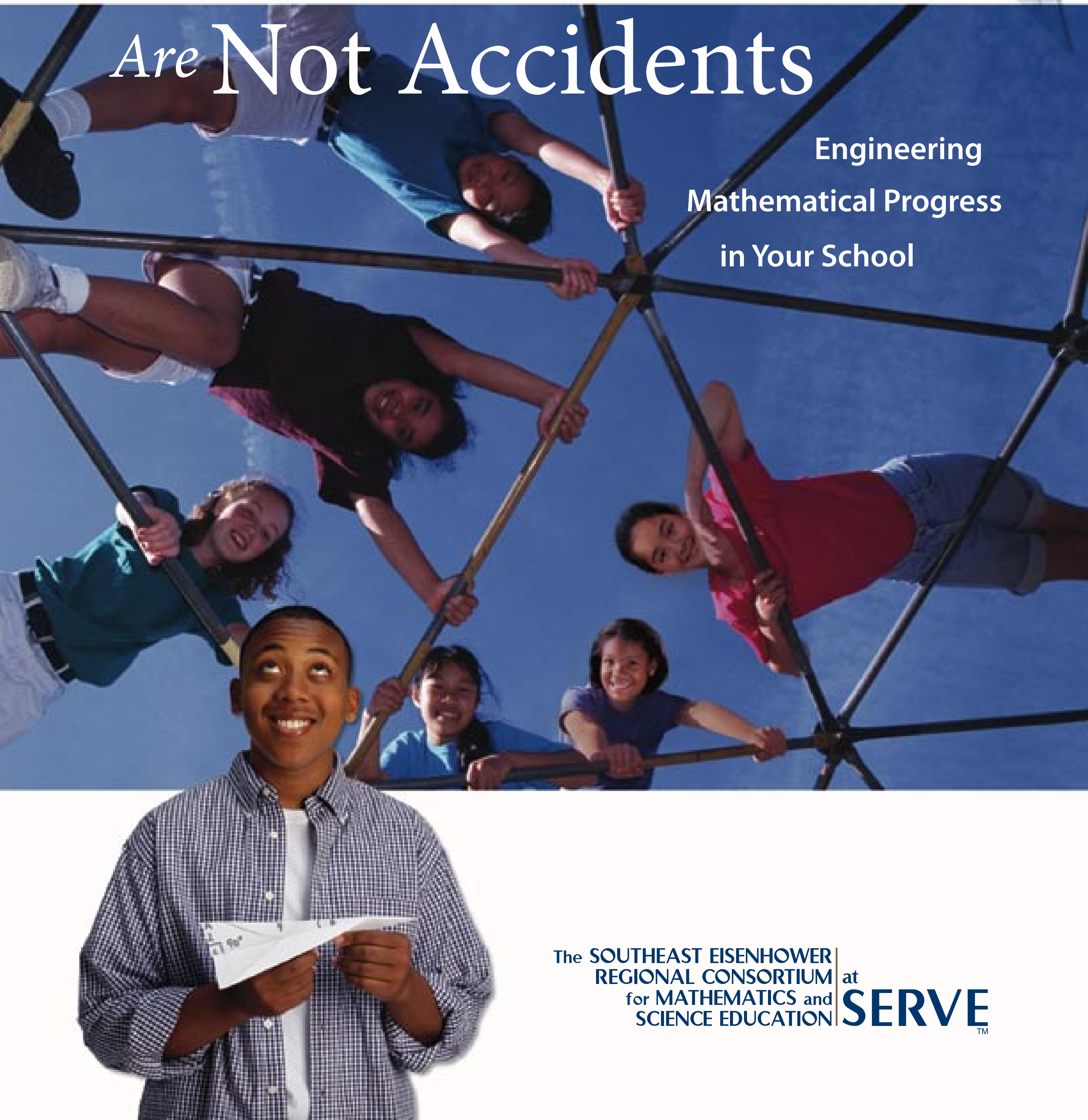
# Access *and* Opportunities *to* Learn *Are* Not Accidents

## Engineering Mathematical Progress in Your School



The SOUTHEAST EISENHOWER REGIONAL CONSORTIUM for MATHEMATICS and SCIENCE EDUCATION at SERVE™

# Access *and* Opportunities *to* Learn *Are* Not Accidents

Engineering
Mathematical Progress
in Your School

Written for SERC@SERVE by
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The SOUTHEAST EISENHOWER REGIONAL CONSORTIUM for MATHEMATICS and SCIENCE EDUCATION at SERVE™

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Associated with the School of Education
University of North Carolina at Greensboro


First Printing, 2005

Produced by
The Southeast Eisenhower Regional Consortium for Mathematics and Science (SERC) at SERVE
www.serve.org

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Mid-Atlantic Equity Center, an educational assistance center serving Delaware, the District of Columbia, Maryland, Pennsylvania, Virginia and West Virginia.
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This publication is based on work sponsored by the U.S. Department of Education under award number R319A000011.



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# Contents

# Foreword

The achievement gap in mathematics remains an abhorrent reality, despite periodic surges and fragmented efforts of school reform movements to eradicate it. We cannot deny that mathematics education in the United States has undergone dramatic transformations during the 20 or more years that have passed since I first encountered Lucy Sells' 1978 seminal research on the relationship between mathematics education and access to courses and careers in science and engineering. Sells, a Berkeley sociologist who sought to understand the under-representation of women in science-related professions, identified mathematics as the "critical filter." At that time, my attention was on the achievement gap in mathematics because it served as an effective pre-college filter for access to science-related courses and careers for African American and Latino/Hispanic and female students. In the introduction to *Mathematics and Science: Critical Filters for the Future of Minority Students* (first published in 1985), the available data allowed me to summarize the situation at that time quite simply:

> Black and Hispanic students are scoring below the national norm on science and mathematics achievement tests and are not enrolling in advanced high school mathematics classes in proportion to their numbers in the population.... Because mathematics is a sequential subject and most science and science-related positions require a mathematics background, minority students must be encouraged to begin their mathematics education early and to continue through high school at a minimum.

William Tate's new monograph *Access and Opportunities to Learn Are Not Accidents: Engineering Mathematical Progress in Your School* comes at a time when eliminating this gap takes on a new urgency, one driven by this country's quest to maintain its position in a technology-driven, global economy that requires a new level of mathematical competency from its workers, even those who are not directly engaged in science and engineering fields. The 2000 Census and subsequent demographic projections strongly suggest that it is foolhardy not to prepare all students for a meaningful role in addressing the challenges the nation can expect to face in light of rapidly expanding globalization. Large-scale past failures to achieve parity of outcomes in mathematics learning makes this monograph a welcome tool for those who are determined to eliminate the achievement gap.

While my 1985 publication sought to develop for educators—particularly elementary and middle school principals and teachers—a research-based awareness of then-known cognitive, affective, and classroom variables related to minority student performance in mathematics and science, *Access and Opportunities to Learn Are Not Accidents: Engineering Mathematical Progress,* takes us deeper, particularly into the issues of classroom and instructional variables. Using an engineering metaphor, Dr. Tate has carefully developed a tool to help readers—whether they are concerned with policy, practice, or equity issues in mathematics—know the kind and quality of information they would need in designing effective mathematics intervention programs. He provides the "designer" with the historical context for this work: a summary of the events, movements, and policies that have had a significant impact on school mathematics, with particular attention to the unique mathematics reform history and challenges faced by urban schools. True to the spirit of engineering, he defines the problem, providing a rich exploration of current demographic trends juxtaposed with mathematics achievement trends. His summaries of the research and analyses of data from the National Longitudinal Study (NELS) and the National Assessment of Educational Progress (NAEP) can serve as cohesive resources on trends. We usually read these kinds of reports individually, but his analysis across these two major assessment programs quite effectively highlights for even the busiest reader trends in mathematics performance by race/ethnicity and socioeconomic status. The data give concrete meaning to the term "achievement gap," making a strong case for sufficiently resourced, cohesive intervention in the mathematics education of low SES students in general—and low SES minority students, in particular.

To assist educators in designing a cohesive set of intervention strategies, Dr. Tate introduces a user-friendly theoretical framework, based on Opportunity to Learn research and data from international assessments. With this framework in mind, he engages the reader in an exploration of powerful classroom/instructional variables related to "time and quality" factors in the learning of mathematics. Appropriate content exposure, coverage, and emphasis and quality instructional delivery are all essential. Fortunately, in the discussion of instructional delivery, the often-overlooked issue of some students having access but not the support that would enable them to exploit the opportunity to learn mathematics is addressed.

*Access and Opportunities to Learn Are Not Accidents: Engineering Mathematical Progress* offers us much solid information, substantive recommendations, thoughtful strategies, and innovative models. This monograph offers tools for understanding and action. With comprehensive planning, intentional implementation, monitoring, and appropriate assessment, we can eliminate the achievement gap.

Thank you, William Tate, for the hard facts and the promising strategies that you offer here! Thank you, Dr. Francena Cummings, Director of the Mathematics and Science Consortium at SERVE, for recognizing the need and supporting the development of this monograph.

DeAnna Banks Beane, Director
Partnership for Learning
Association of Science Technology Centers
Incorporated

# Preface

About 20 years ago, I began working with schools to improve minority student participation and achievement in mathematics and science, and there were only a few resources available on this topic. The most practical tool available was *Mathematics and Science: Critical Filters for the Future* (Beane, 1985). In this document, Beane described research-based factors that influenced the achievement and participation of minority students. (See the Foreword by Beane in this document.) In addition to delineating research-based factors, *Critical Filters* offered strategies to support elementary principals and school-based teacher leaders in designing intervention plans to address improving mathematics and science achievement. While there are signs that there have been many initiatives targeting minority students' achievement in mathematics since 1985, there is still a considerable dearth of research and practical tools related to this issue. Further, current trends across national assessment sources show that there have been some changes in the achievement of underserved and minority students; however, the "achievement gap" persists.

With the release of *Curriculum and Evaluation Standards for School Mathematics* in 1989 and the subsequent release of *Principles and Standards for School Mathematics* in 2000, the National Council of Teachers of Mathematics (NCTM) set a clear standard: Mathematical power must be considered the right of—and the expectation for—every child. To this end, in *Principles and Standards for School Mathematics,* the equity principle offers a vision of mathematics education that includes high expectations, and worthwhile opportunities for **all** students. While the "mathematics-for-all" disposition may not be new, it is much more explicit about who can and should have access to quality mathematics.

The Southeast Eisenhower Regional Consortium at SERVE commissioned this monograph, *Access and Opportunities to Learn are Not Accidents: Engineering Mathematical Progress in Your School,* to build on the literature related to factors and interventions impacting the achievement of underserved students in mathematics education. As the title implies, the author, Dr. William F. Tate, asserts that access and opportunities to quality mathematics education require thoughtful action and planning. Utilizing an Opportunity to Learn (OTL) framework, he argues that time, quality, and design are key building blocks for engineering mathematical progress in schools. These building blocks, however, must be situated within the larger context of the system that supports the mathematics program. In essence, the mathematics program will be impacted by factors like policies, fiscal resources, and community and national contexts.

Dr. Tate amplifies his message of engineering mathematical progress by stressing the importance of a clear vision and learner goals that reflect state and local mathematics standards and accountability structures. While many arguments around improving mathematics for underserved and minority students center on access to courses and tracking, he focuses on equally important variables related to quality instruction in mathematics classrooms and support infrastructures. This focus includes the selection and implementation of a quality curriculum and an accountability plan that monitors student progress, ultimately providing data that may be used in continuous refinement of the mathematics program.

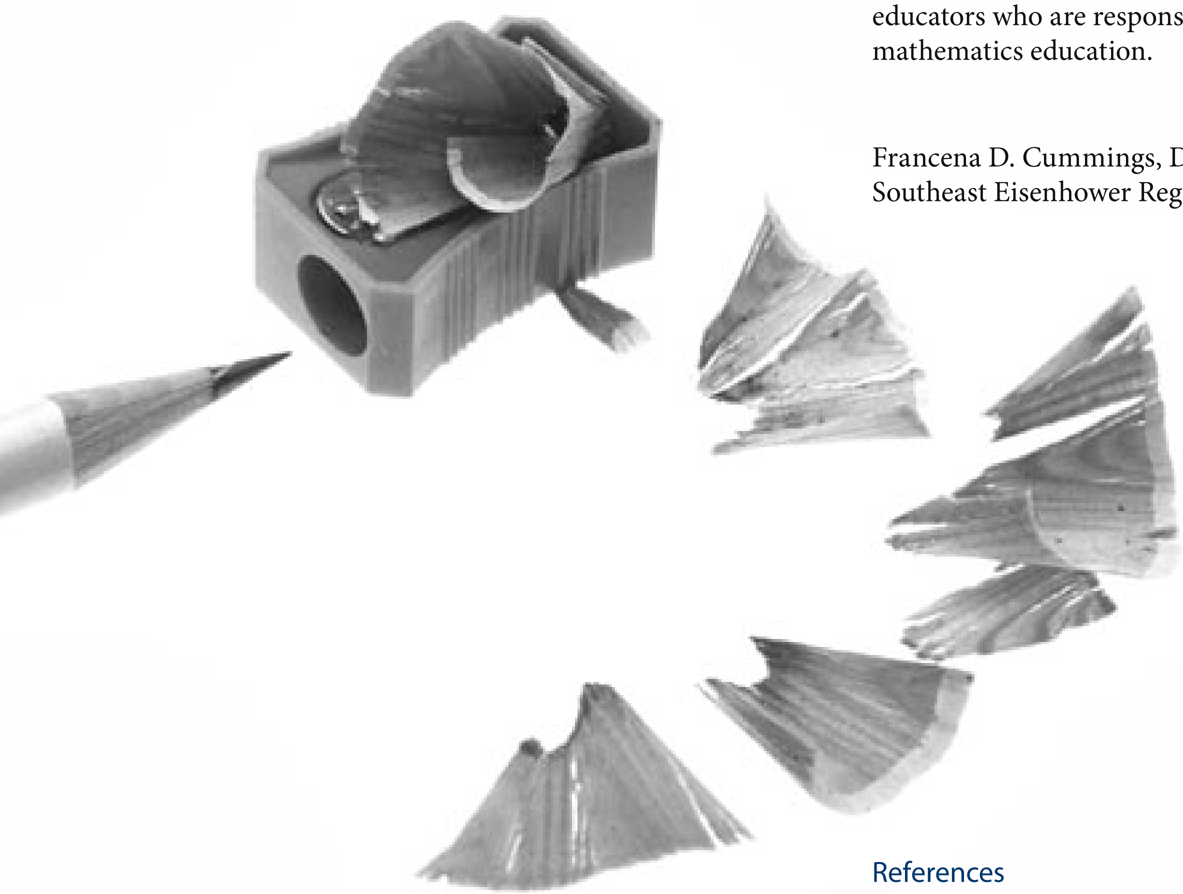
What does this mean for advancing underserved populations' participation in quality mathematics programs? There is an expectation that teachers will be the heart of delivering quality instruction, embracing instructional practices that include a major shift from their traditional methods of teaching—lecturing and textbook-oriented instruction. To this end, Dr. Tate encourages providing models of professional development that afford teachers similar opportunities—active learning that is designed from the ideas and resources related to their daily work with students. Moreover, there is a clear expectation that teachers have an opportunity to learn together as they consider standards-based instruction. As teachers learn to negotiate various professional development strategies like coaching, cases, mentoring, and study groups, they are often empowered to provide leadership within the local schools.

Empowering teachers! Empowered students! Reform in mathematics has been ongoing for quite a while but Cummins (1989) asserts that it is only possible when educators play an active role in involving students in the process. He believes that:

> Students who are empowered by their interactions with educators experience a sense of control over their own lives and they develop the ability, confidence, and motivation to succeed academically. They participate competently in instruction as a result of having developed a confident cultural identity and appropriate strategies for accessing the information or resources they require in order to carry out academic tasks to which they are committed (p.4).

Cummins' remarks emphasize how important teachers are to students' learning and liking mathematics. Access and *Opportunities to Learn: Engineering Mathematical Progress in Your Schools* offers valuable data and strategies for designing and maintaining quality mathematics programs. This monograph should be valuable to policymakers, teacher leaders, principals, and educators who are responsible for providing K–12 mathematics education.

Francena D. Cummings, Director
Southeast Eisenhower Regional Consortium



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# Acknowledgments

The ideas in this monograph were developed from many conversations among colleagues and educators who are interested in quality learning opportunities for underserved students. The author thanks the following colleagues who took the time to review various drafts of this monograph: Paul Cobb, Joseph Harris, Gerunda Hughes, Kay Gilliland, Celia Rousseau, Marilyn Strutchens, Michele Chappell, Yuria Orihuela, Doris Hipps, and Jerome Shaw. In addition, the contributions of all those who attended the Southeast Eisenhower Regional Consortium at SERVE's Special Issues Forum* to discuss this monograph are also very much appreciated.

I want to thank Jere Confrey and the McKenzie Group for permission to use tools constructed under their respective programs of research and development.

The opinions expressed in this monograph are those of the author and do not necessarily reflect the views of the supporting agencies or reviewers. Versions of this monograph were presented at the 2003 Annual Meeting of the National Council of Teachers of Mathematics and the 2004 Annual Meeting of the American Educational Research Association.

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# Introduction

In 1985, the Mid-Atlantic Equity Center published *Mathematics and Science: Critical Filters for the Future,* addressing mathematics education and academic opportunity. In this monograph, DeAnna Banks Beane argued, "The success of many intervention programs demonstrates that there are no permanent barriers to minority student achievement in science and mathematics. However, the data tell us that the longer we wait to intervene, the more invincible the barriers become" (p. 1). Her remarks are a reminder of the challenges and opportunities in school mathematics requiring clarification and associated strategies for change and improvement. This monograph represents an effort to build upon and extend beyond the literature on school mathematics as discussed in *Mathematics and Science: Critical Filters for the Future*.

The political and educational landscape in school mathematics has changed in important ways since 1985. Three significant changes are discussed here. The first change is the introduction of mathematics standards to the education community, specifically the 1989 release of the *Curriculum and Evaluation Standards for School Mathematics* published by the National Council of Teachers of Mathematics (NCTM). This document was a part of a series of mathematics standards documents produced by the Council (NCTM, 1991; 1995; 2000). The role of standards in educational practice and policy making has gained traction, and today dominates discourse related to school mathematics. The NCTM Standards documents and related educational policy developments have resulted in the rapid evolution of standards-based language. In the post *Curriculum and Evaluation Standards for School Mathematics* era (1990-2002), the word "standard" produced 26,843 documents in the ERIC database. While the citations were not all directly related to school mathematics, the point here is that standards-based language permeates the education terrain. Most states have standards for school mathematics that signal to local school districts goals for instruction and desired student outcomes.

A second change is a movement calling for educational leadership to more directly address issues of learning and teaching in schools (Rowan, 1995). Significant changes are taking place in the ways the constructs of teaching and learning are now being defined by researchers, practitioners, and policymakers. During the 1980s and 1990s, cognitive models of teaching and learning were formulated and tested, and many small-scale efforts to transition from the predominant behaviorist models of instructional theory occurred. This research and development has implications for understanding best practice in the design of educational goals, implementation of instructional practices, and development of assessment techniques. Thus, instructional leadership requires a deep understanding of research and development. Many state and federal policies require school district instructional leadership to document the effectiveness or research-base undergirding local change strategies. This represents a new demand on those charged with district-wide and school-level improvements. This monograph is designed for instructional leaders facing today's research-focused managerial demands.

A third and related change in the educational landscape is the *No Child Left Behind Act of 2001* (NCLB). The NCLB Act calls for a new level of Title I accountability by requiring each state to implement accountability systems covering all public schools and public school students. These systems must be based on rigorous state standards in mathematics, annual testing for all students in grades 3–8, and annual statewide progress objectives ensuring that all groups of

students reach established levels of mathematical proficiency within 12 years. Assessment findings and state progress objectives must be broken out by poverty, race, ethnicity, disability, and limited English proficiency to ensure that no group is left behind. School districts and schools that fail to make adequate yearly progress (AYP) toward statewide proficiency goals will, over time, be subject to improvement, corrective action, and restructuring measures aimed at getting them back on course to meet state standards. Schools that meet or exceed AYP objectives or close achievement gaps will be eligible for State Academic Achievement Awards.

Setting rigorous state standards and related accountability models is placing significant pressure on school districts to rethink past practice and to look for effective and sound strategies to support the teaching and learning of mathematics. This monograph is designed to assist teachers, administrators, and community supporters in their efforts to incorporate research-based strategies into the school mathematics program.

CHAPTER 1

# Engineering a Change in Mathematics Education

*"Knowledge and productivity are like compound interest. Given two people of approximately the same ability and one person who works 10% more than the other, the latter will more than twice out produce the former. The more you know, the more you learn; the more you learn, the more you can do; the more you can do, the more the opportunity—it is very much like compound interest. I don't want to give you a rate, but it is a very high rate. Given two people with exactly the same ability, the one person who manages day in and day out to get in one more hour of thinking will be tremendously more productive over a lifetime."*

*–Richard Hamming*[1]

How can mathematics educators be more productive teachers? How do we accelerate students' learning of school mathematics? These are difficult questions. The teaching and learning process is embedded in a complex web of schools, school districts, communities, and state governance systems that each play a role in expanding students' opportunity to learn and think about mathematics. Some have criticized the mathematics education community for failing to adequately articulate how access and opportunity to learn mathematics can be expanded to traditionally underserved students (Apple, 1992; Hilliard, 1991; Meyer, 1991). The National Council of Teachers of Mathematics (NCTM) has recognized this criticism. Recent standards documents produced by the NCTM have called for a focus on equity. For example, the *Principles and Standards for School Mathematics* (NCTM, 2000) stated:

> The vision of equity in mathematics education challenges a pervasive societal belief in North America that only some students are capable of learning mathematics. This belief, in contrast to the equally pervasive view that all students can and should learn to read and write in English, leads to low expectations for too many students. Low expectations are especially problematic because students who live in poverty, students who are not native speakers of English, students with disabilities, females, and many nonwhite students have traditionally been far more likely than their counterparts in other demographic groups to be the victims of low expectations. Expectations must be raised—mathematics can and must be learned by all students. (pp. 12–13)

High expectations for all students is a new challenge in school mathematics education. Past reform efforts in mathematics education were designed for more select groups. For example, in the post-*Brown* era, the "new math" reform movement sought to improve mathematics education in the United States, as it was thought that good scientific education was a vital component of a strong national defense program and a robust economy (Kliebard, 1987). Initiated in response to the launch of Sputnik by the Soviet Union, this mathematics reform effort designed to address the nation's scientific crisis did little to address the problems of students of color in urban and rural areas of the United States (Garcia, 1995; Nieto, 1995; Tate, 1997). Many responsible for the reform effort stated that their programs should be

[1] This quote is taken from a transcription of the Bell Communications Research Seminar, March 7, 1986.


limited to "college-capable" students (Devault & Weaver, 1970; Kleibard, 1987; NCTM, 1959). The code words "college capable" were a signifier to the educational establishment that only a select few communities and students were appropriate for the reform activities. This is not to say that urban, rural, and poor communities were completely denied opportunities to participate in this reform effort. Instead, these opportunities were limited and insufficient for the curricular and pedagogical changes called for within the reform movement. Thus, for many students—particularly African American and Hispanic students—the late 1950s and 1960s are best characterized as an era of benign neglect with respect to opportunity to learn challenging, high-level mathematics (Tate, 1996).

The focus of mathematics curriculum and pedagogy has evolved in a cyclic fashion. In the late 1960s and early 1970s, a different mathematics movement, "back to basics," emerged, which focused primarily on elementary and middle schools (NCTM, 1980). This movement was a product of policy directives conceived to address equality of educational opportunity through compensatory education. The back-to-basics effort called for instruction in a narrow set of rudimentary mathematics procedures and facts, often to the exclusion of conceptually rich tasks and advanced mathematical ideas.

Members of the National Council of Supervisors of Mathematics (NCSM) were concerned about the effect this would have on the teaching and learning of mathematics appropriate to the needs in a modern society. An NCSM 1977 position paper urged that we move forward, not "back" to the basics. Not included in the back to basics movement were ten important areas of mathematics students would find essential as adults: problem solving; applying mathematics to everyday situations; alertness to reasonableness of results; estimation and approximation; appropriate computational skills; geometry; measurement; reading, interpreting, and constructing tables, charts and graphs; using mathematics to predict; and computer literacy. The NCSM position paper was widely influential in school mathematics circles; however, the back to basics movement had a pronounced impact on the learning opportunities of low-income urban schools (Strickland & Ascher, 1992).

On the positive side, the basic skills effort resulted in limited gains on narrowly defined aspects of school mathematics for traditionally underserved student demographic groups (Secada, 1992). It served as an existence proof that when teachers and administrators agreed on and supported a common goal in mathematics, students would learn the content. However, as the vision of mathematics education has shifted from largely rudimentary notions to a more challenging standard, the limitations of past pedagogical and school organizational support systems are apparent. The National Research Council (2001) stated:

> To many people, school mathematics is virtually a phenomenon of nature. It seems timeless, set in stone—hard to change and perhaps not needing to change. But the school mathematics education of yesterday, which had a practical basis, is no longer viable. Rote learning of arithmetic procedures no longer has the clear value it once had. The widespread availability of technological tools for computation means that people are less dependent on their own powers of computation. At the same time, people are much more exposed to numbers and quantitative ideas and so need to deal with mathematics on a higher level than they did just 20 years ago. Too few U.S. students, however, leave elementary and middle school with adequate mathematical knowledge, skill, and confidence for anyone to be satisfied that all is well in school mathematics. (p. 407)

One response to the current state of affairs in school mathematics has been the rapid development and adoption of state-level mathematics standards. Typically, there is an accountability model associated with the mathematics content standards to provide indicators of student progress. However, situated in the time between the adoption of mathematics standards and the application of accountability models are important aspects of the educational process. There is an unstated assumption that standards and accountability models are only part of the solution strategy for school improvement in mathematics education. The assumption is that armed with quantitative data, local leadership—teachers, mathematics coordinators and supervisors, principals, assistant superintendents, superintendents, and school board members—will proactively respond to data. The way in which local school leadership responds to system data has a profound consequence for students' opportunity to learn.

Hence, the focus of this monograph is largely devoted to supporting the improvement of mathematics teaching and learning and, ultimately, the performance of students on measures of mathematics achievement. This monograph is written with the hope that it will help the reader understand how research-based strategies can support the engineering of positive change to the structures supporting the teaching and learning of mathematics in educational settings.

The engineer as a metaphor representing a change agent requires a brief explanation. To some, the engineer may appear to be synonymous with the scientist.[2] The distinction between a

[2] In fact, Hurd (1997) argued the paradigmatic boundaries of science are shifting toward a science guided by the coaction of science and technology, perceived as an integrated system. Further, he indicated, many in the science community speculate that engineering education may be the best preparation for the natural sciences. Yet, this speculation suggests there are distinct paradigmatic differences.

scientist and engineer is partially clarified by examining two activities related to the preparation of each professional—analysis and design. In science classes, students are required to answer problems, observe phenomena in lab settings, record observations, and perform calculations. This process is the essence of analysis. In engineering classes, the instruction often stresses the importance of design. The difference between analysis and design can be described in the following way: If only one solution to a problem exists, and discovering it merely entails putting together pieces of discrete information, the activity is probably analysis (Horenstein, 2002). In comparison, if more than one solution exists, and if determining a reasonable path demands being creative, making choices, performing tests, iterating, and evaluating, then the activity is design. Design often includes analysis; however, it also must involve at least one of these latter components. Horenstein (2002) offered the following example to further clarify the difference between analysis and design:

> [A] remote-controlled buoy is located off the coast of California and is maintained by the U.S. National Oceanic and Atmospheric Administration (NOAA). It provides 24-hour data to mariners, the Coast Guard, and weather forecasters. Processing the data stream from this buoy, posting it on the Internet, and using information to forecast the weather are examples of analysis. Deciding *how* [his emphasis] to build the buoy so that it meets the needs of NOAA is an example of design. (p. 29)

Administrator and teacher leadership charged with addressing our nation's school mathematics challenges must decide how to build effective programs. Clearly, there is more than one solution to our school mathematics problem, and designing appropriate solutions will require creativity, hard choices, performance tests, iterative action, and evaluation. Like engineers, mathematics educators must study access and opportunity-to-learn issues in great depth, and then design an intervention—"learn to build." In contrast, most scientists construct instruments to measure and study phenomena of interest—they "build to learn." This monograph is dedicated to those interested in "learning to build" outstanding school mathematics programs.

The next two chapters provide an examination of the challenges facing school mathematics change agents. Chapter 2 documents changes in U.S. mathematics achievement by reviewing population trends and national achievement trend studies. A focus of this chapter is to determine achievement trends of various racial-ethnic and socioeconomic groups. The third chapter examines opportunity-to-learn (OTL) factors that have the potential to positively influence the learning of mathematics. The intent in this chapter is to offer possible building blocks to support the engineering of positive change in school mathematics and to review the work of some scholars who have designed school mathematics improvement models based on important OTL factors. The fourth chapter provides a closer look at research-based cases of successful mathematics programs. This chapter will highlight both classroom and organizational components that are present in high performing school mathematics programs. The fifth and final chapter is a brief review of the engineering perspective—learning to build—and its importance for school mathematics improvement.

CHAPTER 2

# Learning to Build: The Problem Defined

Who are the children in the classrooms of today and the workforce of tomorrow?

One of the goals of recent calls for mathematics reform is to accelerate the achievement levels of all students, and particularly students traditionally underserved in mathematics classrooms. For example, the *National Education Goals Report: Building a Nation of Learners* (National Education Goals Panel, 1995) called for the mathematics performance of all students at the elementary and secondary levels to increase significantly in every quartile and for the distribution of minority students in each quartile to more reflect the student population as a whole. Thus, it is important for the education community to understand population trends related to various demographic groups.

The student race/ethnicity population trends have changed dramatically since the 1985 release of *Mathematics and Science: Critical Filters for the Future*. Figure 1 provides insight into this trend.

The information in Figure 1 requires additional explanation. The U.S. school-age population declined between 1980 and 1990 but became more diverse. The United States General Accounting Office (GAO, 1993) reported in 1990 there were about 44.4 million school-age children (ages 5–17), a decline of more than 2.3 million, or 5.8% since 1980. In 1992, the percentages of male and female students 5–18 years old enrolled in school were 51.4% and 48.6%, respectively (NSF, 1994).

**Figure 1 United States Student Race/Ethnicity 1986 and 2000**

| Race/Ethnicity | Fall 1986 | Fall 2000 |
|---|---|---|
| **White, non-Hispanic** | 70.4% | 61.2% |
| **Black[3], non-Hispanic** | 16.1% | 17.2% |
| **Hispanic** | 9.9% | 16.3% |
| **Asian or Pacific Islander** | 2.8% | 4.1% |
| **American Indian or Alaskan (native)** | 0.9% | 1.2% |

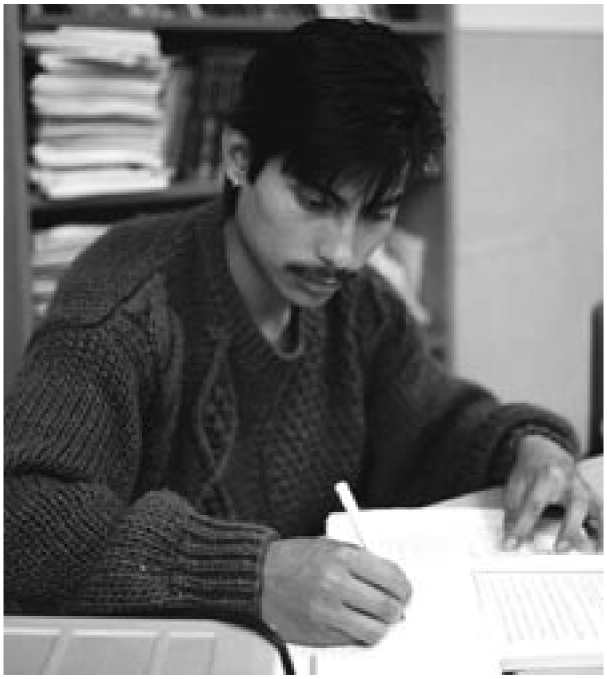
Source: U.S. Department of Education (due to rounding may not add up to 100%).

Changes in the racial-ethnic characteristics of the U.S. population have been a part of American life since the first European settlements. However, only in recent decades has the population in the United States become less, rather than more, White. The racial-ethnic diversity of the country is much greater now than at any previous period in history and seems on course to become progressively more diverse for some time to come (Riche & Pollard, 1992; Vernez, 1992). This diversity is reflected in recent trends of school-age children.

During the 1980s, the White school-age population declined by more than 4 million children, or about 12%, and the number of African American children decreased by about 250,000, or about 4%. In contrast, the number of Hispanic school-age children increased by 1.25 million, or 57%, and the number of Asian children rose by over 600,000—an 87% increase. In 1990, White children made up less than 70% of the total school-age children, down from about 75% in 1980 (GAO, 1993).

As with the total school-age population, poor children became more racially and ethnically diverse. On the 1990 census, an individual or family would be categorized as poor if its annual before-tax cash income was below the corresponding poverty threshold for a family of that size. On the 1990 census, the poverty cutoff

[3] The terms *Black* and *African American* are used interchangeably in this document.



for a family of four was a 1989 income of $12,674. During the 1980s, the number of poor school-age children increased by 6% from about 7.2 million to 7.6 million (GAO, 1993). The national poverty rate for school-age children rose from 15.3% to 17.1%. The number of poor Hispanic and Asian children grew by almost 600,000; while the number of poor White children declined, and the African American school-age population in poverty remained relatively constant.

Despite the decline in poor White children, they continued to make up more than 40% of all poor school-age children in 1990, but this percentage changes dramatically by geographic region. White children represented over two-thirds of all rural poor children and approximately one-third of the urban school-age population in poverty. Yet, regardless of region, African American children experienced the **highest rates** of school-age poverty, from almost 41% in rural areas to 34% in urban areas.

Three other traditionally underserved demographic groups—immigrant households, linguistically isolated (LI) households, and limited English proficiency (LEP) households—each contributed about 5% of all school-age poverty children (GAO, 1993).[4] Many of the children were categorized into more than one of these groups. When adjusted for overlap, these three groups totaled nearly 4 million children—more than 9% of all school-age children. More than 30% of these 4 million children were also classified as poor.

Current demographic trends should be examined in light of mathematics achievement trends. As the demographic context of the United States changes rapidly, how well is our system of education performing in school mathematics across demographic groups?

## Proficiency Trends in Mathematics

The purpose of this section is to document changes in mathematics achievement by examining national trend studies to better understand the status of the United States education system. The discussion of national trend data is offered for two related reasons. The first reason is to clearly describe the student achievement problem. The trend studies reviewed in this section are in part a reflection of past practice in school mathematics. Thus, the mathematics trends are linked to limitations of the implemented curriculum, pedagogy, and school organizational strategies. A second reason to discuss national mathematics trend studies is to describe the measures used to determine mathematics achievement and to interpret the findings with a focus on engineering change.

The trend studies should be examined with several concepts in mind. Miller (1995) argued there are three intertwined concepts that should be taken into consideration when attempting to build effective strategies to accelerate minority student performance on the basis of academic achievement data:

1. Generally, differences in academic achievement patterns among racial/ethnic groups reflect the fact that the variation in family resources is greater than the variation in school resources. His analysis of achievement patterns and resource allocations

[4] Some definitions of terms are required here. LI children are in households where no persons aged 14 or older speak "only English" and no persons aged 14 or older who speak a language other than English speak English "very well." There is no generally accepted definition of LEP. The term generally refers to students who have difficulty with speaking, writing, and/or reading English. The GAO (1993) defined LEP children as all persons aged five to 17 living in families whose members the Census reported as speaking English "well," "not well," or "not at all." It should be noted that there is considerable variation in actual English-speaking ability among those classified in the "speaks English well" category.

confirms that most high-SES students receive several times more resources than most low-SES students receive, and much of this resource gap is a function of family resources rather than school resources.

2. Demographic group educational advancement is an intergenerational process. From this perspective, education-related family resources are school resources that have accumulated across multiple generations. On average, investments in the current generation of African American, Hispanic, and American Indian children in the form of intergenerationally accrued education-relevant family resources are significantly less than comparable investments in White and Asian children.
3. Educational attainment is a function of the quality of education-relevant opportunity structure over several generations. The pace of educational advancement depends on multiple generations of children attending good schools.

Miller (1995) stated the following about these three interrelated concepts:

> Current variations in education-relevant family resources are heavily a function of variations in the historical opportunity structure experienced by generations of racial/ethnic groups. At the same time, the quality of the contemporary opportunity structure is crucial to the further evolution of family resource variation patterns. The nation's ability to accelerate the intergenerational advancement process for minorities may be decisively shaped by its capacity to **engineer** [my emphasis] a more favorable opportunity structure for them in the years ahead as well as to supplement family and school resources for those groups at a level commensurate with their actual needs. (p. 339–40)

The first step in engineering change is problem identification. One goal of recent federal (NCLB Act) legislation and state policy focused on mathematics standards and accountability is to document the achievement level of traditionally underserved students' yearly progress and to provide performance trends at a local level. The theory of action of most standards-based reform initiated at the state and federal level of governance suggests that armed with quantitative data on how students perform against standards, school leadership will react by making instructional changes required to improve student performance. According to the National Research Council (1999[a]), "Research on early implementation of standards-based systems shows, however, that many schools lack an understanding of the changes that are needed and lack the capacity to make them. The link between assessment and instruction needs to be made strong and explicit" (p. 5).

Why do schools lack an understanding of administrative changes that are needed to improve student performance on specifically designated tests? One or all of the following problems may hamper many school leaders:

- Failure to disaggregate and organize data by race, class, language proficiency, or other relevant demographic variables
- Failure to align local content standards with external performance standards associated with the designated testing system
- Failure to align the testing cycle and fiscal planning

One reason many schools lack the insight to make appropriate instructional changes is related to how they organize and analyze data. While many states, schools districts, and schools disaggregate data to help provide a more accurate picture of student performance, many educational leaders do not have insight into student mathematical performance by demographic group. This is problematic in that student achievement patterns and trends are potentially overlooked; thus, opportunities for instructional intervention are lost, and future student performance is hampered. Further, lack of clarity about the relationship between content standards and performance standards can result in the implementation of curriculum that is not consistent with outcome measures being employed (NRC, 1999[a]). Thus, any discussion of achievement trends should be coupled with a clear description of what is being measured. Moreover, the discussion of trends must occur in a timeframe that allows for immediate intervention. The timing of tests and the administrative planning cycle

further complicate the possibility of intervention. In many states, the test results are produced after fiscal planning has taken place in school districts. This disconnect makes it difficult to plan appropriate interventions for the upcoming school year.

## Racial-Ethnic Trends[5]

Rapid growth of the school-age population and changing discourses about racial categories has made it more difficult to classify racial-ethnic, immigrant, and language groups. For example, within the Hispanic, Asian, and African American populations, distinct subgroups have formed, and many have requested unique demographic characterizations. Most national trend analysis of mathematics performance is not conducted at this level of detail. This limitation stated a review of this literature remains instructive for evaluating national trend direction in school mathematics.

NAEP Trends. The National Assessment of Educational Progress (NAEP) trend assessment is largely a basic skills examination. To measure performance trends, subsets of the same items have been a part of successive assessments. Some items have been included in each examination. This practice means that findings from nine NAEP trend assessments provide insight into how students' mathematics proficiency has changed from 1973–1999. NAEP mathematics proficiency scores are available for 1973, 1978, 1982, 1986, 1990, 1992, 1994, 1996, 1999, and 2003.[6] Tests are administered to a sampling of students across the United States at ages 9, 13, and 17. The scale scores, which range from 0 to 500, provide a common metric for determining levels of proficiency across assessments and demographic characteristics. NAEP scores reflect student performance at five levels on the scale:

- Level 150—Basic Arithmetic Facts
- Level 200—Beginning Skills and Understanding
- Level 250—Basic Operations and Beginning Problem Solving
- Level 300—Moderately Complex Procedures and Reasoning
- Level 350—Multi-step Problem Solving and Algebra

The performance-level categories were developed for the 1973 assessment and have continued to be used through the 1999 assessment. However, the language associated with these categories has evolved and changed over this time period. Thus, it is important for the "engineer" charged with making decisions about curriculum, teaching, and other relevant educational inputs to be aware that this trend analysis may use language consistent with today's standards-based discourse (NCTM, 1989; 2000). However, the test items may

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[5] The trend studies reviewed in this monograph are limited to select national-level analyses that provide insight into student mathematics performance across demographic groups. National studies that did not disaggregate data by demographic group are not included. Moreover, no state-level trend studies or international studies (TIMMS) are included. The period from 1985 to 1999 is a particular focus of this trend analysis summary. This report continues the 1985 effort of DeAnna Banks Beane.

[6] The 2003 NAEP scores are not included in this discussion. At the time of publication, these findings were not included in the trend study.

**Figure 2 NAEP Trends in Average Mathematics Scale Scores by Race/Ethnicity**

| Race/ Ethnicity | Year | Age 9 | Age 13 | Age 17 |
|---|---|---|---|---|
| White | 1999 | 238.8 (0.9) | 283.1 (0.8) | 314.8 (1.1) |
| | 1996 | 236.9 (1.0) | 281.2 (0.9) | 313.4 (1.4) |
| | 1994 | 236.8 (1.0) | 280.8 (0.9) | 312.3 (1.1) |
| | 1992 | 235.1 (0.8)* | 278.9 (0.9)* | 311.9 (0.8) |
| | 1990 | 235.2 (0.8)* | 276.3 (1.1)* | 309.5 (1.0)* |
| | 1986 | 226.9 (1.1)* | 273.6 (1.3)* | 307.5 (1.0)* |
| | 1982 | 224.0 (1.1)* | 274.4 (1.0)* | 303.7 (0.9) |
| | 1978 | 224.1 (0.9)* | 271.6 (0.8)* | 305.9 (0.9)* |
| | 1973 | 225.0 (1.0)* | 274.0 (0.9)* | 310.0 (1.1)* |
| Black | 1999 | 210.9 (1.6) | 251.0 (2.6) | 283.3 (1.5) |
| | 1996 | 211.6 (1.4) | 252.1 (1.3) | 286.4 (1.7) |
| | 1994 | 212.1 (1.6) | 251.5 (3.5) | 285.5 (1.8) |
| | 1992 | 208.0 (2.0) | 250.2 (1.9) | 285.8 (2.2) |
| | 1990 | 208.4 (2.2) | 249.1 (2.3) | 288.5 (2.8) |
| | 1986 | 201.6 (1.6)* | 249.2 (2.3) | 278.6 (2.1) |
| | 1982 | 194.9 (1.6)* | 240.4 (1.6)* | 271.8 (1.2)* |
| | 1978 | 192.4 (1.1)* | 229.6 (1.9)* | 268.4 (1.3)* |
| | 1973 | 190.0 (1.8)* | 228.0 (1.9) | 270.0 (1.3) |
| Hispanic | 1999 | 212.9 (1.9) | 259.2 (1.7) | 292.7 (2.5) |
| | 1996 | 214.7 (1.7) | 255.7 (1.6) | 292.0 (2.1) |
| | 1994 | 209.9 (2.3) | 256.0 (1.9) | 290.8 (3.7) |
| | 1992 | 211.9 (2.3) | 259.3 (1.8) | 292.2 (2.6) |
| | 1990 | 213.8 (2.1) | 254.6 (1.8) | 283.5 (2.9)* |
| | 1986 | 205.4 (2.1)* | 254.3 (2.9) | 283.1 (2.9)* |
| | 1982 | 204.0 (1.3)* | 252.4 (1.7)* | 276.7 (1.8)* |
| | 1978 | 202.9 (2.2)* | 238.0 (2.0)* | 276.3 (2.3)* |
| | 1973 | 202.0 (2.4)* | 239.0 (2.2)* | 277.0 (2.2)* |

Standard errors of the scale scores appear in parentheses.
*Significantly different from 1999. Source: NAEP 1999 Trends in Academic Progress, NCES (2000).

not reflect the problem solving and reasoning descriptions found in more recent standards documents and state content and performance assessment documents. With this limitation noted, the NAEP trend analysis is a valuable gauge of student performance progress over time. Figure 2 provides a summary of NAEP racial-ethnic trends in mathematics performance from 1973–1999.

The racial-ethnic mathematics scores as measured by the NAEP long-term trend assessment improved for all racial-ethnic subgroups from 1973–1999. The scores for Black and Hispanic students are less consistent than White students and demonstrate more abrupt changes. However, the samples of Black and Hispanic students are smaller than that of White students. Smaller samples typically have more variability. Overall, the NAEP trend assessment indicates that all three racial-ethnic groups have experienced positive growth in mathematics proficiency. However, no group by age 17 was performing on average at the highest student performance level. This finding is a concern given that the performance levels are more closely aligned with a basic skills mathematics curriculum.

NELS Trends. The National Education Longitudinal Study of 1988 (NELS:88) included a nationally representative sample of over 10,000 students, followed from eighth grade (1988) through twelfth grade (1992) in nearly 800 high schools nationwide. The schools in the study include public, Catholic, and other private schools and represent a range of enrollment, religious affiliations, geographic settings, school social composition, as well as various levels of restructuring activity (Newmann & Wehlage, 1995). The NELS:88 mathematics tests were constructed to measure both high-level and low-level skills at three points in time: 1988, 1990, and 1992. Thus, students in the sample were assessed in mathematics at grades 8, 10, and 12, respectively. The difficulty levels of the first and second follow-up mathematics tests were adapted to the students' performance levels in the previous administration. There were 40 items on each mathematics test. Eighty-one items were used in all forms of the test. The different forms of the test were equated using item response theory (IRT) so the various forms of the test could be equated with a common metric. Units on these tests refer to the number of items answered correctly, after the IRT procedures were used to score the tests and to assign all students on the same scale.

Green and colleagues (1995) reported findings from the NELS:88 second follow-up data set that included mathematics achievement results of high school seniors in 1992. The 1992 NELS:88 second follow-up examination items represent items typically characterized as traditional, basic skills curriculum. Five levels of mathematics proficiency were defined in the study (see Appendix A, Table A1). Green et al. (1995) found that African American and Hispanic students were less likely than White and Asian students to demonstrate advanced proficiencies (Levels 4 and 5) on the standardized test of mathematics (12% and 20% compared with 39% and 45%, respectively). Further, 50% of the African American and 42% of Hispanic students were categorized at Level 1 or below. In comparison, 14% of the Asian and 21% of White students performed at Level 1 or below.

Rasinski, Ingels, Rock, and Pollack (1993) compared mathematics scores for sophomores in the 1980 High School and Beyond (HS& B) study and the 1990 NELS:88 (a follow-up study conducted in 1990) by using an IRT scaling procedure that linked the two assessment instruments. The HS&B sophomore cohort mathematics test administered in 1980 consisted of 38 test items and required students to complete the examination in 21 minutes. The test items were quantitative comparisons that required students to mark which of two quantities is greater, indicate their equality, or note a lack of sufficient information to determine a relationship between the quantities. The 1990 NELS:88 first follow-up mathematics test contained 40 items to be completed in 30 minutes. The test items assessed advanced skills of comprehension and simple mathematical application skills. The items included geometric figures, graphs, word problems, and quantitative comparisons (as in the HS&B). Consistent with the HS&B, a multiple-choice format was used in this follow-up test. To compare the performance of the 1980 HS&B sophomore cohort and the 1990 NELS:88 sophomores, 16 quantitative comparisons from the HS&B were included in the 1990 NELS:88 mathematics assessment. Thus, the findings from this study should be viewed as a comparative analysis of a narrow scope of the mathematics content. The statistical findings are listed in Appendix A (Table A2). All racial and ethnic groups with the exception of Asian students made statistically significant gains in mathematics performance on the test. In each administration of the test, Asian students on average were the highest performing of the four demographic groups. African American and Hispanic students gained more than Asian and White students in this comparison.

Racial-Ethnic Trend Analysis Summary. The NAEP trend analysis indicates improvement between 1973 and 1999 in all racial-ethnic groups at each age level. During this period, African American and Hispanic students made larger gains than did White students; thus, the performance gap on this assessment between White students and the other two demographic groups closed slightly. The 1980 HS&B and the 1990 NELS:88 sophomore cohort study reported a similar result: African Americans, Hispanics, and Whites made statistically significant gains in mathematics achievement. Further, the gains made by African American and Hispanic students were larger than those of White students.

The NAEP trend analysis and the 1990 NELS:88 sophomore cohort study indicate that the mathematics performance on basic skills items over the past 20 years has improved for the largest racial-ethnic demographic groups in the United States. However, no racial-ethnic demographic group has consistently produced scores that are aligned with the highest levels of performance being measured by the NAEP trend analysis.

## Socio-Economic Trends

The literature on social class is a product of multiple academic domains and traditions. Most notions of social class build on the economic roots of class and to varying degrees link class to political and cultural indicators. The traditional practice in school mathematics achievement data is to organize a hierarchy of classes—working class, lower-middle class, middle class, and so on. This hierarchical framework objectifies high, middle, and low positions on some metric, such as socioeconomic status (SES) where "Parents' Education" or "Family Income" is a proxy for class. The limitations of this practice are discussed elsewhere (Knapp and Woolverton, 1995; Grant and Sleeter, 1986; Secada, 1992). However, for the purpose of understanding SES trends in mathematics achievement, a proxy like "Parents' Education" is instructive. One major limitation of this proxy—and others like it—is that school administrators cannot intervene directly on this variable.

**NAEP trends.** From 1978 to 1999, the National Assessment of Educational Progress provided trends in average mathematics proficiency by the highest level of education that students reported for either parent. A summary of the trends in average mathematics scale scores for students at three age levels by parents' highest level of education is provided in Appendix A (see Table A3). Students at all three ages who indicated their parents had less than a high school education have exhibited overall gains in average mathematics proficiency since 1978 across all ages. For students who reported their parents' highest education level was high school graduation, the average proficiency trend has generally improved at ages 9 and 17. The performance of 13-year-olds was relatively the same during this time period. For students with a parent who graduated from college, only 9-year-olds had an average score in 1999 that was significantly higher than in 1978.

**NELS Trends.** Rasinski's and colleagues' (1993) comparison of sophomore cohorts from the 1980 HS&B study and the 1990 NELS:88 follow-up study documented a consistent pattern of positive gains within SES groups during this period and a difference that is related to student SES. Four SES categories were created by framing the socioeconomic status composite into SES high quartile, SES high middle half, SES low middle half, and SES low quartile. The statistical results are presented in Appendix A (see Table A4). The findings appear to suggest that the highest quartile improved more than the lowest quartile; however, approximately 12% of the lowest quartile in 1990 was missing math test scores, whereas nearly all the 1980 lowest quartile reported mathematics scores. The researchers speculated that the lowest quartile gain could be biased downward as a result of the missing data. The missing data make any interpretation of differential gain between quartiles difficult to make. However, it is clear that within each data set—i.e., HS&B 1980 and 1990 NELS:88 Follow-up—SES status is related to mathematics performance.

Green et al. (1995) reported findings from the 1992 NELS:88 second follow-up survey of seniors. In one analysis, Green and colleagues compared achievement across racial and ethnic groups controlling for SES. The mathematics proficiency of Asian, Hispanics, African Americans, and Whites, controlling for SES is presented in Appendix A (see Table A5). The two lowest proficiency levels—below basic and level 1—and the two highest proficiency levels—levels 4 and 5—are contrasted. The data indicate that achievement differences exist even when the effects of socioeconomic status are held constant. For example, this study reported that significant differences existed between Whites' and African Americans' test performance within each SES category. Also, there were significant differences between White and Hispanic seniors in the high SES group. The percentage differences among racial and ethnic groups were generally larger in the higher SES groups. There was one exception: differences in Asian and White seniors' performance were not significant.

**SES Trend Analysis Summary.** The studies reviewed in this chapter should be considered with population trends in mind. Clearly, poverty is more severely concentrated among Hispanic and African American children than it is among Whites. Across the various studies of mathematics achievement, a strong relationship between SES and mathematics achievement was present. These studies indicate a need to improve the mathematics achievement of low-SES students as a whole, and even more pressing is the need to raise the mathematics achievement of low-SES minority students. In light of these findings and population trends, the need for intervention in the two geographic regions with the highest poverty levels—urban and rural communities—is apparent.

CHAPTER 3

# Opportunity to Learn Factors: Time, Quality, and Design

A close look at the achievement trends reviewed in the prior chapter suggests that student demographic background is strongly related to mathematics achievement. This is important to know; however, demographic background is out of the control of the teacher, instructional supervisor, school board member, and other school personnel. An educator interested in improved student performance in mathematics must focus on the variables associated with learning mathematics that can be influenced by specific action and intervention. One response to current student underperformance is to examine how opportunity-to-learn variables might inform the design of active intervention on student learning.

Opportunity-to-Learn (OTL) as an important construct influencing—and possibly explaining—the impact of instruction, was introduced during the 1960s. Carroll (1963) included OTL as one of five critical constructs in his model of school learning. He defined OTL as the amount of time allocated to the learner for the learning of a specific task. If, for instance, the task assigned a student is to understand the concept of place value, opportunity-to-learn is simply the amount of time the student has available to learn what place value is.

In Carroll's (1963) model, opportunity-to-learn is contrasted with the amount of time the student requires to learn a principle or concept. This latter construct is largely related to the student's aptitude in a concept domain. Thus, whereas teachers have some control over the time available for student learning, they have little control over the time required for student learning. Carroll also contrasted OTL with the amount of time the student actually spends engaged in the learning process. The latter variable, often referred to as time-on-task or engaged time, is thought to be affected by the perseverance of the student and the quality of the teaching. In Carroll's model, OTL represents the maximum value for engaged time.

In contrast to Carroll, Husén (1967) organized OTL in terms of the relationship between the mathematics content taught to the student and mathematics content assessed by achievement tests. In Husén's model, OTL is the overlap of mathematics taught and mathematics tested. Simply stated, the greater the overlap, the greater the opportunity-to-learn.[7]

Scholars, school leaders, and government agencies have used various combinations of the Carroll and Husén models to design their own frameworks of opportunity-to-learn (National Governors' Association, 1993; Robitaille & Travers, 1992; Winfield, 1987, 1993). However, Stevens (1993a) identified four variables related to teacher instructional practice and student learning that consistently emerge in these interpretations. In this monograph, two of the variables are combined; thus, the following three variables form an opportunity-to-learn framework:

[7] Carroll's (1963) and Husén's (1967) opportunity-to-learn models have two important differences. First, whereas Carroll's model describes OTL as an instructional variable (under the control of teachers), Husén's model frames OTL as a measurement variable. Second, Carroll describes OTL as a continuous variable, whereas Husén designed OTL as a dichotomous variable. The most important concern from Carroll's perspective is how much time the student has to learn a specific concept. The most important concern from Husén's perspective is whether or not a student has been provided with quality instruction relative to the concepts included on achievement tests.

1. **Content exposure and coverage variables** measure the amount of time students spend on a topic (time-on-task) and the depth of instruction provided. These variables also measure whether or not students cover critical subject matter for a specific grade or discipline.
2. **Content emphasis variables** affect the selection of topics within the implemented curriculum and the selection of students for basic skills instruction or for higher order skills instruction.
3. **Quality of instructional delivery variables** reveals how classroom pedagogical strategies affect students' academic achievement.

The purpose of these OTL variables is to determine whether or not students are provided sufficient access to learn the mathematics curriculum expected for their grade level and age. According to Stevens (1993b), the OTL variables are "deceptively simple" (p. 234). In general, research in this area examines one variable at a time; however, the OTL conceptual framework developed by Stevens (1993a, 1993b) encourages teachers, administrators, and researchers to examine the interaction of all three variables simultaneously (see Figure 3).

This theoretical framework will remain a theory, rather than an active change strategy for most teachers, unless their work is part of a coherent "design" that allows them to take advantage of what is known about opportunity to learn. Two very important variables that emerge from the OTL literature are *time* and *quality.* Time and quality are critical variables because they can be altered with interventions. Thus, time and quality variables derived from the OTL literature form a basis for the construction of school design strategies aimed to improve learning. For purposes of management and leadership, design is critical.

Think of "design" as an innovative portfolio of strategies that will provide students appropriate content exposure, content coverage, content emphasis, and quality instructional delivery. The term *design* is used here to describe how school personnel can construct and package opportunities to learn. Those responsible for the education of children need to be challenged to accept a greater level of responsibility for how teaching and learning is organized. Every educator—teachers, principals, superintendents, and school board members—should have a clear understanding of how the school system and, more specifically, how each school is designed to improve student performance in mathematics. Too many educators fail to see the limitation of longstanding design principles. Still others fail to recognize existing design principles. Some may question the need for a transparent opportunity-to-learn design. However, not having a design is a design for failure. Each state has a measurement system to gauge student performance. These systems are transparent. Similarly, every school and school district should have a learning design that is transparent, open to ongoing monitoring, assessment, and revision.

The appropriate design and management of OTL variables is central to the improvement of school mathematics for many students. The remainder of this chapter will be devoted to the role of time, quality, and design as they relate

**Figure 3 Opportunity to Learn: A Theoretical Framework Derived from International Assessments and Research Studies to Examine Students' Access to Intended Curriculum**

| Variable/Related Study | Definition |
|---|---|
| **Content exposure and coverage** (Leinhardt & Seewald, 1981; Leinhardt, 1983; Brophy & Good, 1986; Winfield, 1987, 1993; Suter, 2000) | Teacher arranges class so that there is time-on-task for students. Teacher arranges adequate time for students to learn subject matter and to cover adequately a specific topic. Teacher arranges the curriculum to overlap test content. |
| **Content emphasis** (Floden, Porter, Schmidt, Freeman, & Schwille, 1981; LeMahieu & Leinhardt, 1985; McDonnell, Burstein, Catterall, Ormseth, & Moody, 1990; Oakes, 1990; Stevens 1993b; Porter, 1989, 1993; Suter, 2000) | Teacher chooses content from the curriculum to teach. Teacher chooses the dominant level to teach the curriculum (recall, higher order skills). Teacher chooses which skills to teach and which skills to highlight with different groups of students (ability grouping and tracking). |
| **Quality of instructional delivery** (Brophy & Good, 1986; Stevenson & Stigler, 1992; Stevens, 1993b) | Teacher uses different pedagogical strategies to meet the learner's needs. Teacher has understanding of the subject matter. |

to student OTL with traditionally underserved student groups.

## Time and School Mathematics

Policies and practices that influence content coverage and time on task in school mathematics are pivotal to the improvement of student performance in the domain. The purpose of studying these opportunity-to-learn variables is to determine whether or not students are provided sufficient time to learn the mathematics curriculum expected for their grade level and age. One very basic principle related to time should be transparent in every classroom. Significant time should be dedicated to mathematics instruction each school day. Further, appropriate time should be allotted to ensure students develop understanding of key concepts and procedures.[8] Many factors can influence whether or not this basic principle is followed. In this section, several factors related to time and school mathematics will be reviewed.

**Course-Taking.** Two of the most powerful predictors of school mathematics achievement in large-scale assessments of mathematics have been (a) increased time on task in high-level mathematics and (b) the number of courses taken in mathematics. Generally, these two predictors are interrelated. Evidence indicates that African American, Hispanic, and low-SES students are less likely to be enrolled in higher-level mathematics courses than middle-class White students (Secada, 1992). Further, White students on national assessments of mathematics achievement consistently outperform African American and Hispanic students. Thus, it is not shocking that a positive relationship between mathematics achievement and course taking exists across measurement systems (e.g., NAEP, SAT, and ACT).

Course-taking options in the United States are organized in a technology that takes on two forms—curricular and ability tracking. Many comprehensive high schools offer a wide range of mathematics courses linked to various work-related opportunities. No student could experience all of the coursework, so schools design technologies to regulate the selection process. To this end, students in most high schools are sorted into a curricular track involving a specific course sequence and, ultimately, different opportunities to learn mathematics. Generally, three curricular tracks—college preparation, vocational, and general education—are offered within most traditional high schools. It is clear that the college preparation track has higher status and provides greater opportunity to learn more demanding mathematics. Curricular tracking has serious implications for student opportunity to learn mathematics.

Similarly, ability tracking is a technology used to sort students into curriculum experiences.[9] This mechanism for sorting provides different levels of instruction to students across two tracks based on perceived ability. This version of sorting is more difficult to recognize because course labeling can disguise the practice. For example, schools may offer two different courses in geometry. Both may have the same title; however, the mathematics covered in each course may differ in dramatic ways. Another sorting strategy is to offer students different entry points into the college-preparatory coursework at different times (e.g., freshmen year versus junior year). The organizational structure of the school may recognize many tracks or just a few; schools may or may not link tracks to a block of courses or to mathematics only; and schools may have loosely or tightly coupled curricular and ability tracking. Additionally, students may or may not have the option to move across tracks. The opportunity to negotiate new curricular possibilities is an important equity consideration.

Tracking is a serious challenge to mathematics achievement and opportunities to learn mathematics. In theory, tracking as a technology is designed to benefit all students. However, evidence strongly suggests that this goal is not being accomplished (Hoffer, Rasinski, and Moore, 1995). Instead, research studies have indicated that even when tracking systems have positive effects, those effects are more closely associated with those

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8 Sufficient and appropriate time to learn the mathematics curriculum should be a data-driven decision. Certain mathematical concepts are more difficult to understand. System-wide data can inform the process as well as classroom-based assessments. Both assessment formats are informative with respect to determining the amount of time to devote to a concept.

9 I use the term *ability grouping* because this is consistent with the literature on tracking. However, a more appropriate term is *perceived ability*.

students assigned to high-status tracks (Oakes, 1990; Rock and Pollack, 1995).

One possible solution to the differential opportunities to learn across tracks is to constrain the curriculum options in mathematics at the secondary level. Currently, African Americans and Hispanic students are over-represented in vocational programs and low-track options. Lee, Croninger, and Smith (1997) found that students learn more mathematics in schools that offer them a narrow curriculum composed of college-preparatory academic courses. This research is suggestive, rather than definitive.

A word of caution: "Course-taking patterns are an important indicator of system quality." It is quite possible that many students are enrolled in low-track mathematics courses due in part to prior experiences in elementary and middle school mathematics. Merely mandating a narrower curriculum consisting of college prep mathematics will not address the endemic quality problem of the preK–8 mathematics program. Thus, it is imperative that curriculum constraints toward the college prep model at the secondary level occur in tandem with a close examination of the preK–8 effort.

One state-level change strategy to improve elementary and middle school mathematics is to align the mathematics curriculum with state assessments. This model has implications for time and school mathematics. The next section examines this strategy.

**Assessment Practices.** The mathematics curriculum in many school districts is aligned with mathematics standards adopted or derived from state or national curricular frameworks. The standards-based reform of mathematics education is often part of a larger systemic change effort that includes: academic standards in the core disciplines by grade, holding all students to the same standards, statewide assessments closely linked to the standards, accountability systems with varying levels of consequences for results, computerized feedback systems, and data for continuous improvement (NRC, 1999[a]). State-level assessment systems and most national testing proposals call for students to be tested in mathematics and reading (NRC, 1999 [b]). This practice has implications for content coverage and time on task in mathematics classrooms in urban school districts and other school systems with large percentages of traditionally underserved students.

Students' opportunities to learn mathematics are influenced by the assessment policies of the school district. Assessment policy often influences the nature and pedagogy in a classroom. The influence of standardized tests—and, more recently, state-mandated testing—is arguably greater in high-minority classrooms. In a nationwide survey, teachers of high-minority classrooms reported test-specific instructional practices more often than teachers of low-minority classrooms (STEEP, 1992). For example, in high-minority classrooms, about 60% of the teachers reported teaching test-taking skills, teaching topics known to be on the test, increasing emphasis on tested topics, and starting test preparation more than a month before the examination. These practices were reported significantly less often in low-minority classrooms. Moreover, mathematics teachers with high-minority classes indicated more pressure from school district officials to improve test scores than teachers with low-minority classes.

Today, school districts across the country use testing technology as a mechanism to measure school and student progress. However, the role of testing technology is much greater than measurement concerns. Tests do change or at least influence teaching behavior. Many districts are ignoring best practice related to assessment and school mathematics. Two recommendations related to school mathematics and student assessment performance are listed below:

1. Design a curriculum, select quality instructional materials, align curriculum and instructional materials, and then use aligned instructional materials all year. Testing systems are intended to measure the quality of a school's instructional program. Avoid spending significant time on test preparation. If the combination of the curriculum, instructional materials, and teaching fall short of school district goals, then these factors must be reviewed and improved upon.
2. Use state and classroom assessment data as a way to build a solid instructional program linked directly to student thinking in the content domain.

**Fiscal Adequacy.** Limited course-taking options and narrow assessment practices are compounded by problems of fiscal inadequacy and resource distribution. The Council of Great City Schools [CGCS](1992) calculated that the average-per-pupil expenditure in 1990–91 was $5,200 in large urban school districts compared with $6,073 in suburban public school systems. Although both types of school systems allocated about 62% of their budgets to classroom instruction, urban schools spent about $506 less per child on instruction. While this study does not use current data related to fiscal resources, it reflects a growing fiscal disparity between urban school systems and some suburban systems, and illustrates an important point. How money is spent should be examined carefully. For example, the Commissioner of Education of New York State reported, "The more advantaged districts (in New York state, my addition) spend over $3,000 more per student and pay their teachers $20,000 more annually. Students in more advantaged districts are substantially more likely than students in less advantaged districts to perform with distinction on Regents examinations, and they are more than twice as likely to plan to attend four-year colleges" (2002, pp. vi–vii).[10] The CGCS (2003) calculated that the New York Public Schools would need $12,537 per pupil to have the resources equivalent to the highest achieving school districts in the state.[11] The fiscal support undergirding instructional practice has implications for meeting new and more challenging demands in mathematics education.[12]

Over the past decade, the average-per-pupil expenditure has constantly increased for urban and suburban school districts. Yet, as Cohen, Raudenbush, and Ball (2003) propose, rather than focus on fiscal resources as the center of research and policymaking, teaching and learning should be centered, and questions of adequate fiscal resources should derive from carefully planned instructional programs. The call for "Mathematics for All" or "Algebra for All" associated with many state content standards proclamations has placed new demands on urban school systems to prepare larger numbers of students in content traditionally reserved for a small percentage of students. Never before has there been a greater need to extend the amount of time students have with mathematics content that is aligned to state curriculum guides and appropriate tests.

Unfortunately, the old saying "time is money" is directly applicable to the implementation of design strategies capable of providing students more time on task in mathematics. Some considerations related to extending time for students in mathematics are listed below:

- Preschool availability
- Early intervention programs for low performing schools
- Extended school day opportunities
- After- and before-school tutorial programs
- Saturday school
- Summer school enrichment for all students (not just remediation)
- Community college/university programs
- Longer school day and/or expanded year
- Enrichment and mentoring programs
- More individualized or small group instruction

Each of the strategies listed is integral to a standards-based approach to educational policymaking. These strategies require a sound vision that is directly linked to fiscal policy. State standards provide an opportunity to plan for success. A simple planning strategy includes (a) adopting a set of mathematics standards, (b) identifying resources needed to achieve the standards (including time-related strategies), (c) formulating a long-term plan that aligns the standards and resources, (d) developing the plan before spending money, and (e) adopting the necessary structural changes to maximize cost-effectiveness (e.g., Clune, 1997). Planning for more engaged time in mathematics is a purposeful act that should be aligned with fiscal management. A school district's portfolio of mathematics practices and interventions should be clearly aligned to

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[10] See http://www.emsc.nysed.gov/irts/655report/2002/home.html (cited August 2, 2004).

[11] See http://www.cgcs.org/pdfs/NYBrief.pdf (cited August 2, 2004) to review this analysis.

[12] Additional reports by the Council of Great City Schools suggest the need for system leaders to continue examining how their systems use resources on instructional components (see e.g., http://www.cgcs.org/taskforce/finance3.html).

uniform content goals and fiscal management. Too often, districts fail to produce aligned practices and fiscal policy. Yet, a portfolio of aligned practices, interventions, and fiscal policy is the essence of a district's learning design.

## Quality and School Mathematics

It should be obvious to most observers that the call for more demanding standards in mathematics is a signal for not only what students must know but also what teachers must understand and school systems must support. High standards in school mathematics demand quality instruction and supporting infrastructure. The purpose of this section is to examine quality factors that influence mathematics instruction.

The OTL literature defines *quality* as classroom pedagogical strategies that affect students' academic achievement. In this case, quality is defined as those pedagogical strategies that positively influence student achievement in school mathematics. Before discussing quality factors, a baseline review detailing what is typical with respect to mathematics pedagogy is helpful.

Traditionally, mathematics pedagogy has emphasized whole-class lectures with teachers modeling one strategy for solving a problem and students passively listening to the explanation. Generally, the lecture is followed by students working alone on a large set of problems that reflect the lecture topic (Fey, 1981; Porter, 1989; Stodolsky, 1988). The purpose of the lecture and problem set is to prepare students to produce correct responses to narrowly defined problems. This pedagogical strategy is often coupled with curricular or ability grouping, with many African American and Hispanic students selected to participate in compensatory mathematics programs that focus on the mastery of low-level computational skills (Strickland & Ascher, 1992). These phenomena are so "normal" in many schools, they have become cultural artifacts. The achievement trends as a result of this model of instruction were reviewed earlier in this monograph.

In contrast, high-quality mathematics programs generally deviate in important ways from the "normal" approaches to mathematics instruction and classroom practice. A comparison of mathematics teachers in higher- and lower-performing schools conducted by the North Central Regional Educational Laboratory (NCREL, 2000) revealed important quality factors related to instruction. The findings are summarized in Figure 4.

It is important to note that the NCREL findings must be understood in light of the centrality of students' **mathematical reasoning** in higher-performing schools. Higher-performing schools and teachers provide a learning environment that supports sustained engagement

**Figure 4**

| Higher-Performing Schools | Lower-Performing Schools |
|---|---|
| Teachers and students participate in two-way conversations about mathematical ideas. | Conversations tend to be one-way: The teachers tell information to students or look for answers and move on. |
| Classes exhibit the characteristics of learning communities. There are norms in place so students and teachers are learning together. | Classes have few learning community characteristics. Individuals are more disconnected. |
| Teachers push for mathematical meaning behind the task. | Teachers lead math tasks; however, meaning-oriented discussion is missing. |
| Teachers have high expectations that all will learn. They review concepts often, explain things thoroughly, invite student thinking, and assess student competence, and re-teach when necessary. | The expectation is that there will be other sources of help that will fill in gaps for struggling students. |
| Teachers build continuity in the mathematical domain from day to day. | Little continuity is built into mathematical content from day to day. |
| Students are comfortable with classroom routines and expectations and take initiative in their progress. (They know where to find enrichment materials when finished with an assignment and get started on their own.) | Classroom routines are teacher initiated rather than student initiated. Lots of teacher reminding of expectations. |

on rigorous mathematical tasks. Teaching as characterized in the higher-performing schools is complex and demanding. In contrast, the teaching in lower-performing schools is routine and limited with respect to teacher-student discourse patterns. Further, instructional practices in lower-performing schools do not center on students' mathematical understandings and thinking. The characteristics found in teachers working in higher-performing schools can be supported in other schools by administrative planning and instructional leadership with the following specific actions:

- Provide professional development that prepares teachers to focus on mathematical understandings and reasoning.
- Provide ongoing professional development focused on content, effective instruction, and student thinking in the content domain.
- Design a curriculum that provides sufficient exposure to difficult concepts.
- Develop programs to address the impact of student/teacher mobility in low-performing schools.

Each of these quality factors will be discussed in greater detail. The focus of the discussion will center on why these factors are key support mechanisms for achieving the quality teaching characteristics indicated in the NCREL study.

**Quality Professional Development.** What are the "best practices" related to the professional development of mathematics teachers? Every year, school districts sponsor thousands of professional learning opportunities for teachers. There has been a gradual shift in thinking about professional development in many sectors including education and the corporate world (Meister, 1998). A summary of recent shifts in emphasis related to professional development is provided in Figure 5.

Are shifts in thinking about professional development (as reflected in Figure 5) consistent with research in mathematics education and teacher learning? What works?

Garet and colleagues (2001) conducted the first large-scale empirical comparison of effects of different characteristics of professional development on teachers' learning. The study used a national probability sample of 1,027 mathematics and science teachers. The results confirm and extend the literature on "best practice" in several ways. The study confirms past literature in that the research indicates sustained and intensive professional development is more likely to influence teacher learning, as reported by teachers, than shorter professional development. Also, the research indicates that professional development that focuses on academic work (content), provides teachers opportunities for "hands-on" work (active learning), and is integrated into the daily life of the school (coherence) is more likely to result in enhanced knowledge and skills.

Garet and associates (2001) extend what is known about professional development and confirm speculation in the following manner:

> Our results provide support for previous speculation about the importance of collective participation and the coherence of professional development activities. Activities that are linked to teachers' other experiences, aligned with other reform efforts, and encouraging of professional communication among teachers appear to support change in teaching practice, even after the effects of enhanced knowledge and skills are taken into account. Such coherence has been hypothesized as important, but with little direct empirical support in the literature to date. Similarly our data provide empirical support that the collective participation of groups of teachers from the same school, subject, or grade is related both to coherence and active learning opportunities, which in turn are related to improvements in teacher knowledge and skill and changes in classroom practice. (p. 936)

This study suggests that if those who are concerned about education are serious about improving the quality of teaching in mathematics classrooms, they need to support and invest in professional learning opportunities for teachers that foster enhanced instructional practice. A major challenge to the kind of professional development outlined in this study is cost. It is very important that sufficient resources be in place to support a quality professional development model.

**Quality Curriculum.** The need for a demanding mathematics curriculum aligned with high-quality instructional materials is intuitively

**Figure 5 Professional Development Paradigm Shift from Staff Training to Learning**

| Old Training Paradigm | | Learning Paradigm |
|---|---|---|
| Central Office | **Location** | On Demand—Anywhere |
| Upgrade Math Skills | **Content** | Build Core Workplace Competencies |
| Lecture | **Methodology** | Action Learning |
| Individual Teachers | **Audience** | Intact Teams of Teachers, Principals, other Staff |
| External University Professor/Consultants | **Faculty** | Internal Senior-level District Staff and a Consortium of University Professors and Consultants |
| One Time Service | **Frequency** | Continuous Learning Process |
| Build Teacher's Inventory of Skills | **Goal** | Solve Real Education Issues and Improve Classroom Teaching |

Source: Adapted from Meister 1998.

obvious. Unfortunately, there is often confusion about the relationship between curriculum and instructional materials. Many systems purchase instructional materials and then treat them like a curriculum. Teachers strive to teach the book from cover to cover with little reflection about the curriculum. In other school districts, curriculum guides are designed, distributed at one-day workshops, placed in school storage, and never used again.

There is serious need for quality district-level curriculum guides in mathematics. In many states, the state-level curriculum framework offers little guidance related to focus; instead, litanies of discrete topics are listed. At the school-district level, curriculum quality can be achieved if the following recommendations for developing and implementing guides are taken seriously:

- Focus on mastery objectives only.
- Reduce the scope of coverage.
- Provide and support the development of more cognitively demanding enrichment materials.
- Allow for variations in completion time and instructional strategy.
- Provide quality instructional materials to schools in a timely fashion.
- Educate principals by focusing their learning opportunities on the relationship between the curriculum guides, district achievement goals, and test materials.

In the world of high-stakes testing, there is tremendous pressure, real or perceived, to teach to the test. A high-quality curriculum guide that demonstrates an alignment between the instructional materials (including the enrichment materials) and assessment tasks is more likely to result in students' experiencing a coherent and cognitively demanding mathematics classroom than pure reliance on test guidelines.

**Mobility and Mathematics.** How do schools address the challenges to quality mathematics instruction presented by student and teacher mobility in low-performing schools? High mobility causes a great deal of stress on campus officials attempting to serve these students. In the context of high mobility, a quality curriculum guide that standardizes the curriculum and instructional materials is vital. While schools and classes may deviate on pacing, teachers have a reasonable opportunity to meet individual needs if the curriculum guide has narrowed the coverage and focused on mastery objectives. Further, it is very important that individual student data is transmissible to the new school setting. This will give the teacher an opportunity to construct a data-driven program of study for the student.

Teacher mobility in low-performing schools also is a major problem. Often, new teachers to a system are sent to low-performing schools. The result is not surprising. These teachers either leave the profession or get seniority and transfer to another school. This pattern is consistent and endemic. The result: low-performing schools are constantly staffed by less experienced teachers and, in many situations, by teachers with emergency teaching certificates.

It is time for new models of operating in these schools. Questions related to how to retain teachers in low-performing schools require empirical evidence. Here are a couple of speculations on the issue. Retention of teachers in challenging settings may be linked to instructional leadership. Good principals create learning communities that support teachers and students.

Another potential strategy involves the recruitment process. Perhaps cohorts of well-established teachers can be recruited with incentives to low-performing schools. The emphasis is on *cohort*. The goal in this strategy is to embed a core group of excellent teachers in the school setting to influence and mentor the less experienced teachers.

Clearly, it is a disservice to new teachers and students to place novice teachers in the most challenging settings. Remedies to the mobility problem will require major rethinking in the areas of human resource management and fiscal management. Moreover, mobility issues are often compounded with other system challenges like cultural factors and student language background.

**Culture and Mathematics Learning.** Today, many calls for equity in mathematics education borrow from opportunity-to-learn constructs found in national and international testing programs. In fact, OTL constructs are foundational in this monograph. These constructs frame equity largely as the overlap of content taught and content tested. The overlap of content taught and content tested is a serious policy concern. Moreover, opportunity-to-learn constructs have additional explanatory power if aligned with the cultural factors that influence students' mathematics learning (Tate, 1995). Research suggests that equity-related policies in mathematics education should carefully consider incorporating recommendations found in the Professional Standards for Teaching Mathematics (NCTM, 1991), which call for mathematics pedagogy to build on (1) how students' linguistic, ethnic, racial, gender, and socioeconomic backgrounds influence their learning; (2) the role of mathematics in society and culture; (3) the contribution of various cultures to the advancement of mathematics;

(4) the relationship of school mathematics to other subjects; and (5) the realistic application of mathematics to authentic contexts (see e.g., Ladson-Billings, 1994; Moses and Cobb, 2001; Nelson-Barber and Estrin, 1995; Meyerson, 2002; Rousseau and Tate, 2003; Secada, 1996).

The first NCTM recommendation calls for understanding how demographic group membership may be linked to the learning of mathematics. This recommendation is consistent with *No Child Left Behind* legislation that requires a national accounting of student performance in mathematics by demographic group. However, gathering achievement data by demographic group is very different than reflecting on race-related achievement patterns. Rousseau and Tate (2003) found that mathematics teachers in their study were reluctant to reflect on race and student performance in mathematics. Instead, some teachers in their study indicated they were color-blind and did not notice race or attend to matters of race-related patterns of student achievement. Further, many of the teachers were unwilling to link poor student performance to their teaching or other school-related factors. There was a tendency by the teachers to blame the students and their families. This kind of practice represents a unique challenge for instructional leadership attempting to engineer school mathematics improvement. The challenge suggests a need for professional practice among teachers and school leaders that differs radically from traditional formats. The need for study groups composed of teachers and school leadership is clear. These groups must foster trust and openly communicate about data and students;

in particular, the challenge of discussing race and culture must be met (e.g., Tatum, 1992).

There are other cultural factors in school mathematics related to quality design and school change. Many of these cultural factors largely deal with the aim of school mathematics. More specifically, the nature and extent the school mathematics curriculum is linked to the liberal arts tradition of reasoning and inquiry in contexts broader than the problems and concepts found in the discipline of mathematics. Should school mathematics include investigations of how mathematics is used in society and culture? For example, how relevant is political numeracy? Mathematics is part of many aspects of the democracy and can inform the reasoning associated with policy formation and policy analysis. Is this appropriate for middle school or high school students?

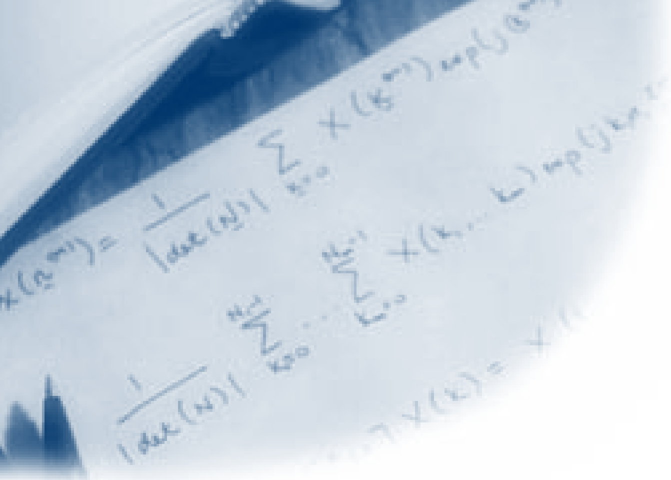
Some teachers have embarked on student-led integrated problem-solving investigations that include mathematics, statistics, legal analysis, multimedia techniques, scientific method, and connections to other disciplines (Tate, 1995). The approach is consistent with calls for authenticity in mathematics instruction (Meyerson, 2002). This strategy is designed to build on students' interest and to provide a liberal arts approach to the middle school and high school experience. However, the liberal arts approach may not be consistent with the current demands of high-stakes testing environments. Any disconnect between the liberal arts perspective of schooling and mathematics education is worthy of discussion by teachers, instructional leaders and policymakers.

Similarly, for some elementary instructional leaders providing an integrated learning experience that connects mathematics, science, and reading is desirable. This kind of integrated approach has many merits including efficient use of time and building on best practice in early childhood education (Bredekamp and Copple, 1997). If the culture of testing, specifically test preparation activities, substitute for real learning experiences and best practice, then long-term skills like student reasoning ability may be sacrificed.

**Language and Mathematics Learning.** In a policy analysis of urban students acquiring English and learning mathematics in the context of reform, Secada (1996) raised the following two questions: "Should their [urban school, *my addition*] efforts at reforming school mathematics specifically address the status of students acquiring English? Or should urban schools assume that these students' needs will be addressed under the broader aegis of reform?" (p. 422). Secada argued that failure to consider the specific learning needs of students acquiring English would be a mistake. He maintains it might be useful for educators to examine common learning processes that cut across language learning and mathematics learning. Two potential areas of analyses include (1) psychological processes that are common to understanding language and mathematics and (2) sociolinguistic and cultural processes that support the creation of discourse communities in school including how sense making takes place and is validated in these communities (e.g., Kinstch & Greeno, 1985; Lampert, 1990; Stanic, 1990). Secada (1996) described a potential scope of work for educators related to bilingual education and school mathematics. Secada (1996) stated:

> Newly developing models for teaching mathematics should be scrutinized for their applicability to bilingual learners and adapted as necessary. The limitations of evolving ways to teach mathematics (Lampert, 1990) is a reason to question, but not reject, the developing visions for teaching mathematics (NCTM, 1991). Maybe, with some adjustments—specifically inviting these students to add their thoughts, encouraging them to use their native languages and asking others to translate, slowing down the fast-pace tempo of the classroom, creating an atmosphere in which language variation in the community of discourse is an accepted fact of life—these methods can apply to bilingual learners. (p. 440)

Secada's remarks concerning bilingual learners and school mathematics focused on the importance of modifying instructional time and appropriate instructional accommodations—both critical OTL variables. Time and quality factors permeate the discussion of the research-based cases of the next chapter.



CHAPTER 4

# Research-Based Cases of School Mathematics Reform[13]

In every mathematics reform effort, significant time should be devoted to information gathering and group study of other similar change efforts. Learn as much as possible about related design. The intent of this chapter is to review a select set of research-based cases to serve as a model for your future information-gathering activities.

The group of studies reviewed in this chapter were included for three reasons. First, the studies were part of large multi-year projects focused on classroom-based research. These studies provide insight into how time, quality, and design interact to produce positive academic results in school mathematics. In each of the projects reviewed, student performance in mathematics improved over time. Second, each project at some point examined equity-related concerns, and looked to intervene in school settings where student proficiency in mathematics was underdeveloped. Finally, each project was included because participants engaged in an effort to reform school mathematics in a manner that was consistent with the teaching practices and/or curricular goals found in the National Council of Teachers of Mathematics (NCTM) reform documents or state/local mathematics standards. Moreover, the three projects included comprehensive research and evaluation components including data on student advancement and other educationally relevant indicators of progress. The research and evaluation aspect of these projects are important because of the rapid advancements of state standards. Massell (1994) reported 41 states have adopted mathematics standards that at least in part are consistent with the NCTM standard series. A brief history of this series is warranted.

In 1980, NCTM, a professional organization of mathematics teachers, supervisors, and college professors, released *An Agenda for Action,* which described a 10-year reform process. A central goal of *An Agenda for Action* was to move the focus of school mathematics from a strictly basic skills curriculum to a more balanced approach that included more demanding mathematics content and appropriate pedagogy to implement this content. Subsequently, but not as a direct result of *An Agenda for Action,* NCTM sponsored the development of the *Curriculum and Evaluation Standards for School Mathematics* (1989), the *Professional Standards For Teaching Mathematics* (1991), the *Assessment Standards for School Mathematics* (1995), and most recently, *Principles and Standards for School Mathematics* (2000). These documents were a product of extensive literature reviews and a series of technical reports that described key themes and ideas in school mathematics. This series of reform documents and the movement to reform school mathematics are important from an equity perspective. Past reform efforts have failed to significantly improve opportunity to learn mathematics for African American, Hispanic, and low-SES students (Tate, 1996). Thus, a close review of more recent reform efforts is part of the process of learning to build.

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[13] Additional information about these cases can be found in Tate and Rousseau (2002) and the January 1996 issue of *Urban Education.* There is some overlap in the evidence presented in this monograph and the Tate and Rousseau article. Adaption of this work is with permission from the Handbook of International Research in Mathematics Education, Lawrence Erlbaum Publishers. The cases are presented in this monograph to highlight the importance of time and quality factors.

## Cognitively Guided Instruction (CGI)

Researchers at the University of Wisconsin developed Cognitively Guided Instruction (CGI). The CGI foundation was in part established on Carpenter and Moser's (1983) analysis of young children's learning of addition and subtraction. Subsequently, other research was conducted to understand how teacher knowledge of children's thinking would affect teachers' pedagogical actions and student learning (Carpenter, Fennema, Peterson, Cary, 1988; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989). This research suggested that knowledge extracted from studies of learners' thinking can be used by teachers to strategically influence students' learning. The CGI research program supports the argument that knowledge of students' thinking, when integrated, robust, and a part of the established curriculum, can affect the teaching and learning of mathematics (Fennema & Franke, 1992). Carpenter and colleagues (1999) described the CGI design process and model as follows:

> Our research has been cyclic. We started with explicit knowledge about the development of children's mathematical thinking, which we used as a context to study teachers' knowledge of students' mathematical thinking and the way teachers might use knowledge of students' thinking in making instructional decisions. We found that although teachers had a great deal of intuitive knowledge about children's' mathematical thinking, it is fragmented and, as a consequence, generally did not play an important role in most teachers' decision making. If teachers were to be expected to plan instruction based on knowledge of students' thinking, they need some coherent basis for making instructional decisions…. We designed CGI to help teachers construct conceptual maps of the development of children's mathematical thinking in specific content domains. (p. 105)

CGI is not associated with particular instructional materials. Moreover, CGI does not have an explicit equity component, nor is it targeted at a particular group of students. However, it has been successfully implemented in classroom settings with diverse student groups.

For example, Carey, Fennema, Carpenter, and Franke (1995) described CGI classrooms in a predominantly African American school district. Twenty-two first-grade teachers from 11 schools in Prince George's County, Maryland, an urban school setting bordering Washington, D.C., participated in a research project organized to evaluate the efficacy of CGI with African American students. The student demographics in the classrooms of the study exceeded 70% African American. Further, seven of the 11 schools participated in Chapter 1, a federally funded program of Title 1 of the Elementary and Secondary Act, a good indicator of high concentrations of low-income students in a school. The teachers who participated in the study attended a two-week summer in-service program that was followed with five full-day professional development days offered during the academic year. The researchers documented a change in the teachers' implemented mathematics curriculum, with a greater focus on problem solving beyond that typically associated with the first-grade curriculum. The teachers also displayed an ability to take advantage of student thinking about important mathematical ideas, ultimately building on student understanding to establish new knowledge of school mathematics.

Villasenor and Kepner (1991) reported on the implementation of CGI in a minority context. The study was carried out with 12 treatment classes and 12 control classes in which the percentage of non-White populations ranged from 57% to 99%. The CGI group performed significantly better on a 14-item word problem posttest, an interview on word problems, and an interview on number facts. The CGI students also used advanced strategies significantly more often than non-CGI students on both problem solving and number facts. Peterson and colleagues (1991) argued that "Villasenor's results are important because they provide concrete evidence for the effectiveness of the CGI approach with a disadvantaged population of students" (p.78).

The CGI studies suggest that an important set of quality factors related to mathematics instruction are how well teachers (1) understand the structure of a specific mathematical concept, (2) understand students' thinking about the particular mathematical idea, and (3) implement instructional strategies that build on this knowledge of student thinking. As a set, these quality factors are powerful indicators of good instruction with a strong relationship to student learning and performance on outcome measures.

## Project IMPACT

Project IMPACT "is a school-based teacher enhancement model for elementary (K–5) mathematics instruction designed to foster student understanding and to support teacher change in predominantly minority schools" (Campbell, 1996, p. 449). There were six schools involved in the original study (three treatment and three control). The model involved (1) a summer in-service program, (2) an on-site mathematics specialist in each school, (3) manipulative resources for each classroom, and (4) teacher planning and instructional problem solving during a common grade-level planning period each week. The focus of the model was on instructional approaches consistent with a cognitive perspective on learning, emphasizing interaction and collaboration rather than the typical direct instruction approach.

Unlike CGI, Project IMPACT focused specifically on teaching for understanding in urban schools. Thus, content addressing "teaching mathematics in culturally diverse classrooms" was included in the program's summer in-service. Supported by campus-based mathematics specialists, instructional change occurred in most treatment classrooms, particularly where the instructional leadership by the principal encouraged and embraced the reform process. The students in these schools were assessed in the middle and at the end of each school year. Campbell (1996) summarized the results:

> The influence of the IMPACT treatment on student achievement was not immediate. The students in the IMPACT treatment schools did not evidence statistically significant higher achievement, as compared to the students in the comparable-site schools, until the middle of second grade; however, once established, this mathematics differential continued through second and third grade. (p. 463)

White (1997), in her dissertation, examined the nature of questioning in four third-grade classrooms both before and after the teachers went through the Project IMPACT summer in-service program. The study documented the question-response pattern, the cognitive level of the question (low or high), and the race and gender of the students who responded. White found that students' educational experiences, as reflected in classroom questioning, differed both between and, in some cases, within classes. There were two teachers, Ms. Davis and Ms. Tyler, who were fairly equitable in their distribution of questions.[14] "They posed questions to all students across questioning patterns and cognitive levels" (White, 1997, p. 300).

In Ms. Atkins' class, however, the distribution was more skewed. Overall, females answered the majority of the questions. Yet, a look at the different cognitive levels reveals racial patterns as well. White and Asian females answered most of the high level questions. Black and Hispanic female students were asked a relatively low number of high-level questions. According to White (1997), the origin of this disparity lies in Ms. Atkins' perceptions of students' academic ability and her own discomfort with mathematics. Ms. Atkins wanted to ask high-level questions, but her own lack of understanding caused her to call only on students whom she thought would give the correct answer. Thus, only the students perceived to be of high ability were selected to answer high-level questions. A similar pattern of focusing only on the students who were perceived to have the greatest mathematical understanding was found in the class of the fourth teacher, Ms. Smith.

This very detailed study of question and response patterns is important for at least two reasons. First, it documents a partial success story for Project IMPACT in terms of improving equity in classrooms. Two of the four teachers appeared to change their practices as a result of their participation in the initial IMPACT summer in-service and ongoing campus level assistance. Both Ms. Davis and Ms. Tyler were more equitable in their distribution of questions after the in-service than they had been before.

This study is also important because it suggests the need to look closely at teachers' explanations for their actions in order to more

[14] The names were changed to protect the identity of the teachers.

fully understand what is happening in the classroom. For example, the case of Ms. Atkins indicates that teachers' inequitable actions can originate from a variety of sources, including inadequate content knowledge.

Project IMPACT suggests that another quality indicator related to mathematics instruction is the relationship between teachers' knowledge of mathematics, teachers' understanding of student thinking about mathematics, and teachers' understanding of race/gender interactions in classroom settings. Project IMPACT is consistent with other research programs that indicate the importance of treating cultural background as a resource for learning (Rousseau and Tate, 2003). For example, Knapp (1995) found that teachers in high-poverty schools who placed the greatest emphasis on meaning in their mathematics instruction made two significant shifts in their thinking about learners. First, they viewed learners as active participants in learning, and second, the teachers used cultural dimensions of instruction to sustain engaged time with academic work. This also is an important lesson from Project IMPACT.

## QUASAR

QUASAR is described as "an educational reform project aimed at fostering and studying the development and implementation of enhanced mathematics instructional programs for students attending middle schools in economically disadvantaged communities" (Silver & Stein, 1996, p. 476). One purpose of the project was to help students develop a meaningful understanding of mathematical ideas through engagement with challenging mathematical tasks. The QUASAR project supported teachers and administrators in six urban middle schools. Each school site worked with a resource partner—typically, mathematics educators from local universities—to improve the school's mathematics instructional program with a focus on mathematical understanding, thinking, reasoning, and problem solving. The site teams operated independently in the design and implementation of its curriculum plan, professional development, and other features of its instructional program. There were regular interactions among representatives from all QUASAR sites. Moreover, each site-based team benefited from financial support, technical assistance, and advice from the QUASAR staff housed at the Learning Research and Development Center at the University of Pittsburgh.

Silver and Stein (1996) describe three different analyses used to assess the effectiveness of instruction in QUASAR sites. Unlike the CGI and IMPACT studies, there was no control group in the QUASAR study. One method used to determine the impact of QUASAR was the examination of changes in student performance over time. The results from the first three years of the project indicated that “students developed an increased capacity for mathematical reasoning, problem solving, and communication during that time period” (Silver & Stein, 1996, p. 505). A second method of evaluation used a variety of tasks from the National Assessment of Educational Progress (NAEP) as pseudo-control groups (Silver & Lane, 1995). The QUASAR students were given items from the 1992 eighth-grade NAEP. The results were compared to those of NAEP’s national sample and disadvantaged urban sample. The findings from the analysis of student performance on the nine open-ended tasks were very informative about the effectiveness of QUASAR. QUASAR students performed at least as well as the national sample on seven of the nine tasks. Silver and Lane (1995) noted that this is an important result, in light of the fact that the national sample had significantly outperformed the disadvantaged urban sample on all nine tasks. They stated:

> The findings clearly suggest that the mathematics performance gap between more and less affluent students has been significantly reduced for students attending the QUASAR schools. Thus, the performance of QUASAR’s students is far greater than would have been expected, given their demographic similarity to NAEP’s disadvantaged urban sample, and one can infer that the instruction at QUASAR has a beneficial impact on students’ mathematical performance. (Silver and Lane, p. 62)

A third method of evaluation examined outcomes other than achievement, considering whether QUASAR instruction was linked to increased access and success in algebra coursework. Silver and Stein (1996) reported that students from QUASAR schools were both qualifying for and passing algebra in ninth grade at substantially higher rates than before QUASAR.

The QUASAR project reinforces the importance of students’ engaged time with cognitively demanding mathematical concepts. Sustained engaged time with quality mathematics tasks resulted in improved student performance on a wide range of indicators.

**Research Case Summary.** These research cases have three overlapping themes worthy of note. First, high-quality mathematics was at the center of each effort. More specifically, each program called for mathematics instruction using mathematical tasks not typically associated with the lower educational expectations often found in large urban and rural school districts. In each program, mathematical proficiency consisted of a balance between conceptual understanding and procedural proficiency. Too often instruction is based on extreme positions, rather than a balanced approach with increasing cognitive demand.

A second common feature of each program was the important role of classroom-based assessment designed to better understand student thinking about mathematical ideas. These studies of mathematics teaching support the idea that teachers’ knowledge of students’ reasoning when it is integrated with a balanced mathematics curriculum can positively affect the teaching and learning of traditionally underserved students. The assessments used in the research-based cases of mathematics reform were designed to support the learning process and to identify areas in which further instruction is needed. The measures included direct observations of children during classroom activities, evaluation of student work, and asking questions in class. The portfolio of measures in the research-based case studies differed from the measures used to gauge national trends. The latter measures are designed to inform the public about trends in student performance or the effectiveness of large-scale educational programs. The research-based cases included standardized tests, selected NAEP items, and classroom-based activities.

A third common feature of each case was the presence of a strong mathematics professional development program. Two key features of these programs were teacher learning opportunities in the areas of school mathematics content and how children’s mathematical knowledge develops in the content domains, including what knowledge students were likely to bring with them to school.

These three common themes represent important quality factors. They reinforce how the combination of quality curriculum, cognitive-based assessment tools, and integrated professional development are central to school mathematics design.

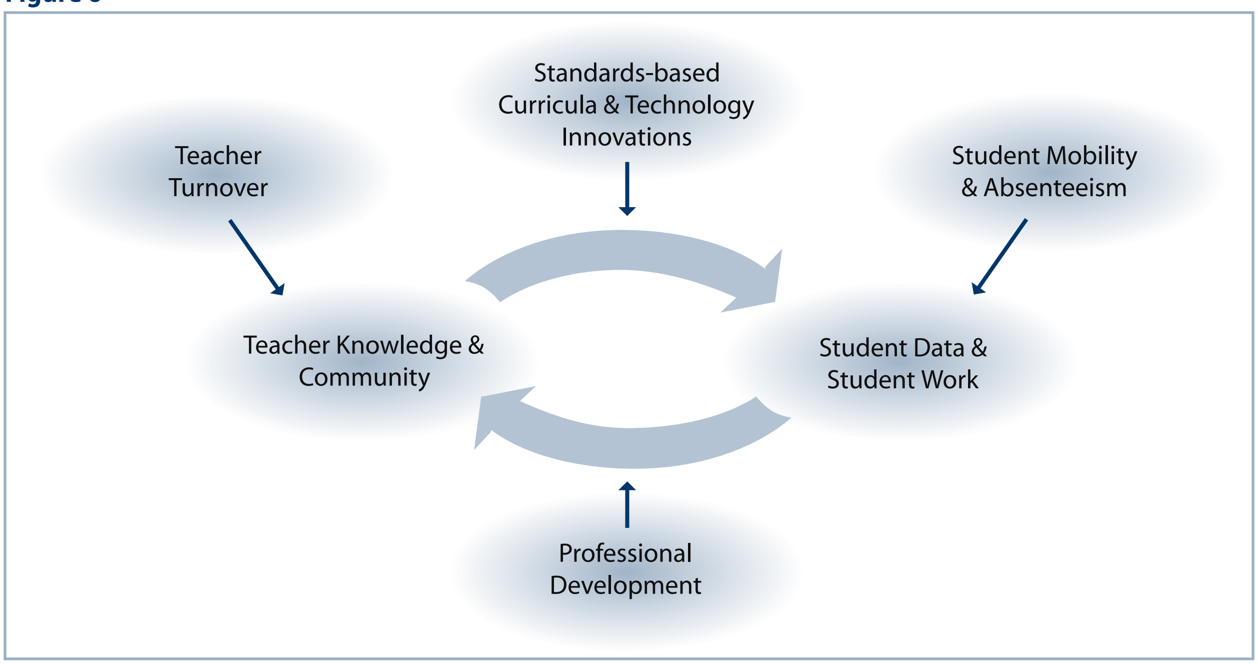
CHAPTER 5

# It's Time to Design

In this monograph, it has been argued that calls for rigorous mathematics standards preK–12 require thoughtful action and planning. Moreover, the building blocks for engineering mathematical progress in any school are time, quality, and design. These three pillars of OTL are foundational for the improvement of the teaching and learning of mathematics in school settings. There are many paths for organizing and implementing change in school mathematics; however, the failure to consider time and quality factors and design issues carefully is a recipe for lost educational opportunity. Jere Confrey and colleagues at the *Systemic Research Center for Education in Mathematics, Science, and Technology* (SYRCE) designed Figure 6 to serve as a conceptual model to inform the organizational design of mathematics teaching and learning in schools.

Figure 6 is included because it serves as a reminder of key opportunity-to-learn factors and how they interact in our systems of education. As an engineer, it is important to keep in mind a broader conceptual model of school change. This is especially important in light of the day-to-day realities of teaching, administration, and political challenges that face educators. The many events and distractions that occur in schools and school districts, such as leadership changes and financial shortfalls, only become real problems when they influence these three foundational pillars of learning and teaching. Unfortunately, instability and interim leadership are rife everywhere in public schooling. Recall, engineers "learn to build." Both learning and building require stability, long-term, and insightful leadership. The building process for the engineer is supported by the following model development sequence:

**Figure 6**




Source: Confrey, Castro-Filho, & Wilhelm (2000)

- Model Construction
- Model Exploration
- Model Application
- Model Revision

Models are a language for describing patterns, patterns that can be observed and tested in the real world of schools. Thus, the process of model development emphasizes understanding school factors that influence opportunity to learn mathematics. The model development sequence requires additional clarification.

**Model Construction.** OTL requires a clear vision and set of learner goals. Many school districts accomplish this part of model construction by adopting all or portions of state mathematics standards and in combination with local system objectives create specific district-level goals for what all students should know and be able to do. District mathematics goals are important quality indicators for teachers, administrators, parents, students, and the broader community. Thus, multiple communication strategies for each constituency should be part of the model's design. Each constituency should be provided samples of student work. The work should exemplify system-wide expectations and illustrate student work products that meet the district's mathematics standards. Setting high standards and communicating a clear vision are only part of the model construction process. Ensuring that all students have access to a quality curriculum also is part of the process.

There are a number of steps that are vital to initiating a quality curriculum. Each school should design an academic plan based on local mathematics standards and an associated accountability structure. The process includes:

1. Communicating the importance of consistent application of curricular programs and standards
2. Eliminating courses and academic experiences lacking the rigor of mathematics standards or inconsistent with developmentally appropriate mathematics practice
3. Providing adequate time in the curricular design to focus on core subjects
4. Building a timely framework for monitoring student progress using data
5. Providing teacher and administrator professional development focused on classroom strategies for assessing student learning of mathematics standards

Vision, curriculum quality and accountability systems are vital to constructing a model. However, policy and resource alignment also contribute to a comprehensive model design.

It is difficult to imagine a sustained change strategy that does not include front-end alignment of school policies and resources to support rigorous standards. For example, ongoing mathematics professional development should be part of the model construction process. In addition, effective student support programs should be prepared and ready to implement in response to updates on student assessments and mobility information. Too often, responses to these types of data are not part of the upfront planning process. Consequently, many school districts find themselves engaged in triage mode, piecing together programs in real-time, rather than implementing planned data-driven interventions. Resources aligned with an appropriate vision, quality curriculum, and accountability systems are part of the technical core of the model construction process. The technical core is vitally important, but not enough. Ultimately, people explore the model and make decisions.

**Model Exploration.** Model construction includes planning for reflective examination of student, teacher, and school-level progress. Embedded in the model construction process are key elements of model exploration. The constructed model should include rich opportunities to explore the progress of the organization in relation to its goals. Yet, model exploration is not merely an instrumental activity; instead, exploration is cultural and people driven, with teachers and administrators central to the evaluative process.

As Figure 6 indicates, teacher community and knowledge are important components of the feedback loop. Teachers interpret student performance and assessments and in turn they should rethink their practice and that of the school in conjunction with other instructional leaders. This process is greatly enhanced where community norms are established and teacher turnover is low. Teacher community and norms are linked to the model application process. The importance of teacher collective practice in school mathematics can't be overstated (see e.g., Gutierrez, 1996). As Campbell (1996) stated, "It may be unreasonable to expect sustained and reflective reform in isolated classrooms across urban settings. It is not unreasonable to address reform in urban schools where teachers and administrators are working together to develop a shared purpose and meaning" (p. 453).

Both administrators and teachers require training to support their community efforts to build a student-centered, data-driven organization. Classroom strategies for assessing student learning should be central to the common professional development. The community building and professional development activities also must be combined with an aligned monitoring process that includes:

1. Timely and usable data on student progress
2. Opportunities for mid-course corrections based on data
3. Disaggregated student achievement data and mobility information
4. Recognition and reward for positive results

Model exploration potentially offers important benefits to schools and school districts. First, model exploration can provide highly visible evidence related to opportunity to learn and support administrators and teachers seeking successful exemplars of effective mathematics practice (Skrla and Scheurich, 2001). Second, incremental success in student achievement and teacher effectiveness can lead to higher expectations and goals for academic achievement of all demographic groups.

Model Application. It is possible to focus on the design of the model and matters of model exploration without attending to the classroom practices and support systems associated with instruction. Most school systems begin the academic year with some kind of school improvement plan, and while the quality of these plans varies widely, substantive change models do exist. Further, it is quite common to find some level of model exploration in most school systems. Although, the quality factors associated with the exploration are often limited, arguably the most serious challenge facing leadership is model application or implementation. Many instructional programs are adopted, distributed, and discarded each year.

There must be a well-thought-out plan to gain any implementation traction. A key factor for success in this area is a fine-tuned curriculum guide that clearly delineates important content aligned to appropriate instructional materials. Further, research-based professional development for teams of teachers and instructional leaders is vital. The work of the teacher collective enterprise and significant time engaged with high-quality professional development are central to the implementation process. And quality student assessments—classroom based as well as more summative assessment—should be linked to collective and individual reflection by members of the teacher community. Quality curriculum, professional development, collective practice and the other aspects of the model design are a support system for creating a successful teaching and learning process.

Teachers are key to model application. Clearly, mathematics teachers at all levels, kindergarten through college, are central to the improvement of mathematics education. If professional development is to a make a difference to students in the classroom, it must be teacher-focused and student-centered. Stigler and Hiebert (1999) write, "Improving something as complex and culturally embedded as teaching requires the efforts of all players, including students, parents and politicians. But teachers must be the primary driving force behind change. They are in the best position to understand the problems that students face and to generate possible solutions" (p. 135).

Successful model application is largely classroom based and includes:

1. Teachers and students participating in two-way conversations about mathematics
2. Teachers pushing for both mathematical meaning behind quality curricular tasks and procedural fluency
3. Teachers building instruction on student thinking and continuity in the mathematics domain daily
4. Teachers and administrators organizing classes and support systems to ensure adequate time for students to learn the mathematics content
5. Teachers and administrators maintaining high expectations for all learners

These five components of instruction are foundational to model application and opportunity to learn. While these components are stable in a broader sense, there are times when the design is not quite adequate to achieve system goals or more ambitious goals require a revised model.

**Model Revision.** Careful reflection on the progress being made is central to future progress. How is the model helping or hindering teachers and students? Each phase of the model development sequence should be reviewed and critical discussions about fine-tuning or model abandonment must be held. Revision is not merely an end of the year activity. Model revision is a continuous process that should be part of the design consideration. To aid in both the design and model revision process, Appendix B includes an *Engineering Change Assessment Instrument*. This instrument can be used to help keep track of school and school district progress on key opportunity-to-learn factors.

Taking a model-based approach to the mathematics change process involves constructing a change strategy, exploring the qualities and feasibility of the strategy, applying or implementing the strategy, and continuously fine-tuning the strategy based on data. A close examination of many school district strategic plans will reveal many goals and targets related to the state accountability systems. Often, what is absent is a coherent change strategy or model for improvement in mathematics that takes seriously the time, quality, and design considerations reviewed in this document. Few school districts explore the qualities or feasibility of their change effort. Rather, many buy into a model without considering the conditions and constraints that exist in the system. For example, this is evident when major initiatives to improve mathematics, reading, and science at the elementary level are occurring simultaneously. The point is not that three reform strategies cannot occur together; rather, failure to coordinate the changes is a common strategic flaw. Many reasonable change strategies are destroyed as a result of the failure to consider the feasibility of the model.

## Engineering Progress: Limiting Conditions

Limiting conditions are conditions that materially affect the appraisal process and, as a consequence, the value conclusion. For example, having no electrical power in a school building is a limiting condition, as it prohibits the use of computers and other electronic equipment. This notion can be applied to mathematics education. What limiting conditions exist that can affect student performance on mathematics outcome measures and, as a consequence, the public's perception of school quality? A brief examination of recent legislation will provide some insight into this question.

Current educational policy and law, more specifically NCLB, calls for educators to carefully examine student achievement by demographic group. Moreover, schools and administrators are being held accountable for improved student performance. This is a radical departure from past educational practice. In fact, this law represents a major shift in federal discourse related to matters of equality. According to Crenshaw (1988), a legal scholar, there are two visions of equality present in anti-discrimination legislation and discourse. One view of equality, which she refers to as the restrictive view, "treats equality as a process, downplaying the significance of actual outcomes" (p. 1341). This monograph highlighted important processes related to student learning. While critical to engineering positive progress, the opportunity-to-learn recommendations and other research-based lessons are limited. Specifically, they represent building blocks. However, someone must build the building. Thus, a potential limiting condition is related to people, more specifically to educators willing to do the hard work associated with building mathematical minds.

In the case of school mathematics, the "product" is optimal student learning as measured by state-mandated tests—the intended outcome. Hence, current law as reflected in NCLB, is more consistent with another view of equality—the expansive view. Professor Crenshaw (1988) stated this second view of equality, the expansive vision, "stresses equality as a result and looks to real consequences" (p. 1341). The NCLB legislation calls for educators to reflect seriously on student outcomes by demographic group. This expansive view suggests that equal treatment of students is not equitable if it leads to differential outcomes. This perspective conflicts with the worldview held by many educators that "equal treatment" of all students is optimal. If educators assume a "one-size-fits-all" approach to classroom practice, without careful reflection and planning for individual as well as collective student learning, the product is likely to be unequally distributed opportunities to learn and continued underperformance of traditionally underserved students. In the case of NCLB this "equal treatment" worldview and its associated ideological perspective—colorblindness—are limiting conditions.

Many educators who view the "equal treatment" position as a well-meaning and fair perspective assume colorblindness as a political or ideological stance. Part of the problem with colorblindness is that it ignores students and their performance. Irvine (1990) states, "by ignoring students' most obvious physical characteristic, race, …teachers are also disregarding students' unique cultural behaviors, beliefs, and perceptions—important factors that teachers should incorporate, not eliminate, in their instructional strategies" (p. 54). Today, the colorblind method of mathematics education creates barriers to true equality by erecting barriers in school mathematics such as

1. Persistent tracking,
2. Fewer opportunities for African American and Hispanic students to learn from the best qualified teachers,
3. Less access to technology, and
4. Cultural discontinuity between school mathematics and the family life of diverse student groups (National Science Board, 1991; Oakes, 1990; Piller, 1992; Stanic, 1991).

The first three of these barriers to equity, which are quantifiable, are considered "acceptable" indicators of unequal educational conditions. In contrast, this fourth barrier is subtle and difficult to identify and measure in everyday schooling. The matter of family life and school mathematics warrants additional discussion.

Less frequently, educators have explored the experiences of stakeholders other than teachers in the process of school mathematics reform (see Graue and Smith, 1996). This is a serious limiting condition. In particular, there is limited information available on how parents

- Perceive their children's mathematics instruction,
- Interpret their children's performance in light of mathematics standards and state testing, or
- View their role in mathematics education process.

As Graue and Smith (1996) noted, despite parental presence in many aspects of educational reform rhetoric, researchers of school mathematics practice and design have shown little interest in parents.[15] Ethically, in the context of high-stakes testing and reformed practice, this is a condition that must be addressed by the focused efforts of scholars, school-based educators, and community-based organizations. Matters of ethics represent the final limiting conditions.

The pressures of high-stakes testing, public disclosure of testing results, and the real possibility of job loss or demotions have placed a new and heavy burden on professional educators. This burden will cause some to carefully design change strategies and create exciting learning environments for students. For others, the score-high mentality will create new ethical dilemmas. Reports have emerged of schools and districts removing large numbers of students from opportunities to test, rather than creating appropriate opportunities to learn. The ethical challenges are endless when the stakes are high and very real. As with good engineers, educators must factor ethics into their thinking, everyday planning, and ultimately into their design strategy. Failure to do so will endanger the building process.

In the pursuance of an engineering strategy in mathematics education, the importance of dedicated educators cannot be underestimated. Many educators are excellent, but some are not. The following questions highlight the traits of those ready to improve school mathematics:

- Does the educator listen to new ideas with an open mind?
- Does the teacher consider a variety of solution

[15] One exception is Family Math (www.lhs.berkeley.edu/equals/FMnetwork.htm).

methods associated with student learning before choosing a design approach?

- Is the educator content with determining a learning design on the basis of trial and error?
- Does the teacher use phases such as, "I need to understand why students learn mathematics with this approach?" and "Let's consider all possibilities."

If educators are eager to listen, open to a variety of educational solutions, never content with just trial and error methods, and pressed to know why a method works with students, they represent the type of teachers and instructional leaders who can engineer changes in mathematics education. These kinds of educators are foundational for "Learning to Build."

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# Appendices

**Table A1: Mathematics Proficiency Levels from the 1992 NELS:88 Second Follow-up Survey**

| Proficiency Level | Proficiency Description |
|---|---|
| Below level 1 | Unable to perform simple arithmetic operations |
| Level 1 (Low) | Able to perform simple arithmetical operations on whole numbers; single step problems |
| Level 2 | Able to perform simple operations with decimals, fractions, powers, and roots |
| Level 3 | Able to perform simple problem solving of low-level mathematical concepts |
| Level 4 | Understands intermediate-level mathematics concepts or demonstrates the ability to formulate multi-step solutions to word problems |
| Level 5 (High) | Able to solve complex multi-step word problems, or demonstrates knowledge of mathematical principles found in advanced mathematics courses, or both |

Source: Green, Dugoni, Ingels, and Camburn, 1995.

**Table A2: Sophomore Cohorts from the HS&B 1980 Study and the 1990 NELS: 88 Follow-up Mathematics Study, by Racial-Ethnic Group**

| Group | HS&B 1980 mean | 1990 NELS: 88 mean | Effect Size |
|---|---|---|---|
| All Students | 32.81 | 35.97 | .26 |
| African American | 24.51 | 28.74 | .35 |
| Asian | 38.82 | 40.26 | .12 |
| Hispanic | 25.96 | 30.75 | .34 |
| White | 35.41 | 37.96 | .21 |

Source: Rasinski, Ingels, Rock, Pollack, 1993.

For all students, the 1980 HS&B mean test score was 32.81; the 1990 NELS:88 mean was 35.97; and the effect size was .26. These are scale scores constructed using IRT scaling procedures. The effect size of .26 is the difference between the 35.97 and 32.81, which is 3.16, divided by the pooled 1980/1990 standard deviation. The .26 effect size indicated that on average, the sophomores in 1990 were performing 26% of a standard deviation higher than the 1980 HS&B cohort.

**Table A3: NAEP Trends in Average Mathematics Scale Scores by Parents' Highest Level of Education**

| Parents' Level of Education | Test Year | Age 9 | Age 13 | Age 17 |
|---|---|---|---|---|
| Less than High School | 1999 | 213.5 (2.8) | 256.2 (2.8) | 289.2 (1.8) |
| | 1996 | 219.8 (3.3) | 253.7 (2.4) | 280.5 (2.4)* |
| | 1994 | 210.0 (3.0) | 254.5 (2.1) | 283.7 (2.4) |
| | 1992 | 216.7 (2.2) | 255.5 (1.0) | 285.5 (2.3) |
| | 1990 | 210.4 (2.3) | 253.4 (1.8) | 285.4 (2.2) |
| | 1986 | 200.6 (2.5)* | 252.3 (2.3) | 279.3 (2.3)* |
| | 1982 | 199.0 (1.7)* | 251.0 (1.4) | 279.3 (1.0)* |
| | 1978 | 200.3 (1.5)* | 244.7 (1.2)* | 279.6 (1.2)* |
| Graduated High School | 1999 | 224.4 (1.7) | 264.0 (1.1) | 299.1 (1.6) |
| | 1996 | 221.2 (1.7) | 266.8 (1.1) | 297.3 (2.4) |
| | 1994 | 225.3 (1.3) | 265.7 (1.1) | 295.3 (1.1) |
| | 1992 | 222.0 (1.5) | 263.2 (1.2) | 297.6 (1.7) |
| | 1990 | 226.2 (1.2) | 262.6 (1.2) | 293.7 (0.9)* |
| | 1986 | 218.4 (1.6)* | 262.7 (1.2) | 293.1 (1.0)* |
| | 1982 | 218.3 (1.1)* | 262.9 (0.8) | 293.4 (0.8)* |
| | 1978 | 219.2 (1.1)* | 263.1 (1.0) | 293.9 (0.8)* |
| Graduated College | 1999 | 239.7 (0.8) | 285.8 (1.0) | 316.5 (1.2) |
| | 1996 | 239.7 (1.4) | 282.9 (1.2) | 316.6 (1.3) |
| | 1994 | 237.8 (0.8) | 284.9 (1.2) | 317.6 (1.4) |
| | 1992 | 236.2 (1.0) | 282.8 (1.0)* | 315.9 (1.0) |
| | 1990 | 237.6 (1.3) | 280.4 (1.0)* | 316.2 (1.3) |
| | 1986 | 231.3 (1.1)* | 279.9 (1.4)* | 313.9 (1.4) |
| | 1982 | 228.8 (1.5)* | 282.3 (1.5) | 312.4 (1.0)* |
| | 1978 | 231.3 (1.1)* | 283.8 (1.2) | 316.8 (1.0) |

Standard errors of the scale scores appear in parentheses.
*Significantly different from 1999. Source: NAEP 1999 Trends in Academic Progress, NCES (2000).

**Table A4: Mathematics Performance of Sophomore Cohorts from the HS&B 1980 Study and the 1990 NELS:88 Follow-up Study, by SES**

| SES Classification | HS&B 1980 mean | 1990 NELS: 88 mean | Effect Size |
|---|---|---|---|
| High | 39.53 | 42.90 | .27 |
| High Middle | 34.58 | 37.15 | .21 |
| Low Middle | 31.65 | 34.10 | .20 |
| Low | 26.73 | 29.17 | .18 |

Source: Rasinski, Ingels, Rock, Pollack, 1993.

**Table A5: Mathematics Proficiency by Race, Controlling for SES, 1992 NELS:88 Second Follow-up Survey of Seniors**

| SES Classification | Below basic or level 1 | Levels 4 or 5 |
|---|---|---|
| **Low** | | |
| Asian | 26.2 | 22.7 |
| Hispanic | 51.4 | 12.5 |
| African American | 60.4 | 4.9 |
| White | 40.2 | 18.3 |
| **Middle** | | |
| Asian | 15.1 | 40.7 |
| Hispanic | 35.0 | 25.3 |
| African American | 44.9 | 15.6 |
| White | 21.7 | 34.9 |
| **Low** | | |
| Asian | 8.1 | 64.7 |
| Hispanic | 16.6 | 43.8 |
| African American | 26.3 | 26.5 |
| White | 7.7 | 58.9 |

Source: Green, Dugoni, Ingels, & Camburn (1995).

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **1** | **Establish Essential Structures — Organizational Context** | | | | | | |
| **1.1** | **Set High Standards** | | | | | | |
| 1.1.1 | Develop clear and rigorous goals for what students should know and be able to do | | | | | | |
| 1.1.2 | Communicate expectations to teachers, administrators, parents, students, community | | | | | | |
| 1.1.3 | Provide samples of student work which meet standards and communicate what is expected to all constituencies | | | | | | |
| **1.2** | **Ensure that all students have access to a challenging curriculum** | | | | | | |
| 1.2.1 | Implement school based planning and accountability processes | | | | | | |
| 1.2.2 | Emphasize consistent application of curricular programs and standards | | | | | | |
| 1.2.3 | Eliminate watered down courses and tracking | | | | | | |
| 1.2.4 | Ensure that curriculum and assignments are aligned with standards | | | | | | |
| 1.2.5 | Focus on core subjects: language arts, reading, mathematics, science, social studies | | | | | | |

| | Opportunity-to-Learn Building Blocks | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| 1 | **Establish Essential Structures — Organizational Context, continued** | | | | | | |
| **1.3** | **Align standards with assessment and monitor progress** | | | | | | |
| 1.3.1 | Provide timely, usable data on student progress | | | | | | |
| 1.3.2 | Encourage mid-course corrections based on data | | | | | | |
| 1.3.3 | Recognize and reward positive results | | | | | | |
| 1.3.4 | Disaggregate student achievement data and carefully monitor minority student data | | | | | | |
| 1.3.5 | Train teachers in classroom strategies for assessing student learning to determine the impact of teaching and classroom activities | | | | | | |
| **1.4** | **Develop programs to address the impact of student/teacher mobility in low-performing schools to include** | | | | | | |
| 1.4.1 | Standardization of curriculum and materials | | | | | | |
| 1.4.2 | Centralized storage of data | | | | | | |
| 1.4.3 | Transmission of individual student data | | | | | | |
| 1.4.4 | Staff training on impact of mobility and how to mitigate this factor (see Dept. of Defense school model) | | | | | | |
| 1.4.5 | Recruitment and retention of quality teachers at low-performing schools | | | | | | |
| 1.4.6 | Additional use of instructional/curriculum specialists | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **1** | **Establish Essential Structures — Organizational Context, continued** | | | | | | |
| **1.5** | **Develop innovative strategies to** | | | | | | |
| 1.5.1 | Organize schools into smaller units-small schools have been shown to improve both "gap" and achievement levels | | | | | | |
| 1.5.2 | Provide quality, sustained professional development and increase its availability of schools and through technology and other innovative approaches. | | | | | | |
| 1.5.3 | Encourage collaborative and team approaches | | | | | | |
| 1.5.4 | Foster collegial networks among teachers, principals, schools | | | | | | |
| 1.5.5 | Extend teacher and team planning time | | | | | | |
| **1.6** | **Provide needed policies and resources to support** | | | | | | |
| 1.6.1 | Ongoing, quality school site professional development | | | | | | |
| 1.6.2 | Effective, timely student support programs | | | | | | |
| 1.6.3 | Parent/community support initiatives | | | | | | |
| 1.6.4 | Rigorous standards-based teaching and learning for all students | | | | | | |
| 1.6.5 | Governance/organizational alignments necessary to ensure accountability, student progress and quality teaching and learning for all students | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **1** | **Establish Essential Structures — Organizational Context, continued** | | | | | | |
| **1.7** | **Foster research-based characteristics of high-performing schools** | | | | | | |
| 1.7.1 | Minimize bureaucracy | | | | | | |
| 1.7.2 | Promote effective leadership at all levels | | | | | | |
| 1.7.3 | Promote access and equity for all students | | | | | | |
| 1.7.4 | Implement rigorous standards-based programs | | | | | | |
| 1.7.5 | Provide significant planning time for teachers | | | | | | |
| 1.7.6 | Orient-learning around essential skills, concepts, and inquiry | | | | | | |
| 1.7.7 | Foster parent involvement | | | | | | |
| 1.7.8 | Develop a sense of team, collaboration, and family within the school system and/or school | | | | | | |
| 1.7.9 | Develop strategies to use research on "bridging the gap" to inform decision-making and to influence the actions of legislators, teacher preparation institutions, educators, community leaders, and parents. | | | | | | |
| 1.7.10 | Accountability for quality classroom teaching | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **2** | **Increasing Opportunities to Learn** | | | | | | |
| **2.1** | **Establish a process for review of subject area achievement goals quarterly, to address needed changed in subject area and grade level expectations, standards-based teaching/learning practices, and assessment techniques** | | | | | | |
| **2.2** | **Foster high levels of teacher engagement in "bridging the gap" process through activities which promote involvement with** | | | | | | |
| 2.2.1 | School and/or school system goals for high achievement | | | | | | |
| 2.2.2 | Identification of skills, practices, and knowledge for effective teaching and high achievement | | | | | | |
| 2.2.3 | Provide teacher training in working with diverse learners | | | | | | |
| **2.3** | **Establish a process for monitoring classroom implementation of performance and content standards to include** | | | | | | |
| 2.3.1 | Depth of content coverage, extent and time allocated to key concepts, and emphasis on general principles and major concepts | | | | | | |
| 2.3.2 | Quality of instructional delivery and teaching practices such as hands-on activities, use of technology, and student performance activities which include work products | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **2** | **Increasing Opportunities to Learn, continued** | | | | | | |
| **2.4** | **Foster implementation of new approaches to support meaningful ways to make schools/classrooms more compatible with the diverse home background of students to** | | | | | | |
| 2.4.1 | Reduce cultural isolation | | | | | | |
| 2.4.2 | Identify individual student learning styles and build on strengths students bring | | | | | | |
| 2.4.3 | Use modeling and interactive practices and scaffolding to guide students to complete complex tasks | | | | | | |
| 2.4.4 | Enhance use of group learning techniques such as cooperative and team learning, peer tutoring, and reciprocal teaching | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **3** | **Expanding Community Connections** | | | | | | |
| **3.1** | **Foster increased and meaningful family involvement activities** | | | | | | |
| 3.1.1 | Provide specific training to families in tutoring and encouraging students to meet high standards | | | | | | |
| 3.1.2 | Provide community and extended educational opportunities for families at schools, in projects, churches, and community centers | | | | | | |
| 3.1.3 | Develop family resource centers | | | | | | |
| 3.1.4 | Initiate and/or extend family participation opportunities to foster meaningful roles for families in support of school system/school goals and to encourage family involvement as a team effort in a supportive school environment | | | | | | |
| 3.1.5 | Communicate importance of family support in establishing homework time, study skills, and academic standards in the home | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **3** | **Expanding Community Connections, continued** | | | | | | |
| **3.2** | **Establish necessary collaboration between schools and other community resources to provide needed assistance to** | | | | | | |
| 3.2.1 | Ensure availability of support mechanisms within each school | | | | | | |
| 3.2.2 | Establish programs to forge connections between families and community organizations in support of student academic learning and rigorous standards | | | | | | |
| 3.2.3 | Establish opportunities for meaningful proactive roles for business and industry in shaping and supporting rigorous standards at district and school-site levels | | | | | | |
| 3.2.4 | Involve universities in "bridging the gap" initiatives that strengthen the K–16 community connections and programs | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **4** | **Enhancing Teacher Quality and Practice** | | | | | | |
| **4.1** | **Implement professional development programs which focus on standards-based learning aligned with assessment and with emphasis on practices which promote: in-depth content knowledge, key concepts and general principles, real life hands-on activities, application of technology, and modeling effective teaching strategies** | | | | | | |
| **4.2** | **Implement quality teaching practices and training programs that utilize strategies for achieving high expectations for all, and focus on the need to address and maximize individual students' learning styles** | | | | | | |
| **4.3** | **Develop effective classroom assessment practices to enhance** | | | | | | |
| 4.3.1 | Use of data to make timely decisions | | | | | | |
| 4.3.2 | Use of a variety of classroom assessments including performance tasks and applications, surveys, interval testing, observations, standardized and criterion-referenced tests, student portfolios, teacher logs, course content, modes of instruction, time allocated to key concepts, student activities, etc. | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **4** | **Enhancing Teacher Quality and Practice, continued** | | | | | | |
| **4.4** | **Implement teacher training programs that develop skills related to student behavior, especially** | | | | | | |
| 4.4.1 | Developing cultural sensitivity | | | | | | |
| 4.4.2 | Working with non-motivated students | | | | | | |
| 4.4.3 | Developing effective classroom management skills | | | | | | |
| **4.5** | **Provide teachers with powerful, proven techniques successful in "bridging the gap" and in raising student achievement through** | | | | | | |
| 4.5.1 | Guiding students to skills and understanding | | | | | | |
| 4.5.2 | Interactive and collaborative learning activities | | | | | | |
| 4.5.3 | Linking academics to community resources | | | | | | |
| 4.5.4 | Promoting action research in classrooms | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **4** | **Enhancing Teacher Quality and Practice, continued** | | | | | | |
| **4.6** | **Establish personnel practices and programs that promote** | | | | | | |
| 4.6.1 | The need to invest in professional development, making available both time and resources | | | | | | |
| 4.6.2 | Availability of quality teachers at all schools and in all classrooms | | | | | | |
| 4.6.3 | Appropriately prepared and certified teachers | | | | | | |
| 4.6.4 | In-house teacher recruitment programs | | | | | | |
| 4.6.5 | Degree programs for work force advancement | | | | | | |
| 4.6.6 | Collaborative programs with universities to support pre-service, in-service and community resource needs | | | | | | |
| 4.6.7 | Staff stability and quality in low performing schools and reduce teacher mobility | | | | | | |
| 4.6.8 | Assignment of high performing teachers to neediest schools | | | | | | |
| **4.7** | **Communicate that research supports three essential characteristics of "quality teaching"** | | | | | | |
| 4.7.1 | In-depth knowledge of content | | | | | | |
| 4.7.2 | Effective teaching practices and pedagogy for all students | | | | | | |
| 4.7.3 | Higher levels of student achievement | | | | | | |

| | Opportunity-to-Learn Building Blocks | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **5** | **Creating Student Support Networks** | | | | | | |
| **5.1** | **Create school environments which foster student resilience, provide timely needed academic, social and psychological support mechanisms** | | | | | | |
| 5.1.1 | Develop clear and rigorous goals for what students should know and be able to do | | | | | | |
| 5.1.2 | Communicate expectations to teachers, administrators, parents, students, and community | | | | | | |
| 5.1.3 | Provide samples of student work which meet standards and communicate what is expected to all constituencies | | | | | | |
| **5.2** | **Extended availability of pre-school and early intervention programs to address needs of low-performing schools and school clusters in critical needs areas, K–12** | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **5** | **Creating Student Support Networks, continued** | | | | | | |
| **5.3** | **Implement innovative approaches for providing more time on task for students in low-performing schools/school clusters by introducing programs which provide** | | | | | | |
| 5.3.1 | Extended school day learning opportunities | | | | | | |
| 5.3.2 | After and before school tutorial programs | | | | | | |
| 5.3.3 | Saturday school | | | | | | |
| 5.3.4 | Summer school enrichment programs | | | | | | |
| 5.3.5 | Community/adult school extended-day programs | | | | | | |
| 5.3.6 | Community college and university programs | | | | | | |
| 5.3.7 | Longer school day approaches | | | | | | |
| 5.3.8 | Expanded school year approaches | | | | | | |
| 5.3.9 | Enrichment and mentoring programs | | | | | | |
| 5.3.10 | Efficient and productive use of time | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **5** | **Creating Student Support Networks, continued** | | | | | | |
| **5.4** | **Increase student support programs to meet needs of students related to increased standards in mathematics through** | | | | | | |
| 5.4.1 | Development of supplementary learning activities and programs to promote achievement of more rigorous standards | | | | | | |
| 5.4.2 | Timely support for high level advanced courses | | | | | | |
| 5.4.3 | Peer tutoring and adult mentoring programs for at-risk students | | | | | | |
| 5.4.4 | Collaborative programs established at universities, libraries, museums, community centers, and with business and industry to support and reinforce academic standards | | | | | | |
| 5.4.5 | Programs that support and increase the number of minority students successfully completing honors/advance placement courses | | | | | | |
| **5.5** | **Closely monitor the availability, enrollment, and content of student support programs to assure access and equity for all students, especially students from low-performing schools/clusters, and to ensure quality of support program content** | | | | | | |

| Opportunity-to-Learn Building Blocks | | Rating Low – High | | | | | Description/Areas To Be Addressed |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **5** | **Creating Student Support Networks, continued** | | | | | | |
| **5.6** | **Focus on early identification of students who are at-risk of academic failure in the classroom and implement processes that promote achievement** | | | | | | |
| 5.6.1 | Develop early intervention programs for all levels and subjects K–12 | | | | | | |
| 5.6.2 | Increase emphasis on reading in early grades | | | | | | |
| 5.6.3 | Implement literacy programs across the curriculum K–12 | | | | | | |
| 5.6.4 | Provide special programs for second-language students | | | | | | |
| 5.6.5 | Establish school linked services/resources to meet multi-ethnic population needs | | | | | | |

Note: The Engineering Change Assessment Instrument is a slightly modified version of the "Bridging the Gap" tool created by the McKenzie Group for urban and rural communities attempting to conduct systemic reform. The McKenzie tool provides a robust and comprehensive framework that can help inform the change process.

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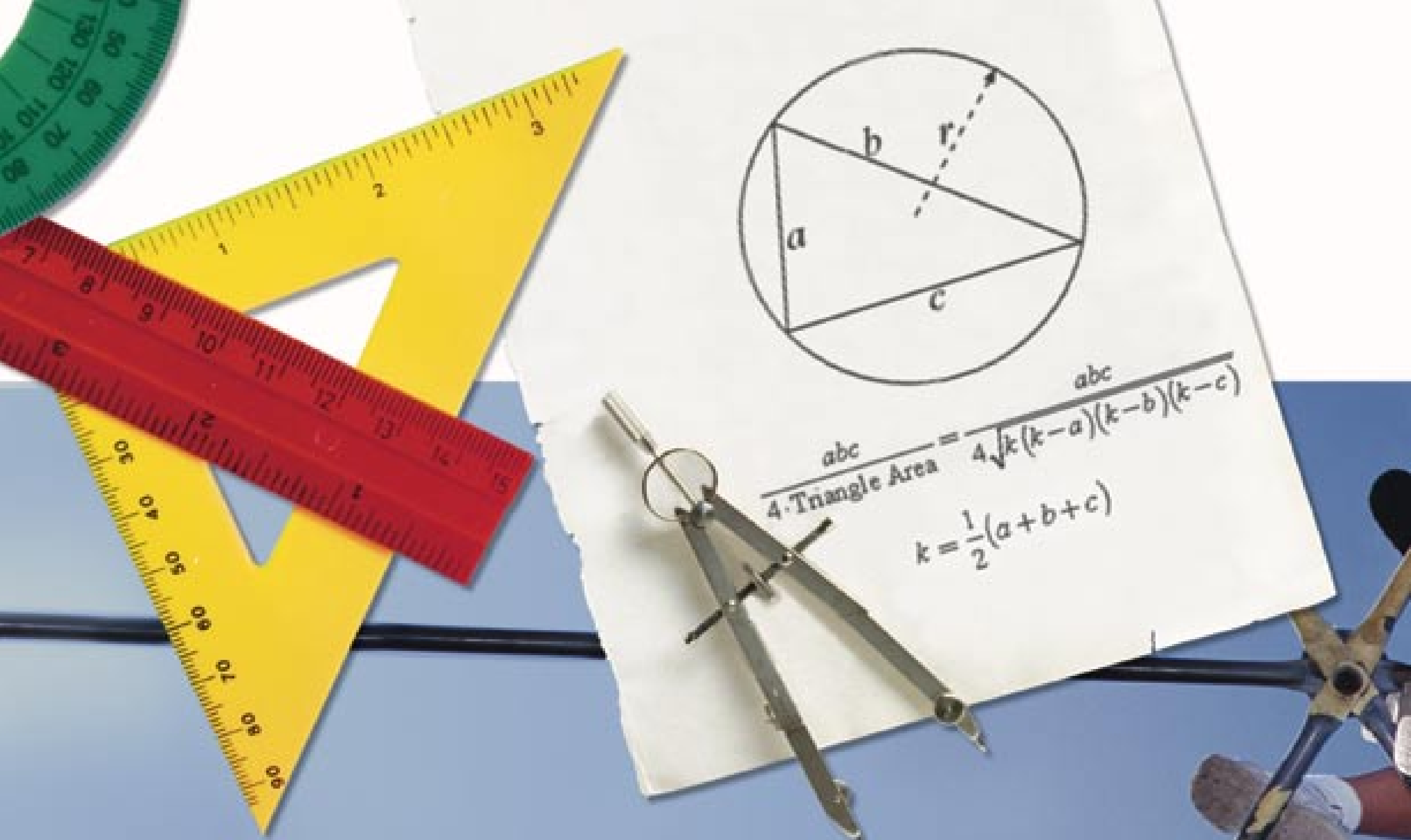


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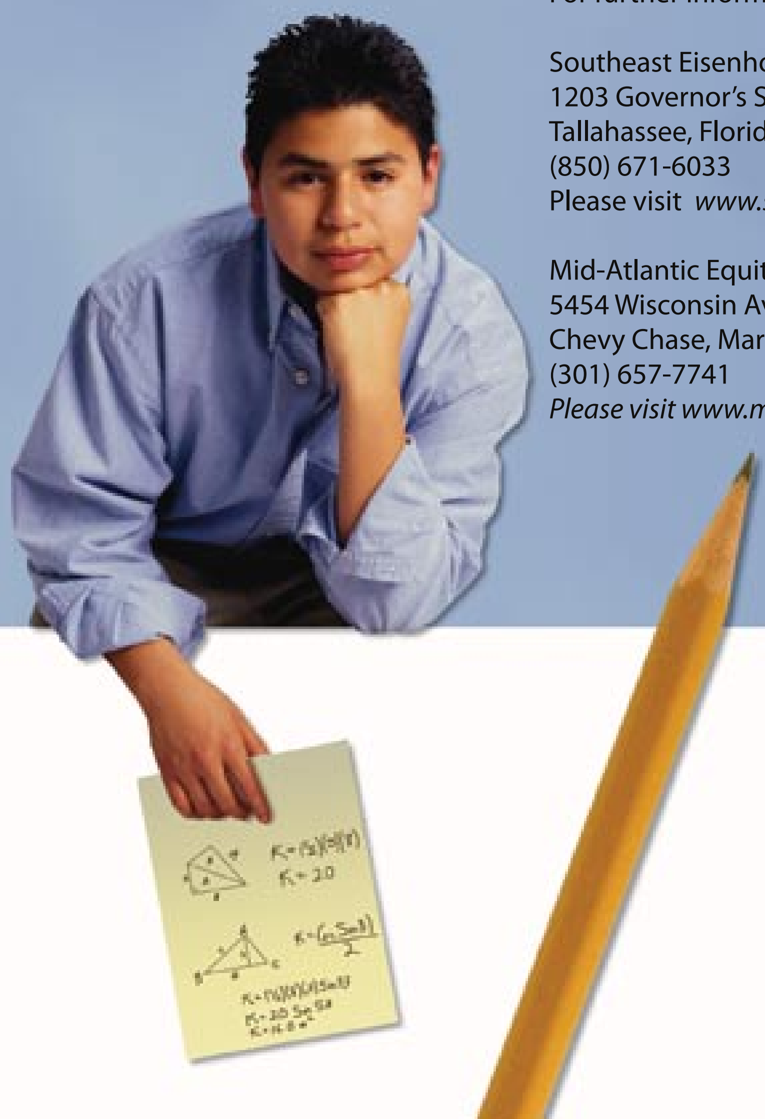

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