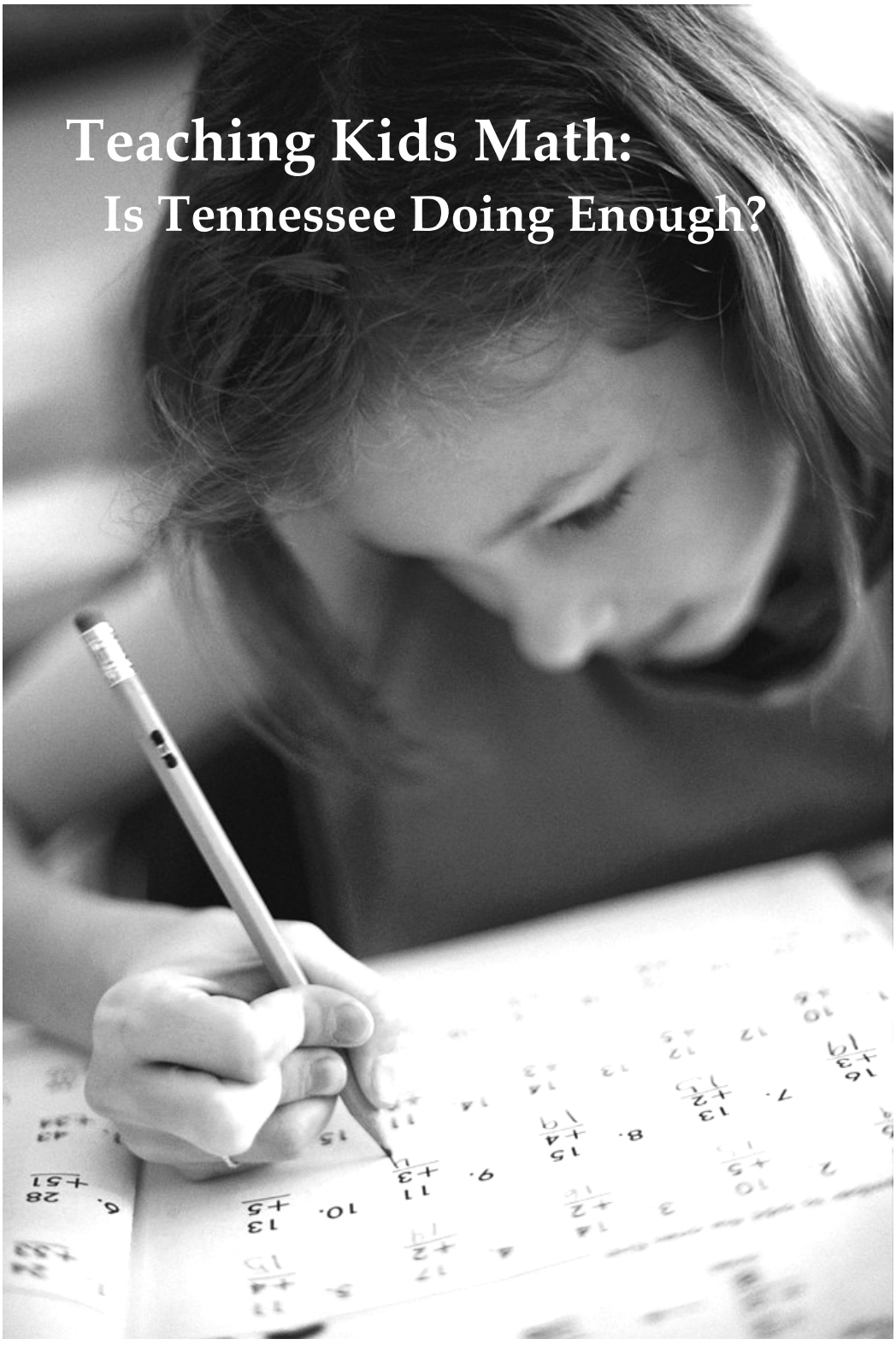
Teaching Kids Math:
Is Tennessee Doing Enough?



John G. Morgan
Comptroller of the Treasury
Office of Education Accountability
January 2005

STATE OF TENNESSEE

John G. Morgan
Comptroller

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January 18, 2005

The Honorable John S. Wilder
Speaker of the Senate
The Honorable Jimmy Naifeh
Speaker of the House of Representatives
and
Members of the General Assembly
State Capitol
Nashville, Tennessee 37243

Ladies and Gentlemen:

Transmitted herewith is a special study prepared by the Office of Education Accountability concerning the math proficiency of Tennessee's K-12 students and related issues, such as teacher preparation and professional development. The report provides information that may be useful to policymakers in considering ways to improve Tennessee's progress in education.

Sincerely,

John G. Morgan
Comptroller of the Treasury

Why is math important?

For people to participate fully in society, they must know basic mathematics. Citizens who cannot reason mathematically are cut off from whole realms of human endeavor. Innumeracy deprives them not only of opportunity but also of competence in everyday tasks.

The mathematics students need to learn today is not the same mathematics that their parents and grandparents needed to learn. When today's students become adults, they will face new demands for mathematical proficiency that school mathematics should attempt to anticipate. Moreover, mathematics is a realm no longer restricted to a select few. All young Americans must learn to think mathematically, and they must think mathematically to learn.

From *Adding It Up: Helping Children Learn Mathematics,* National Research Council, Mathematics Learning Study Committee, 2001

…It's not so cool or hip to be completely illiterate in math. The older generation may be able to get away with it, but the younger generation coming up now can't—not if they're going to function in the society, have economic viability, be in a position to meaningfully participate, and have some say-so in the decision making that affects their lives. They cannot afford to be completely ignorant of these technological tools and languages.

Robert Moses, *Radical Equations: Math Literacy and Civil Rights*, Boston: Beacon Press, 2001

Teaching kids math:
Is Tennessee doing enough?

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John G. Morgan
Comptroller of the Treasury
State of Tennessee
January 2005

The Office of Education Accountability was created in the Office of the Comptroller of the Treasury by *Tennessee Code Annotated* 4-3-308 to monitor the performance of school boards, superintendents, school districts, schools, and school personnel in accordance with the performance standards set out in the Education Improvement Act or by regulations of the State Board of Education. The office is to conduct such studies, analyses, or audits as it may determine necessary to evaluate education performance and progress, or as may be assigned to it by the Governor or General Assembly.

Comptroller of the Treasury, Office of Education Accountability. Authorization Number 307323, 500 copies, January 2005. This public document was promulgated at a cost of $2.90 per copy.

Executive Summary

Is math just too hard for Tennessee students? Do Tennessee math teachers have the qualifications, training, and support they need to teach math? Like other states, Tennessee has spent much time, effort, and resources creating a system of public education based on standards that describe what students should know. The Tennessee State Board of Education has adopted curriculum standards for every core subject – including mathematics – that reflect current research-based thinking of education experts. The Tennessee Department of Education has aligned the curriculum standards with state assessments so that students are tested on what they learn in the classroom.

Simply put, the state has increased expectations and accountability for K-12 students in mathematics as well as other subjects. Yet, Tennessee's overall student achievement in math lags behind much of the rest of the country. And, although some states clearly outperform Tennessee according to national assessments, student achievement in mathematics remains a national concern – indeed, overall U.S. student achievement in math has not kept pace with much of the rest of the world.

Developing math proficiency is important for several reasons affecting individual students as well as the whole of society.

Mastering mathematics is a gateway to college. According to a 1997 U.S. Department of Education report, 83 percent of students who took Algebra I and Geometry went on to college within two years of graduation.[1] Only 36 percent of those who did not take these courses went on to college. Students from low-income families who took Algebra I and Geometry were almost three times as likely to attend college as those who did not.

Mathematics is a filter for employment. Math ability, therefore, is important for the economic viability of Tennessee and for continuing national prosperity in a competitive, information-driven, technological, and changing global market. Mathematics aptitude is a requisite element of job responsibilities for millions of workers – from carpenters to machinists to loan officers. Additionally, with science and mathematics exerting "the most visible influence on the economy through their most rapidly changing offspring – new technologies,"[2] the nation is moving from "an economy based on the production of physical goods to an economy based on the production and application of knowledge." This "Knowledge Economy" includes new high-technology industries as well as "old economy enterprises that are adapting their processes to take advantage of new efficiencies offered by new technologies."[3]

Although the southern region of the United States has historically benefited from a favorable business climate, a diligent and inexpensive workforce, and strategic geography, significant weaknesses persist in the ability to meet the needs of the Knowledge Economy. The region has

[1] U.S. Department of Education, "Mathematics Equals Opportunity: White Paper prepared for U.S. Secretary of Education Richard W. Riley," 1997. See http://www.ed.gov/pubs/math/index.html.
[2] "Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century," Washington, D.C.: U.S. Department of Education, 2000, p. 12.
[3] Tennessee Advisory Commission on Intergovernmental Relations, *Tennessee and the Knowledge Economy*, 2001, p.1.

almost 400,000 fewer manufacturing jobs now than it did a decade ago, and a large percentage of the existing workforce is not oriented towards the Knowledge Economy. The south is relatively undereducated and under-prepared.[4] Unless Tennessee is able to develop an adequately educated workforce to fulfill the occupational demands of today's businesses, "the state will not experience the full prosperity and other rewards of the knowledge economy."[5]

Similar to reading proficiency, math proficiency is integral to the development of a literate, informed, and empowered citizenry. The Program for International Student Assessment (PISA) defines mathematical literacy as "…an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned, and reflective citizen."[6]

Math is important to the financial health and knowledge of all people. Many mathematical procedures are central to daily decision making, such as comparison shopping, choosing the right insurance plan for a family's needs, remodeling a home within a budget, and saving money for retirement. Financial literacy is important, but increasingly rare. What are the effects of financial illiteracy in Tennessee? Tennessee has the second highest rate of Chapter 13 bankruptcy filings per household in the nation. Tennessee, with a population approximately equal to the population of Massachusetts, disbursed almost 11 times more money to Chapter 13 creditors. Tennessee alone generated more than 10 percent of the national total disbursed to creditors.[7]

Conclusions

Tennessee students have significantly higher achievement on state math assessments than they do on national math assessments. More than three-quarters of Tennessee students score at or above the proficient achievement level on the math TCAP exams and on the Algebra I Gateway exam. However, Tennessee has not met five of the federal math benchmarks under No Child Left Behind (NCLB) and consistently performs below the national average on the math National Assessment of Educational Progress (NAEP). These results indicate that Tennessee schools may not be preparing students to master mathematics at sufficient levels. As a result, they may not be competitive with students from other states or adequately prepared for college math.

There are several possible explanations for the disparity in math student achievement between state assessments and NAEP. At the elementary level, Tennessee math curriculum, curriculum standards, and assessment standards may be well aligned with one another, but not as well aligned with the content assessed by NAEP. Alternately, TCAP may assess less rigorous content

[4] "Aligning Resources to Meet State Needs: The Educational Needs Index," Presented at the 2003 Annual Meeting of the Southern Governors' Association, Houston D. Davis, Austin Peay State University and Brian E. Noland, Tennessee Higher Education Commission.

[5] Tennessee Advisory Commission on Intergovernmental Relations, *Tennessee and the Knowledge Economy*, 2001, p. 1.

[6] Organization for Economic Cooperation and Development, *Learning for Tomorrow's World: First Results from PISA 2003*, p. 37.

[7] Gordon Bermant and Ed Flynn, 2000, "Bankruptcy by the Numbers: Measuring Performance in Chapter 13: Comparisons Across States," Washington, DC: U.S. Department of Justice, Executive Office for United States Trustees. See http://www.usdoj.gov/ust/press/articles/abi082000ch13.htm#N_7_ .

than NAEP or have lower cut rates to determine proficiency. That is, a student may have to answer a higher percentage of the questions correctly to score "proficient" on NAEP than on TCAP. (See pages 19-24.)

Tennessee students who earned respectable grade point averages in high school often still require additional assistance in mathematics when they enter college. Many of the state's lottery scholarship recipients are likely to require a developmental class in math. Students may qualify for the basic lottery-funded scholarship (Tennessee HOPE) based on either their ACT score or grade point average.

In 2004, Tennessee's lowest subject area score on the ACT college entrance exam was in mathematics, with an average of 19.7. Students entering a Tennessee public college or university who score less than 19 in the subject areas of reading, writing, or math must be placed in a Developmental Studies Program (DSP) or assessed further.[8]

Providing developmental classes for scholarship students amounts to state dollars paying for the same instruction twice: once in high school (assuming the student attended public school) and again in college. (See pages 24-25.)

At the elementary and high school levels, and on both state and national mathematics assessments, Tennessee has significant, persistent achievement gaps between white students and students of color and between students of lower and higher socioeconomic status (SES). These gaps have far-reaching consequences for subgroups' college readiness and employability. (See pages 25-29.)

U.S. 4th and 8th graders perform well in mathematics compared to their international peers. However, U.S. high school students lag behind the majority of industrialized nations in their ability to apply mathematical knowledge and skills. As a result, the U.S. likely will become less competitive in industries requiring math, especially high growth, high wage industries such as technology and engineering. (See pages 29-31.)

Educators interviewed indicated that U.S. culture dictates that it is acceptable to be "bad at math," a major obstacle to improving students' math achievement. Many draw a comparison to literacy, accurately noting that few would admit publicly to being "bad" at reading. Disparaging remarks about math abound not only in school, but outside school—on television, in public forums, and (perhaps most damaging of all to students' developing attitudes about school) within students' families. (See page 31.)

Like many other states, Tennessee does not set high expectations for potential teachers, including those who must be knowledgeable about mathematics. The Educational Testing Service (ETS) develops and administers the Praxis II exams for beginning teachers seeking licensure. Potential teachers seeking a 7-12 math endorsement must achieve a minimum scale score of 136 on the Mathematics: Content Knowledge test. The possible score range for this assessment is 100-200, and the national performance median is 143.[9] In 2003, only 48 percent of

[8] Tennessee Board of Regents, Basic/Developmental Studies Program (DSP) Operational Guidelines.
[9] ETS, "Understanding Your Praxis Scores 2004-05." See http://ftp.ets.org/pub/tandl/09706PRAXIS.pdf .

Tennessee test-takers passed. Sixty percent of nationwide test-takers would have passed the test given Tennessee's minimum score.[10]

The state has set a minimum scale score of 140 out of a possible 200 for the Elementary Education: Content Knowledge (which includes mathematics questions). Only one state has a lower minimum score – Alabama. This score is well below the national median of 163 and below the national average performance range of 150-175. [11] Therefore, based on 2002-03 national data, 86.9 percent of all test takers across the country achieved Tennessee's 2004 minimum score. [12] (See pages 31-35.)

The pipeline producing math-knowledgeable teachers is inadequate.[13] Sixty percent of all new graduates hired in Tennessee from 1992 to 2001 majored in elementary, early childhood, multidisciplinary studies, or special education. In contrast, few graduates are prepared to teach subject areas in secondary schools. During that time, Tennessee public colleges and universities prepared only 70 mathematics education majors, 39 of whom entered teaching. Of the 180 mathematics majors seeking licensure, 112 began teaching in Tennessee classrooms. (See pages 35-37.)

Research indicates that many elementary teachers lack deep understanding of the fundamental principles underlying school mathematics, which in turn disadvantages their students. A 2001 report titled *The Mathematical Education of Teachers* states:

> There is evidence of a vicious cycle in which too many prospective teachers enter college with insufficient understanding of school mathematics, have little college instruction focused on the mathematics they will teach, and then enter their classrooms inadequately prepared to teach mathematics to the following generations of students.[14] (See pages 38-39.)

Teachers' professional development, including that related to teaching mathematics, varies widely across Tennessee. Research emphasizes the need for teachers to be lifelong learners. The state's funding formula for education, the Basic Education Program (BEP), does not generate monies specifically for teacher professional development, though systems can choose to use some of the funds for that purpose. Larger systems with access to greater resources, such as Memphis City and Metro Nashville, provide a variety of course offerings for teachers. Smaller, more rural systems have more difficulty consistently providing such opportunities. (See pages 40-42.)

Despite adoption of math standards that mirror the National Council of Teachers of Mathematics (NCTM) standards, researchers suggest that many teachers still teach math much as it has been taught for decades. NCTM's *Principles and Standards* recognizes that

[10] ETS, Total Examinees Summary Report, Mathematics: Content Knowledge, 2003.
[11] ETS, "Understanding Your Praxis Scores, 2004-05."
[12] ETS, Passing Rate Summary Report for Tennessee, 2003.
[13] "More Math, Please: The Surprising Consensus on Math Among Parents, the Public, and Business Leaders in Two 'New Economy' States," The Mass Insight Education and Research Institute, April 2004.
[14] Ibid, p. 5.

rote memorization and procedural knowledge are not enough. "In today's world students' basic arithmetic skills must include the ability to choose what numbers to use and what operation is appropriate for carrying out the computation, deciding if the results make sense, and then making a decision about what to do next. Having both computational skills and conceptual understanding will enable students to solve problems that they encounter in their daily lives."[15]

Interviews with higher education faculty, principals, and some K-12 math teachers confirm that Tennessee is much like other states – still in the process of an attempted cultural change among its math teachers. (See pages 42-43.)

Some Tennessee school systems and schools employ mathematics specialists who can help teachers improve classroom instruction. Some larger and mid-size systems in the state – including Davidson County, Knox County, Oak Ridge, and Shelby County – employ one or more math coordinators, consultants, or similarly titled individuals whose time is dedicated exclusively to mathematics at the district level. Their responsibilities include curriculum alignment, improving instructional strategies, professional development, and test data analysis. A few systems also identified specific schools that employ math specialists to facilitate math instruction. The 2001 *Mathematical Education of Teachers* report suggests that elementary school mathematics instruction should be directed by mathematics specialists beginning in 5th grade. (See pages 43-45.)

Anecdotal evidence from Tennessee mathematics and education professors suggests the need for improved cooperation and communication among faculty who prepare future K-12 math teachers. *The Mathematical Education of Teachers* report emphasizes the need for mathematics faculty and mathematics education faculty to develop strong partnerships. Absent such a partnership, the education of mathematics teachers is unlikely to improve. Tennessee higher education institutions are making great strides, but responses to the Office of Education Accountability higher education survey indicated that the degree of cooperation between the two departments varies greatly among the state's public institutions. Some described an excellent collaborative relationship; others indicated that philosophical differences about departmental responsibilities had been a source of friction. (See pages 45-47.)

Legislative Recommendations

The General Assembly may wish to reconsider the qualifying criteria for lottery scholarships given this report's finding that some recipients require developmental instruction in mathematics.

Administrative Recommendations

The Tennessee Department of Education should include annual information on each High School Report Card about the number of graduates who require developmental instruction upon entering college, when it is readily available.

[15] National Council of Teachers of Mathematics, "Answers to Frequently Asked Questions about Principles and Standards for School Mathematics," 2002, p. 3. See http://www.nctm.org/about/pdfs/mathed/pssm_faq.pdf.

The Tennessee Department of Education should consider making closing the achievement gap one of the state's top educational priorities and developing a comprehensive, collaborative initiative to address this issue.
The Department of Education, the State Board of Education, and perhaps Tennessee Tomorrow, along with other education-related organizations, should launch a public campaign to urge students to consider math-related careers, including teaching math, and to inform parents about the importance of math to their children's future educational and economic welfare.

The BEP Review Committee should recommend that the General Assembly include teacher professional development in the funding formula.

The Tennessee Higher Education Commission (THEC) and the State Board of Education should consider hosting a forum inviting representatives from the Department of Education and Tennessee's K-12 and higher education communities to discuss issues including:

- Improving elementary teachers' content knowledge and understanding of fundamental mathematical principles, including Praxis assessments used for teacher licensure.
- Providing mathematics teachers access to results-driven professional development on a continuing basis and encouraging LEAs to develop research-based mentoring programs for new mathematics teachers.
- Improving classroom instruction in mathematics.
- Narrowing the wide achievement gaps in mathematics scores on state and national assessments.
- Improving collaboration among higher education faculty who prepare future K-12 math teachers and between higher education and K-12.
- Creating a long-term task force to address the needs identified.

The Department of Education should improve its dissemination of best practices and research findings about the teaching of mathematics so that all Tennessee educators can benefit from the information.

The State Board of Education may want to consider establishing a mathematics specialist certificate similar to the reading specialist certificate.

See pages 48-49 for further discussion of the legislative and administrative recommendations summarized above.

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Introduction

Is math just too hard for Tennessee students? Do Tennessee math teachers have the qualifications, training, and support they need to teach math? Like other states, Tennessee has spent much time, effort, and resources creating a system of public education based on standards that describe what students should know. The Tennessee State Board of Education has adopted curriculum standards for every core subject – including mathematics – that reflect current research-based thinking of education experts. The Tennessee Department of Education has aligned the curriculum standards with state assessments so that students are tested on what they learn in the classroom.

Simply put, the state has increased expectations and accountability for K-12 students in mathematics as well as other subjects. Yet, Tennessee's overall student achievement in math lags behind much of the rest of the country. And, although some states clearly outperform Tennessee according to national assessments, student achievement in mathematics remains a national concern – indeed, overall U.S. student achievement in math has not kept pace with much of the rest of the world.

How is Tennessee doing in mathematics? The following indicators, explained more fully in the report, should cause concern:[1]

- **Less than one quarter of Tennessee students score proficient on the mathematics National Assessment of Educational Progress (NAEP).** In 2003, 24 percent of the state's 4th graders scored at or above proficient; 30 percent scored "below basic" – the lowest achievement category. In the same year, 21 percent of Tennessee's 8th graders scored at or above proficient and 41 percent scored below basic.

- **The majority of states have a higher percentage of students at or above proficient on the mathematics NAEP than Tennessee.** In 2003, 36 states had a higher percentage of 4th grade students scoring at or above proficient; 33 states had a higher percentage of 8th grade students scoring at or above proficient.

- **On both state and national mathematics exams, Tennessee has a wide "achievement gap" between its white and African American students and between its students of low socioeconomic status (SES) and students of higher SES.** On the Tennessee Comprehensive Assessment Program (TCAP) math exam, the Algebra I Gateway exam, and the NAEP math exam, significantly more white students than African American students score at or above the "proficient" achievement level. Similar gaps exist between students of low SES and their more advantaged peers.

- **In 2004, Tennessee failed to meet the NCLB Adequate Yearly Progress (AYP) mathematics benchmarks in five categories, all of which involve insufficient performance on state assessments by student subgroups (African Americans, students with disabilities, and students with limited English proficiency).**

- **The tests that prospective Tennessee teachers take to obtain licensure, the Praxis examinations, also indicate a racial achievement gap.** In 2003, 74 percent of white students and 42 percent of African American students passed the Praxis I Pre-Professional Skills Test: Mathematics required for admission into teacher preparation programs.[2]

[1] See Analysis and Conclusions, p. 19.
[2] Percentages based on both computer and paper versions of this test. See Appendix C.

In 2000, the Office of Education Accountability published a report mandated by the General Assembly that evaluated the reading proficiency of Tennessee's K-3 students. This report takes a similar look at mathematics, another core subject in Tennessee's K-12 public education system. The report:

- Reviews Tennessee test scores on the TCAP math exam and the Gateway test.
- Reviews Tennessee test scores in math from NAEP and compares them to other states and the nation as a whole.
- Considers U.S. performance on the Trends in International Math and Science Study (TIMSS) in comparison to other countries.
- Looks at how teachers in Tennessee schools teach math and how teachers learn to teach math.
- Considers the state's curriculum standards in math, professional development targeting math instruction, and state initiatives to improve students' math achievement, sometimes with federal support.

Methodology

The conclusions reached and recommendations made in this report are based on the following:

- A literature review of research concerning the teaching of mathematics.
- Interviews with staff of the Tennessee Department of Education, staff at higher education institutions responsible for teacher candidates, principals and teachers at various K-12 public schools throughout the state, and staff at central offices of local education agencies whose responsibilities include assisting teachers.
- A review of national and international test data.
- A review of pertinent Tennessee state test data.
- A questionnaire directed at deans of colleges of mathematics and colleges of education at six of the state's higher education institutions.
- A brief survey of superintendents and directors of schools through the state's superintendent listserv.

Background

Why is math important?

Mathematics represents more than simply calculations and formulas, more than pondering imaginary numbers, or calculating difficult equations. More importantly, mathematics can teach students how to think logically – a skill applicable to many situations that all individuals encounter. Students need to acquire the ability to think conceptually, not just procedurally; demonstrate flexibility and adaptability; revise unproductive strategies; explain and justify answers; and question results. They need to be prepared for activities that involve patterning and repetition, notation and other systems of recording, calculation, construction, arrangement, and estimation.[3] They need to be able to simplify a complex set of relationships by modeling a situation so that it is easier to understand and solve related problems. Math is the subject that best develops these skills.

[3] Lynn Arthur Steen, "Back to the Future in Mathematics Education," in *Education Week*, April 7, 2004. RAND Mathematics Study Panel, *Mathematical Proficiency for All Students: Toward a Strategic Research and Development Program in Mathematics Education*, 2003.

However, classroom instruction in math often emphasizes techniques, concepts, and processes at the expense of teaching the broader uses of mathematical reasoning. The traditional math classroom, with its emphasis on memorization and rote learning, has not fostered a deep understanding of mathematics in students – and the model is still prevalent in U.S. schools. Large numbers of American elementary students lack the knowledge base to study algebra in middle school and large numbers of middle school students are inadequately prepared for advanced mathematics courses in high school – deficiencies that affect students' futures, whether entering college or obtaining employment.[4] It is important to recognize that "just as the inability to read puts a child at risk of truancy and becoming a school dropout, deficiencies in mathematics and science have become a barrier to higher education and the 21st century workplace."[5]

Educators say that they "generally know what needs to be done to improve student literacy, but that improving math achievement presents a set of more complex, more deeply embedded challenges."[6] Part of the problem may stem from the idea that "[i]n the United States, most people would be ashamed to admit that they never could learn to read, yet it is perfectly respectable to confess that one can't do math."[7] American culture accepts illiteracy in math in the same way that it renounces illiteracy in reading and writing, and often places more academic emphasis on reading to the detriment of mathematics. One result: nearly one half of U.S. nine-year-olds cannot multiply or divide whole numbers accurately, and half of 13- and 17-year-olds cannot compute correctly with fractions.

Developing math proficiency is important for several reasons affecting individual students as well as the whole of society.

Mastering mathematics is a gateway to college. According to a 1997 U.S. Department of Education report, 83 percent of students who took Algebra I and Geometry went on to college within two years of graduation.[8] Only 36 percent of those who did not take these courses went on to college. Students from low-income families who took Algebra I and Geometry were almost three times as likely to attend college as those who did not.

Math skills are needed in a variety of college courses, but there is often a disconnect between what college professors, even those outside of mathematics departments, expect incoming students to have mastered during pre-college mathematics instruction and what high school graduates are actually prepared to do. According to one professor at the University of Memphis, too many students arrive in university science courses without appreciating the wide practical applicability of mathematics. They have developed neither skills in formulating a mathematical solution for word problems nor a fundamental understanding of precision and accuracy. Many lack the ability both to do simple arithmetic without a calculator and to spot gross calculator errors by estimation.

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[4] Tom Loveless, "Trends in Math: The Importance of Basic Skills," *The Brookings Review* 21(4), 2003, pp. 41-43. See http://www.brookings.edu/press/review/fal2003/loveless.htm.

[5] National Science Foundation Task Force on Mathematics and Science Achievement, *Preparing Our Children: Math and Science Education in the National Interest*, p. 7.

[6] "More Math, Please: The Surprising Consensus on Math Among Parents, the Public, and Business Leaders in Two 'New Economy' States," The Mass Insight Education and Research Institute, April 2004, p. 1.

[7] Claudia Zaslavsky, *Fear of Math: How to Get Over It and Get on With Your Life* as cited in "More Math, Please: The Surprising Consensus on Math Among Parents, the Public, and Business Leaders in Two 'New Economy' States," The Mass Insight Education and Research Institute, April 2004.

[8] U.S. Department of Education, "Mathematics Equals Opportunity: White Paper prepared for U.S. Secretary of Education Richard W. Riley," 1997. See http://www.ed.gov/pubs/math/index.html.

Often, they are not in the habit of doing homework; more than 50 percent of students entering the University of Memphis averaged less than two hours of homework per week while seniors in high school.[9]

According to Clifford Adelman of the U.S. Department of Education, "The sequence of math courses a student takes in high school is even more important than [socioeconomic status] in predicting a student's odds of finishing college." For example, "finishing a course beyond the level of Algebra II (for example, trigonometry or pre-calculus) more than doubles the odds that a student who enters postsecondary education will complete a bachelor's degree."[10] In fact, the highest level of mathematics studied has the strongest correlation to eventual degree attainment.

Mathematics is a filter for employment. Math ability, therefore, is important for the economic viability of Tennessee and for continuing national prosperity in a competitive, information-driven, technological, and changing global market. Mathematics aptitude is a requisite element of job responsibilities for millions of workers – from carpenters to machinists to loan officers. The U.S. Bureau of Labor Statistics provides lists of current occupations requiring various levels of math ability.

Exhibit 1: Occupations by Category of Required Math Skills

Advanced or theoretical math [a]	Applied math [b]	Practical math [c]	General math
Architects	Accountants and auditors	Air traffic controllers	Bank tellers
Medical scientists	Pilots	Mechanics	Bookkeeping clerks
Economists	Construction and building inspectors	Water treatment plant operators	
Computer systems analysts	Construction contractors	Heating, air-conditioning, and refrigeration technicians	Loan clerks and credit authorizers
Engineers	Cost estimators	Electricians	Cashiers
Meteorologists	General managers	Concrete masons	Medical assistants
Astronomers	Pharmacists	Sheetmetal workers	Postal clerks
Chemists	Real estate agents	Carpenters	Secretaries
Social Scientists	Surveyors	Nurse	Stock clerks

a = calculus and linear algebra; b = statistics and trigonometry; c = algebra and geometry
Source: U.S. Bureau of Labor Statistics, "Core Subjects and Your Career," Occupational Outlook Quarterly, Summer 1999.

However, more than 60 percent of employers nationwide "question whether a high school diploma means that a typical student has learned even the basics, and they rate graduates' skills in grammar, spelling, writing, and basic math as only 'fair' or 'poor.'"[11] One study estimates that

[9] Office of Institutional Research, University of Memphis, "New Student Profiles: Categorized by Major College," October 2002. See http://oir.memphis.edu/ir_group/retention/report2_october.doc.
[10] Clifford Adelman, U.S. Department of Education, *Answers in the Tool Box: Academic Intensity, Attendance Patterns, and Bachelor's Degree Attainment,* 1999, U.S. Department of Education, Office of Educational Research and Improvement. See http://www.ed.gov/pubs/Toolbox/Exec.html.
[11] The American Diploma Project, *Ready or Not: Creating a High School Diploma that Counts*, 2004, Achieve, Inc., p. 3. See http://www.achieve.org/dstore.nsf/Lookup/ADPintro/$file/ADPintro.pdf.

more than one-third of businesses provide remedial math instruction.[12] A study of Michigan businesses estimates that the state's cost of remedial training in reading, writing, and basic mathematics is nearly $40 million a year.[13]

Additionally, with science and mathematics exerting "the most visible influence on the economy through their most rapidly changing offspring – new technologies,"[14] the nation is moving from "an economy based on the production of physical goods to an economy based on the production and application of knowledge." This "Knowledge Economy" includes new high-technology industries as well as "old economy enterprises that are adapting their processes to take advantage of new efficiencies offered by new technologies."[15] The transition places a premium on highly trained people and necessitates the placement of math literacy as a top priority. Too many Americans are ill-prepared for workplace roles in this new economy. By one count, 90 million adult Americans have limited quantitative skills. [16]

Although the southern region of the United States has historically benefited from a favorable business climate, a diligent and inexpensive workforce, and strategic geography, significant weaknesses persist in the ability to meet the needs of the Knowledge Economy. The region has almost 400,000 fewer manufacturing jobs now than it did a decade ago, and a large percentage of the existing workforce is not oriented towards the Knowledge Economy. The south is relatively undereducated and under-prepared.[17] Unless Tennessee is able to develop an adequately educated workforce to fulfill the occupational demands of today's businesses, "the state will not experience the full prosperity and other rewards of the knowledge economy."[18]

To keep pace with many of the fastest growing occupations in the 21st century, Tennessee and the United States will need professionals that can produce and direct innovation and a populace that can assimilate the range of tools and technologies. For example, while knowledge of how and why a computer or formula works is not necessary to use it, this knowledge is essential in expanding its capacity and functions.

According to the National Science Foundation, however, the United States as a nation is not imparting the necessary knowledge, or the skills to acquire it, to its students – therefore, the nation's capacity for problem solving, innovation, and production is in jeopardy.[19] Because of this, the Computer Systems Policy Project, a coalition of CEOs of the nation's leading information

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[12] Robert Franciosi, "No Voice, No Exit: The Inefficiency of America's Public Schools," IPI Policy Report #158, Lewisville, TX: Institute for Policy Innovation, 2001.
[13] Jay P. Greene, *The Cost of Remedial Education: How Much Michigan Pays When Students Fail to Learn Basic Skills*, Mackinac Center for Public Policy, September 2000.
[14] "Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century," Washington, D.C.: U.S. Department of Education, 2000, p. 12.
[15] Tennessee Advisory Commission on Intergovernmental Relations, *Tennessee and the Knowledge Economy*, 2001, p.1.
[16] Committee on Civilian Industrial Technology, *Technology in the National Interest*, 1996, Office of Technology Policy, U.S. Department of Commerce. See http://www.technology.gov/Reports/TechNI/TNI.pdf.
[17] "Aligning Resources to Meet State Needs: The Educational Needs Index," Presented at the 2003 Annual Meeting of the Southern Governors' Association, Houston D. Davis, Austin Peay State University and Brian E. Noland, Tennessee Higher Education Commission.
[18] Tennessee Advisory Commission on Intergovernmental Relations, p. 1.
[19] National Science Foundation Task Force on Mathematics and Science Achievement, *Preparing Our Children: Math and Science Education in the National Interest*, p. 9.

technology firms including Intel, Dell, Hewlett-Packard, and Motorola, believes that "the U.S. public education system remains the nation's biggest competitive disadvantage."[20]

The U.S. Department of Labor predicts that health science and computer industry jobs alone will increase by 5.6 million by 2008. Meeting this demand will require four times as many graduates in computer science as U.S. higher education institutions currently produce. In addition, the U.S. accounted for only seven percent of the 868,000 bachelor-level engineering degrees granted worldwide in 1999. The U.S. granted approximately 61,000 bachelor-level engineering degrees while Japan granted more than 103,000, the European Union granted more than 134,000, and China granted more than 195,000. The United States "needs to focus on educating and constantly training its current and future workforce, especially in science, mathematics, and engineering, to maintain global leadership in innovation and create more opportunities for American workers."[21]

Similar to reading proficiency, math proficiency is integral to the development of a literate, informed, and empowered citizenry. The Program for International Student Assessment (PISA) defines mathematical literacy as "…an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned, and reflective citizen."[22]

Some advocates argue that algebra should be regarded as "the new civil right" accessible to all U.S. citizens. Without advanced math, Bob Moses believes many poor and minority children will be effectively cut off from a living wage.[23] Therefore, it is imperative that "all students, especially females and minorities who have traditionally been underrepresented in mathematics-intensive fields, be strongly supported in mathematics education."[24]

Some educators and employers maintain that people who lack math literacy "are like the people who couldn't read and write in the industrial age."[25] According to one major Tennessee employer:

> As leaders in our communities, we must refute the thinking that students can lead successful lives without a basic knowledge of science and mathematics. I really don't know how one gets to that point except by simply giving up and thinking that "algebra is too difficult." Why should I be able to read Shakespeare or listen to a string quartet if I am not an English or music major? Why should I be able to listen attentively to legal arguments, if I'm not an attorney? The reason is that we are challenged by a complex world and that our quality of life and survival depend on our being economically competitive. It is the responsibility of effective leadership to set standards that will drive us toward greater opportunity for all. We should not limit a student from future achievement by making an

[20] Computer Systems Policy Project. 2004. *Choose to Compete: How innovation, investment and productivity can grow U.S. jobs and ensure American competitiveness in the 21st century*, p. 16. See http://www.cspp.org/reports/ChooseToCompete.pdf.
[21] Ibid., p. 8.
[22] Organization for Economic Cooperation and Development, *Learning for Tomorrow's World: First Results from PISA 2003*, p. 37.
[23] Robert Moses and Charles Cobb, 2001, *Radical Equations: Math Literacy and Civil Rights*, Boston, MA: Beacon Press.
[24] Tennessee Department of Education, "Mathematics Curriculum Standards, Grades 9-12, Philosophy."
[25] Robert Moses and Charles Cobb, p. 14.

arbitrary decision that this student will not "need" this knowledge. In fact we should strive to prepare every student for the highest potential.[26]

Math is important to the financial health and knowledge of all people. Many mathematical procedures are central to daily decision making, such as comparison shopping, choosing the right insurance plan for a family's needs, remodeling a home within a budget, and saving money for retirement. Financial literacy is important, but increasingly rare. Consider the following facts:

- The American family spends $1.22 for every dollar it earns.[27]
- Outstanding non-secured consumer debt rose from $805 billion in 1990 to $1.65 trillion in 2001. [28]
- The U.S. has the lowest personal savings rate of any major industrialized nation.[29]
- Average U.S. credit card debt per household is on the rise from $2,985 in 1990 to $8,562 in 2002, with an average interest rate of 14.71 percent. [30]
- 45 percent of college students are in credit card debt, the average credit card debt being $3,066.[31]
- A University of Indiana administrator remarked in 1998 that "we lose more students to credit card debt than to academic failure."[32]
- The number of bankruptcies among young people under age 25 has grown by 50 percent since 1991. This is the fastest growing age range for bankruptcies. [33]
- More young adults filed for bankruptcy than graduated from college in 2001.[34]
- "A 2002 survey by the Jump Start Coalition for Personal Financial literacy measuring 12th graders level of knowledge of personal finance concepts indicated that Tennessee's high school seniors are financially illiterate with an average score of 51.8%."[35]

"Predatory lenders sometimes go after people they assume don't have a high level of education," said Connie Cline, consumer credit and housing counselor at the non-profit agency United Family Services.[36] Borrowers lose an estimated $9.1 billion annually due to predatory mortgages, $3.4 billion from payday loans, and $3.5 billion in other lending abuses, such as overdraft loans, excessive credit card debt, and tax refund loans.[37] Under a typical rent-to-own contract, a consumer may pay as much as $2,200 over two years to purchase a $500 TV.[38]

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[26] Information provided by Laura Tew, Director of Stakeholder Relations, Arch Chemicals, Chattanooga, Tennessee.
[27] Tennessee Bankers Association, 2004, "Tennessee Teach Children to Save Day." See http://www.tnbankers.org/consumers/saveday.htm**.**
[28] Center for Economic Education, "Making the Case for Economic and Financial Education: A Collection of Current Statistics Regarding Youth and Money," University of Memphis. See http://www.econedcenter.org/youth.asp.
[29] Indiana Bankers Association, "Bankers to Teach Kids Financial Facts of Life on National Teach Children to Save Day," March 2004. See http://www.indianabankers.org/displaycommon.cfm?an=1&subarticlenbr=234#Mar04.
[30] Center for Economic Education.
[31] Senate Resolution 48, 108th CONGRESS, 1st Session, "Designating April 2003 as 'Financial Literacy for Youth Month.'" See http://thomas.loc.gov.
[32] Barbara O'Neill, "College Students and Credit Card Information," Rutgers Cooperative Extension. See http://www.rce.rutgers.edu/ru-fit/collegestudents.asp.
[33] Ibid.
[34] U.S. Department of the Treasury, JS-1297, "Treasury's Office of Financial Education Joins Florida International University to launch Financial Education Program in Miami," April 6, 2004.
[35] State of Tennessee Proclamation by the Governor, March 24, 2003. See http://www.jumpstart.org/bills/TN_Proclamation.pdf.
[36] "Lenders May Prey on (NC) Mill Workers," *Charlotte Observer*, August 6, 2003. See http://www.responsiblelending.org/news_headlines/charlobserver080603.cfm.
[37] Center for Responsible Lending, "A Resource for Predatory Lending Opponents."

What are the effects of financial illiteracy in Tennessee? Chapter 13 consumer bankruptcy filings in Tennessee rose from 23,336 in 1993 to 33,040 cases in 2003, an increase of 41.5 percent in the past decade.[39] Tennessee has the second highest rate of Chapter 13 bankruptcy filings per household in the nation. As of March 2004, one in every 38.7 households in the state filed for bankruptcy. This is more than twice the national average of one case for every 72.8 households and the national median of one in every 79.2 households. The average for Tennessee's border states is one filing in every 60 households. South Carolina, however, has the eighth lowest rate at one case filed for every 111.9 households.[40]

The reports of the Executive Office for U.S. Trustees contain records of the returns from Chapter 13 bankruptcy filers to creditors. It is therefore possible to calculate returns, called disbursements, by state. The following table shows the five states with the largest disbursements, the six states in the middle of the distribution, and the five states with the lowest disbursements.

Exhibit 2: Total Payments to All Creditors, by State, Fiscal Year 1998

Highest Disbursements		Middle Disbursements		Lowest Disbursements	
		Minnesota-North Dakota	$33,319,502		
Tennessee	**$303,424,262**	Puerto Rico-Virgin Islands	$28,884,891	Rhode Island	$2,176,580
Texas	$255,751,205	Massachusetts	$27,921,556	Hawaii	$1,903,131
Georgia	$248,511,363	Kentucky	$27,161,966	Vermont	$1,400,215
California	$231,785,864	Arizona	$25,078,583	Alaska	$1,262,719
Florida	$119,442,740	Oregon	$24,690,265	South Dakota	$1,037,949

Source: Gordon Bermant and Ed Flynn, 2000.

The top five states contributed more than 45 percent of the $2.5 billion disbursed nationally in 1998. The mean amount per state was slightly over $52 million and the median, falling between the values for Massachusetts and Kentucky, was $27.5 million. Tennessee, with a population approximately equal to the population of Massachusetts, disbursed almost 11 times more money to Chapter 13 creditors. Tennessee alone generated more than 10 percent of the national total disbursed to creditors.[41]

Tennessee's approach to teaching K-12 mathematics

The sections that follow describe the state's current approach to teaching mathematics in grades K-12, briefly describing the mathematics curriculum, assessments, teacher education and professional development programs.

See http://www.responsiblelending.org.

[38] Center for Responsible Lending, "Rent-to-Own Contracts."
See http://www.responsiblelending.org/practices/rent.cfm.

[39] Based on Bankruptcy Statistics from the U.S. Courts. See www.uscourts.gov/bnkrpctystats/statistics.htm#fiscal.

[40] American Bankruptcy Institute, 2004, "Households Per Filing, Rank."
See http://www.abiworld.org/statcharts/HouseRank.htm.

[41] Gordon Bermant and Ed Flynn, 2000, "Bankruptcy by the Numbers: Measuring Performance in Chapter 13: Comparisons Across States," Washington, DC: U.S. Department of Justice, Executive Office for United States Trustees. See http://www.usdoj.gov/ust/press/articles/abi082000ch13.htm#N_7_ .

Mathematics Curriculum

Tennessee's Mathematics Curriculum Standards are rooted in the evolving standards developed by the National Council of Teachers of Mathematics (NCTM). NCTM produced the first national mathematics curriculum standards in 1989, followed by professional standards for teaching in 1991, and mathematics assessment standards in 1995. More recently, NCTM's *Principles and Standards for School Mathematics*, released in 2000, presents a revised version of the original standards with input and feedback from organizations and experts, including the National Research Council, teachers, mathematics educators, and mathematicians, as well as the general public.[42]

NCTM's *Principles and Standards* recognizes that rote memorization and procedural knowledge are not enough. "In today's world students' basic arithmetic skills must include the ability to choose what numbers to use and what operation is appropriate for carrying out the computation, deciding if the results make sense, and then making a decision about what to do next. Having both computational skills and conceptual understanding will enable students to solve problems that they encounter in their daily lives."[43]

NCTM's six principles for school mathematics programs support themes of equity, curriculum, teaching, learning, assessment, and technology. While these principles are not unique to school mathematics, they can influence the planning of instructional lessons, the design of assessments, instructional decisions in the classroom, and the establishment of supportive professional development.

Equity

NCTM's theme 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."[44] This "societal tolerance makes it less likely that all students will be motivated to sustain the effort needed to learn mathematics, which in turn makes the job of their teachers even more challenging."[45] Achieving NCTM's goal of equity requires high expectations for all students in math, a strong instructional program that supports all students' learning, and significant allocations of human and material resources in schools and classrooms.[46]

Curriculum

A coherent, focused, and well-articulated curriculum across the grades should link important mathematical ideas so that students' understanding deepens, thus expanding their ability to apply mathematics. A clear articulation of curriculum across all grades helps teachers understand what students learned at previous levels and what they need to know for the next level. Teachers can plan lessons accordingly.

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[42] National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics*, NCTM: Reston, VA, 2000.
[43] National Council of Teachers of Mathematics, "Answers to Frequently Asked Questions about Principles and Standards for School Mathematics," 2002, p. 3. See http://www.nctm.org/about/pdfs/mathed/pssm_faq.pdf.
[44] National Council of Teachers of Mathematics, 2000, pp. 12-13.
[45] Ibid., p. 372.
[46] Ibid.

Teaching

Effective teaching requires several kinds of mathematical knowledge that influence teachers' curricular judgments and response to students' questions. To raise the overall capacity of the middle school mathematics teaching force to teach rigorous and relevant mathematics content, NCTM recommends that middle school mathematics teachers have college coursework in abstract algebra, geometry, calculus, probability and statistics, applications of mathematics/problem solving, and history of mathematics.[47] However, knowing mathematics for oneself may not be equivalent to knowing mathematics in order to teach it.

A teacher plays the pivotal role in "guiding the direction, balance, and rhythm of classroom discourse."[48] Therefore, teachers also need knowledge about students as learners and what students will do when presented with particular problems and tasks. They need to know how to use a range of pedagogical strategies to address common mathematical misunderstandings effectively. Teachers must have this knowledge to decide "how to organize and orchestrate the work of students, what questions to ask to challenge those with varied levels of expertise, and how to support students without taking over the process of thinking for them and thus eliminating the challenge."[49] (See Exhibit 3.)

The common outcome of school mathematics instruction has long been students who have memorized facts or procedures without understanding. The little attention given to helping students connect the procedures they are learning with the concepts that show why they work is a glaring omission in many classrooms. In the lessons included in the TIMSS video study, 96 percent of the time spent "doing seatwork [students] were practicing procedures they had been shown how to do."[50] Because "such learning is often quite fragile,"[51] these students frequently are not sure when or how to adjust procedures to solve new problems.

In contrast, "well-connected, conceptually grounded ideas are more readily accessed for use in new situations."[52] Therefore, students should be encouraged to build new knowledge and understanding from experience and prior knowledge. For example, high quality teachers often try to "shift the locus of authority in the classroom away from the teacher as a judge and the textbook as a standard for judgment and toward the teacher and students as inquirers who have the power to use mathematical tools to decide whether an answer or a procedure is reasonable."[53] These teachers choose the tasks on which students work, but their students' answers form the basis for the class discussion and further work. (See Exhibit 3.)

The following are examples from mathematics lessons that illustrate high and low quality intellectual engagement, respect and rigor, level of questioning, and sense-making opportunities.

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[47] Dawayne Whittington, *2000 National Survey of Science and Mathematics Education: Status of Middle School Mathematics Teaching*, (Chapel Hill, NC: Horizon Research, Inc.), December 2002.
[48] Deborah Lowenberg Ball, "Research on Teaching Mathematics: Making Subject Matter Knowledge Part of the Equation," p. 36.
[49] National Council of Teachers of Mathematics, 2000, p. 19.
[50] James Hiebert, "Relationships Between Research and the NCTM Standards," Journal for Research in Mathematics Education 30(1), 1999, pp. 3-19, p. 11.
[51] National Council of Teachers of Mathematics, 2000, p. 20.
[52] Ibid.
[53] Ball, p. 34.

Exhibit 3: Examples from Mathematics Lessons

High Quality	Low Quality
Intellectual Engagement	
An elementary mathematics teacher asked the class to find a number of shapes in the classroom.	A 1st grade teacher directed the students to complete a test preparation worksheet for 30 minutes.
Respect and Rigor	
A 3rd grade mathematics teacher allowed students to challenge one another's answers. "Does anyone have a different idea?"	Four times during the lesson a 9th grade pre-algebra teacher told his students to use the calculators and not to trust their own thinking.
Level of Questioning	
Rather than asking students to recall the name of a shape, a teacher asked, "How would you describe this shape to a friend over the telephone so that they could draw a copy?"	A 6th grade mathematics teacher asked "micro-questions." As she worked the long division problem on the board, she asked, "What is 9 minus 8?" rather than "What is 99-78?"
Sense Making Opportunities	
If a group did not answer correctly, the 2nd grade mathematics teacher would ask questions to see if they could identify their own error.	A 3rd grade teacher guided the class through a worksheet by telling them to turn to specific pages in textbook and look for the answers. [54]

Source: Horizon Research, Inc., *Looking Inside the Classroom: A Study of K-12 Mathematics and Science Education in the United States*, 2003.

According to NCTM, proficiency in this type of high quality instruction is currently beyond the scope of many standard pre-service mathematics courses in the United States.

Assessment

To enhance students' learning, assessment should be more than a test at the end of instruction. It should be a routine part of instruction that informs teachers' instructional decisions. For example, teachers can continually assess student thinking through informal means, such as asking questions during the lesson.

When students give answers or make assertions, high quality teachers follow up with questions that push students to examine and articulate their ideas, such as "Why do you think that?" or "How did you figure that out?"[55] This informal assessment strategy helps teachers understand how their students are thinking, which is critical information for subsequent pedagogical decisions.

Technology

NCTM claims that "[w]hen technological tools are available, students can focus on decision making, reflection, reasoning, and problem solving."[56] Students can examine more examples than are feasible by hand and can access powerful visual models that were heretofore inaccessible. Technology is transforming the landscape of mathematics education, but technology should not be used as a replacement for basic understanding. "In mathematics instruction programs, technology should be used widely and responsibly, with the goal of enriching students' learning of mathematics."[57]

[54] Although this example was from a science class, the practice is likely common in mathematics classrooms as well.
[55] Ball, p. 29.
[56] National Council of Teachers of Mathematics, 2000, p. 24.
[57] Ibid., p. 25.

Tennessee's Mathematics Curriculum Standards

State regulations mandate the development of curriculum standards for each subject area in the *Rules, Regulations, and Minimum Requirements for the Approval of Tennessee Public Schools*.[58]

The current *K-8 Mathematics Curriculum Standards* were approved by the Tennessee State Board of Education in 2001. The Mathematics K-8 Curriculum Standards Committee, formed by the Tennessee Department of Education and the State Board of Education, revised the K-8 standards to reflect the state's existing curriculum, the 2000 NCTM Standards, curriculum guides from other states, and current educational research.

The K-8 math standards include five content standards – number and operations, algebra, geometry, measurement, and data analysis and probability – and five process standards – problem solving, reasoning and proof, communication, connections, and representation. These standards "serve to focus classroom instruction and assessment on important mathematical ideas for each grade level that are connected and that build on one another. Thus, at all grade levels, effective mathematics curriculum units make connections within mathematics, to other disciplines, and to the real world in order to expand students' knowledge and understanding along with their ability to apply mathematics."[59]

Similarly, the *Secondary Mathematics Curriculum Standards* are "designed so that all students who meet the three mathematics credit graduation requirement will have studied these five content standards: Number Sense and Number Theory; Estimation, Measurement, and Computation; Patterns, Functions, and Algebraic Thinking; Statistics and Probability; and Spatial Sense and Geometric Concepts."[60] The content standards are achieved through four process standards – mathematics as problem solving, reasoning, communication, and connections.

By emphasizing various approaches to investigate, understand, and apply mathematical concepts, mathematics as problem solving endorses the first recommendation of NCTM's *An Agenda for Action*: "Problem solving must be the focus of school mathematics." Mathematics as communication develops students' ability to explain, conjecture, and defend ideas. Mathematics as reasoning emphasizes critical thinking, logical argument, and justification of solutions and thought processes. Mathematics as connections emphasizes linking "topics within mathematics, between mathematics and other disciplines, and between mathematics and 'real world' situations."[61]

Mathematics Assessment in Tennessee

Several assessments provide information about Tennessee's student achievement in mathematics. (See pages 19-29 for an analysis of the state's student achievement results according to these assessments.)

[58] Rules of the State Board of Education, Minimum Requirements for the Approval of Public Schools, Chapter 0520-1-3-.05, See http://www.state.tn.us/sos/rules/0520/0520-01/0520-01-03.pdf.
[59] Tennessee State Board of Education, "Mathematics Curriculum Standards, Preface."
[60] Tennessee State Board of Education, Mathematics Curriculum Standards, Grades 9-12, "Philosophy, History, and Process Standards." Note that the State Board of Education approved new secondary mathematics curriculum standards on final reading at the State Board of Education's August 27, 2004 meeting. See http://www.state.tn.us/education/ci/cistbdreview/index.htm.
[61] Ibid.

Tennessee Comprehensive Assessment Program (TCAP)

All Tennessee students in grades 3-8 are required to take the TCAP Achievement Test each spring. TCAP is a timed, multiple choice assessment that measures skills in Reading, Language Arts, Mathematics, Science, and Social Studies. Beginning in 2004, TCAP includes both norm-referenced and criterion-referenced items. Norm-referenced items compare the achievement of Tennessee students with the performance of students from across the nation. These items are aligned with objectives designed to measure concepts, processes, and skills taught throughout the nation. Criterion-referenced items measure a student's performance according to specific standards, rather than to the performance of other test takers. These items are directly aligned with the Tennessee Content Standards and State Performance Indicators.[62] The criterion-referenced portion of TCAP is used to fulfill the No Child Left Behind (NCLB) accountability requirements at the elementary level.

Gateway

The Gateway tests are end-of-course exams in English II, Algebra I, and Biology. They were first administered in 2001-02, when they replaced the state's Competency Test. Beginning with incoming high school freshmen in 2001-02 (who will graduate in 2004-05), Tennessee students must pass all three tests to earn a high school diploma.[63] State Board policy also requires that Gateway scores be made a part of students' grades for those subjects. Once three years of Gateway data are available, test data will be used as part of the Tennessee Value-Added Assessment System (TVAAS) to produce cumulative gains for students, teachers, schools, and systems. Gateway exams are also used to fulfill the NCLB accountability requirements at the secondary level.

No Child Left Behind

The No Child Left Behind Act of 2001 (NCLB) is the latest reauthorization of the Elementary and Secondary Education Act, the principal federal law affecting education from kindergarten through high school. A central component of NCLB is increased accountability for academic achievement at the school, district, and state levels. A keystone of the NCLB accountability provisions is adequate yearly progress (AYP), which each state must define within the law's parameters. To define AYP, each state sets the minimum levels of improvement – measurable in terms of student performance on state assessments – that school districts and schools must achieve within time frames specified in the law. Subsequent thresholds must be raised at least once every three years, until, at the end of 12 years, all students in the state are expected to achieve at the proficient level on state assessments in reading/language arts and math.[64] Each school and district must meet the AYP benchmarks for both its student population as a whole and for certain demographic subgroups.[65] In addition, at least 95 percent of the entire school's and district's population and of each demographic student subgroup must take the state assessments.

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[62] Tennessee Board of Education, "Achievement Test: Frequently Asked Questions." See http://www.state.tn.us/education/tsachfaq.htm.

[63] Tennessee Department of Education, "Gateway Tests – Questions and Answers," 2002. See http://www.state.tn.us/education/ci/cigateendofcourse/cigatewqa.htm.

[64] U.S. Department of Education, "Questions and Answers on No Child Left Behind." See http://www.ed.gov/nclb/accountability/schools/accountability.html#4.

[65] Subgroups: White, Hispanic, African American, Native American, Asian/Pacific Islander, Economically Disadvantaged, Students with Disabilities, Limited English Proficient.

National Assessment of Educational Progress (NAEP)

Often called "The Nation's Report Card," the NAEP is a nationally representative, continuing assessment of what students in the United States know and can do in multiple subjects, including mathematics, at grades 4, 8, and 12. NAEP has three achievement levels: basic, proficient, and advanced.

Exhibit 4: NAEP Achievement-Level Policy Definitions

Basic	**Basic denotes partial mastery** of prerequisite knowledge and skills that are fundamental for proficient work at each grade.
Proficient	**Proficient represents solid academic achievement** for each grade assessed. Students reaching this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter.
Advanced	**Advanced represents superior performance.**

Source: National Center for Education Statistics, "The NAEP Mathematics Achievement Levels." See http://nces.ed.gov/nationsreportcard/mathematics/achieve.asp.

Since 1990, NAEP assessments have also been conducted to give results for participating states, including Tennessee. States that choose to participate receive assessment results on the performance of students in that state. The 2003 assessments in mathematics had a state component at grades 4 and 8.

The NAEP sample in each state is designed to be representative of the students in that state. At the state level, results are reported for public school students only and are broken down by several demographic subgroups. When NAEP is conducted at the state level, results are also reported for the nation. The national NAEP sample is then composed of all the state samples of public school students, as well as a national sample of nonpublic school students.

American College Test (ACT)

The ACT is a national college admission and placement examination that encompasses four subjects: English, math, reading, and science. It is taken by the vast majority of high school graduates in Tennessee. The highest possible score is 36. Of the 215 test questions, 60 are math questions. [66]

Trends in International Mathematics and Science Study (TIMSS)

The TIMSS (formerly known as the Third International Mathematics and Science Study) was developed by the International Association for the Evaluation of Educational Achievement (IEA). TIMSS resulted from the American education community's need for trend data on the mathematics and science achievement of U.S. students compared to that of students in other countries.[67] It has been offered in 1995 (grades 4, 8, and 12), 1999 (grade 8), and 2003 (grades 4 and 8).[68] In mathematics, TIMSS assesses the following content areas: fractions and number sense; algebra; geometry; data representation, analysis, and probability; and measurement.

[66] ACT, Facts about the ACT Assessment, 2004. See http://www.act.org/news/aapfacts.html.
[67] Trends in International Mathematics and Science Study (TIMSS). Homepage. See http://nces.ed.gov/timss/.
[68] TIMSS, Frequently Asked Questions. See http://nces.ed.gov/timss/faq.asp#differences.

Teacher Education and Professional Development in Mathematics

All Tennessee teacher education programs must undergo licensure program approval. Each teacher-training unit must meet the National Accreditation of Teacher Education (NCATE) standards[69] and maintain high levels of collaboration with other units within the institution, such as the liberal arts and science departments. The state Department of Education also encourages and requires that institutions develop relationships with pre-K-12 educators.

Tennessee requires that candidates seeking admission to a teacher education program must either pass the Pre-Professional Skills Test (PPST), earn a minimum score of 22/36 on the ACT, or earn a minimum score of 1020/1600 on the SAT. The candidates must have also maintained a 2.5 GPA on a 4.0 scale on their previous college course work. In addition, teacher candidates must have acquired early, varied, and well-sequenced field experiences. Students must acquire a 15-week, full-time student experience or a one-year, full-time internship. The state considers the full-year internship as the candidate's first year of teaching. Finally, the candidate must also pass the Principles of Learning and Teaching (PLT) exam of the Praxis Series and a specialty area test to qualify for licensure.

Tennessee state law (T.C.A. 49-5-5601) acknowledges that "[t]he general assembly must maintain a proper balance between the academic freedom of higher education and the need to respond to the public's expectations of quality in the state's teacher training programs. The general assembly, therefore, does not seek to impose restrictions on the philosophy or course selection of teacher training programs." The resulting varied requirements for teacher education programs in Tennessee's higher education institutions are difficult to summarize.

Although the State of Tennessee allows institutions flexibility in designing their programs, they must design curriculum based on three broad areas of study: the general education core, academic major, and professional education core. Future teachers can no longer major in education, but must declare an academic major. The general education core of a typical liberal arts education comprises approximately 50 percent of the degree program, the academic major about 30 percent, and the professional education core the remaining 20 percent. The professional education core consists of classes that are fundamental to teaching children. Mathematics methods classes fall in this category.[70] The Tennessee Board of Regents mandates only three hours of general education mathematics.

Teachers who are already licensed must have opportunities to keep up with the changes in the knowledge base and to develop improved instructional strategies. According to the State Board of Education, "Professional development is the keystone, the central supporting element, needed to accomplish the ambitious student learning goals in state and federal legislation and the *Master Plan*."[71] It is "an essential ingredient in the continuous improvement of schools and is embedded within any sound improvement plan."[72]

Although Tennessee state law (T.C.A. 49-5-5703) contains professional growth components for principals and administrators, professional growth opportunities for classroom teachers remain

[69] See http://www.ncate.org/standard/m_stds.htm.
[70] Tennessee Department of Education, Teacher Education Fact Sheet. See http://www.state.tn.us/education/factw2.htm.
[71] Tennessee State Board of Education, Professional Development Policy, p. 1.
[72] Ibid., p. 5.

largely a local decision, with "the needs of apprentice teachers…given priority in the planning of in-service activities" (T.C.A. 49-6-3004). Recognizing the need for schools to "give particular attention to the early years of each teacher's career," the State Board of Education developed the *Tennessee Standards for Teaching: A Guide for Mentoring* in 1998. Organized around six interrelated categories of teaching practice – planning, teaching strategies, assessment and evaluation, learning environment, professional growth, and communication – the standards guide the content of teacher mentoring.

Tennessee's *Professional Development Policy* is designed to be consistent with the National Staff Development Council (NSDC) standards that forge a tight link between educator knowledge and student results. It assigns responsibilities to state, school system, and school leadership, as well as individual teachers. While not specifically directed toward the mentoring and in-service professional development of mathematics teachers, such efforts certainly impact mathematics instruction. (See Appendix A for a list of responsibilities.)

K-12 professional development opportunities are also linked to the teacher training faculty in higher education institutions. Tennessee state law (T.C.A. 49-5-5631) mandates that "[a]ll full-time college of education faculty members, including deans of such colleges and universities, shall further their professional development through direct personal involvement in the public school setting of kindergarten through grade twelve (K-12)…Such faculty involvement shall take the form of in-service training activities for public school teachers, observation and evaluation of student teachers, or classroom instruction in a public school." (See Appendix B: Grants and Partnerships Targeting Mathematics for examples of such collaboration.)

Research About the Teaching of Mathematics

Federal agencies formed two major committees in the late 1990s to sift through an enormous body of literacy research and make practical recommendations for policy makers and teachers regarding reading instruction—mathematics received similar scrutiny in a 2001 National Research Council (NRC) report titled *Adding it Up: Helping Children Learn Mathematics.* The authors of the report comprised the Committee on Mathematics Learning, which the NRC established in 1998 at the request of the National Science Foundation and the U.S. Department of Education. The committee's charge was to:

- Synthesize the rich and diverse research on pre-kindergarten through 8th grade mathematics learning.
- Provide research-based recommendations for teaching, teacher education, and curriculum for improving student learning and identify areas where research is needed.
- Give advice and guidance to educators, researchers, publishers, policy makers, and parents.

The study found that:

- U.S. student mathematical performance is generally low, but has been improving in some respects; however, "many students are still not being given the educational opportunities they need to achieve at high levels."
- Teacher preparation does not necessarily equip teachers with the knowledge and skills they need for helping students achieve mathematical proficiency.

The report defined mathematical proficiency as having five "interwoven and interdependent" strands. The report links these strands to the development of proficiency in teaching mathematics as well as learning. (See Exhibit 5.)

Exhibit 5: The Five Strands of Mathematical Proficiency Linked to Teaching and Learning

Strand of Mathematical Proficiency	Student	Teacher
Conceptual Understanding	Comprehension of mathematical concepts, operations, and relations	Knowledge of mathematics, students, and instructional practices
Procedural Fluency	Skill in carrying out procedures flexibly, accurately, and properly	Skill in carrying out basic instructional routines
Strategic Competence	Ability to formulate, represent, and solve mathematical problems	Ability to plan effective instruction and resolve student misunderstandings
Adaptive Reasoning	Capacity for logical thought, explanation, and justification	Capacity to justify and explain one's practices and reflect on those practices
Productive Disposition	Inclination to see mathematics as sensible, useful, and worthwhile	Positive inclination toward mathematics, teaching, and learning

Source: National Research Council, *Adding It Up: Helping Children Learn Mathematics*, 2001.

The report made five recommendations:

1. All five strands of mathematical proficiency should guide the teaching and learning of school mathematics.
2. Teachers' professional development should be high quality, sustained, and systematically designed and deployed to help all students develop mathematical proficiency. Schools should support, as a central part of teachers' work, engagement in sustained efforts to improve their mathematics instruction. This support requires the provision of time and resources.
3. The coordination of curriculum, instructional materials, assessment, instruction, professional development, and school organization around the development of mathematical proficiency should drive school improvement efforts.
4. Efforts to improve students' mathematics learning should be informed by scientific evidence, and their effectiveness should be evaluated systemically. Such efforts should be coordinated, continual, and cumulative.
5. Additional research should be undertaken on the nature, development, and assessment of mathematical proficiency.

A 2003 RAND study, *Mathematical Proficiency for All Students: Toward a Strategic Research and Development Program in Mathematics Education*, supports the NRC's final recommendation about the need for additional research, but adds more specifics about what research is needed to improve classroom instruction in math. The RAND study notes that efforts to improve student proficiency in mathematics "have been supported by only a limited and uneven base of research and research-based development, which is part of the reason for the limited success of those efforts."[73] Such limitations have given rise to disputes – sometimes collectively referred to as the "math wars" – among educators and other interested citizens largely about how K-12 math should be taught.

According to RAND researchers, "There has never been a long-range programmatic effort to fund research and development in mathematics education, nor has funding been organized to focus on

[73] RAND, p. xi.

knowledge that would be usable in practice." The 2003 report strongly recommends such an effort and suggests the need to focus on:

1. Developing teachers' mathematical knowledge in ways that are directly useful for teaching. Within this category, RAND researchers recommend targeting three areas: developing a better understanding of the mathematical knowledge needed for the actual work of teaching; developing improved means for making useful and useable mathematical knowledge available to teachers; and developing valid and reliable measures of the mathematical knowledge of teachers.
2. Teaching and learning mathematical practices, or the "know-how, beyond content knowledge, that constitutes expertise in learning and using mathematics." The study's authors conjecture that improving competency in these areas "could greatly enhance the education community's capacity to achieve significant gains in student proficiency in mathematics, especially among low-achieving students who may be the least likely to develop these practices in settings outside of school."[74]
3. Teaching and learning of algebra from kindergarten through the 12th grade (K-12). Researchers indicate that they chose algebra because it is the foundation of all mathematical areas and because it "provides the tools…for representing and analyzing quantitative relationships, for modeling situations, for solving problems, and for stating and proving generalizations." They also note that algebraic thinking and concepts are important in many workplace contexts and "in the interpretation of information by Americans on a daily basis."

RAND researchers believe that an organized, well-funded research effort could lead to increased certainty about how teachers could improve K-12 student achievement in mathematics.

[74] Ibid., p. xviii.

Analysis and Conclusions

Tennessee students have significantly higher achievement on state math assessments than they do on national math assessments. More than three-quarters of Tennessee students score at or above the proficient achievement level on the math TCAP exams and on the Algebra I Gateway exam. However, Tennessee has not met five of the federal math benchmarks under NCLB and consistently performs below the national average on the math NAEP. These results indicate that Tennessee schools may not be preparing students to master mathematics at sufficient levels. As a result, they may not be competitive with students from other states or adequately prepared for college math.

There are several possible explanations for the disparity in math student achievement between state assessments and NAEP. At the elementary level, Tennessee math curriculum, curriculum standards, and assessment standards may be well aligned with one another, but not as well aligned with the content assessed by NAEP. Alternately, TCAP may assess less rigorous content than NAEP or have lower cut rates to determine proficiency. That is, a student may have to answer a higher percentage of the questions correctly to score "proficient" on NAEP than on TCAP.

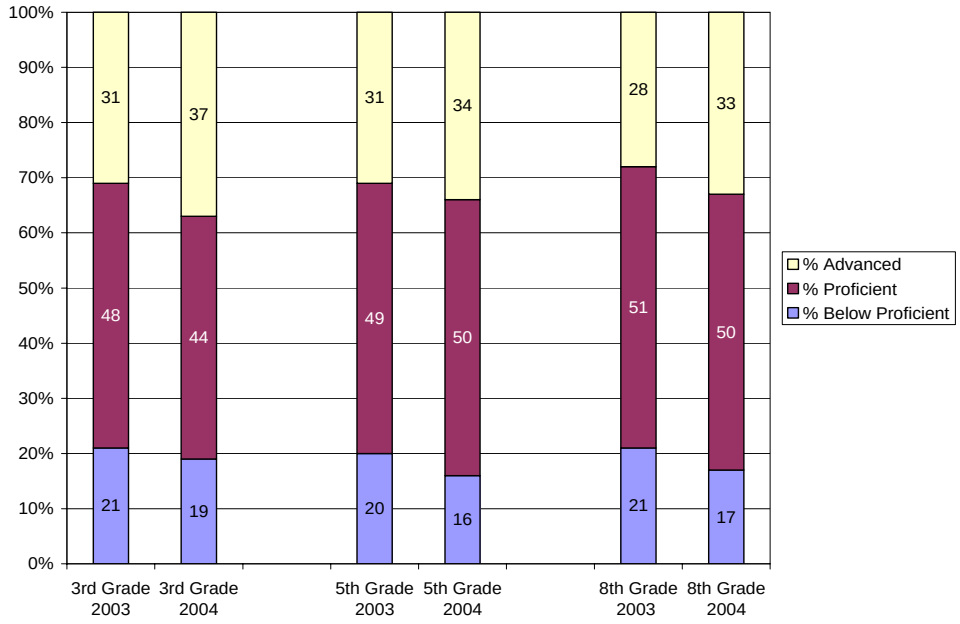
NCLB has focused the public's and educators' attention on the percent of students who score "proficient" on the criterion-referenced portion of TCAP. However, there is rarely any mention of what "proficient" represents on the TCAP assessment; that is, the percent of questions students must answer correctly to be deemed proficient. The required percents correct for the math assessments are strikingly low, and decline as students move through the elementary grades. In 3rd grade, students must answer 61 percent of the criterion-referenced questions correctly to score proficient. In 4th grade, the required percent correct is 53 percent, 48 percent in 5th grade, 46 percent in 6th grade, and 43 percent in 7th and 8th grades.[75]

In 2003, on the criterion-referenced portion of the mathematics TCAP, 79 percent of 3rd-grade students scored at proficient or advanced, 80 percent of 5th-grade students, and 79 percent of 8th-grade students. In 2004, student achievement improved at all three grade levels: a lower percentage of students scored below proficient, and a higher percentage of students scored advanced. (See Exhibit 6.) At the high school level, in 2002, 77 percent of students who took the Algebra I Gateway scored proficient or advanced; in 2003, 75 percent of students scored proficient or advanced. (See Exhibit 7.)

Although Tennessee students perform fairly well on state math assessments on average, under NCLB, numerous student subgroups must also reach the same level of proficiency as the general population. Tennessee has been less successful meeting these performance benchmarks. In 2003, Tennessee missed 11 total NCLB mathematics AYP benchmarks: five at the elementary level and six at the high school level.[76] In 2004, Tennessee missed three NCLB mathematics benchmarks at the elementary level and two mathematics benchmarks at the high school level.[77]

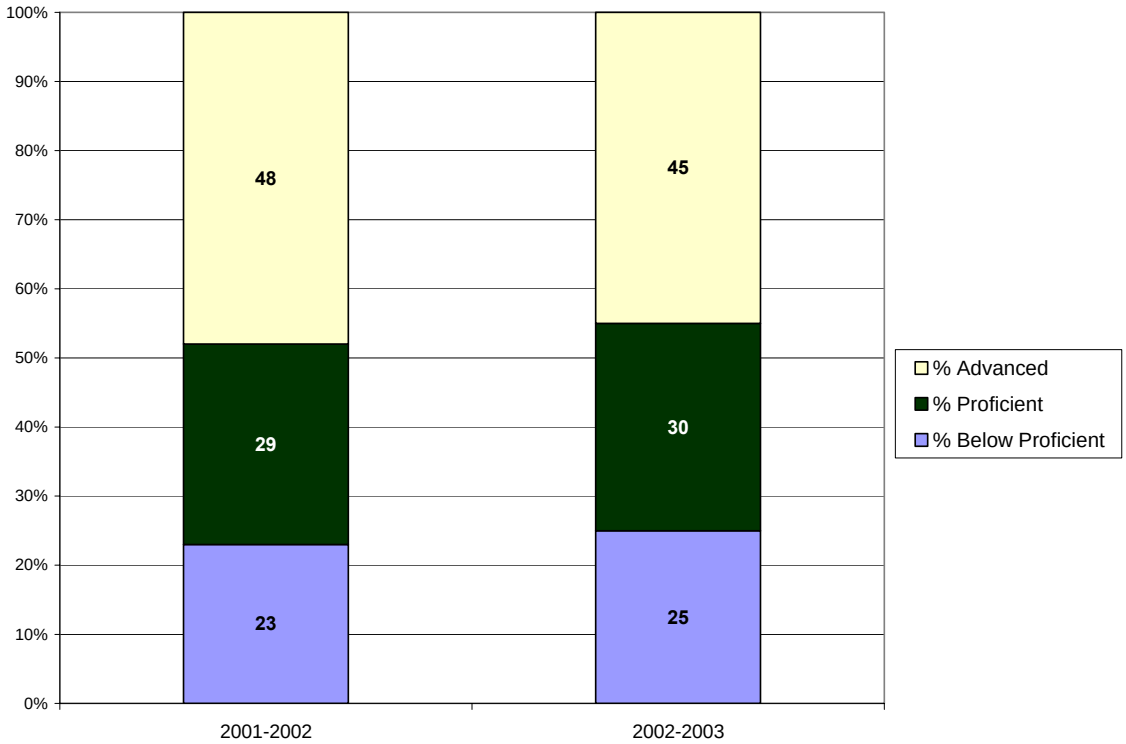
[75] Data provided by the Tennessee Department of Education via email, Nov. 18, 2004.
[76] Tennessee Statewide Report Card 2003. See http://evaas.sas.com/tn_reportcard/welcome.jsp.
[77] Tennessee Statewide Report Card 2004. See http://www.k-12.state.tn.us/rptcrd04/.

Exhibit 6: 2003-04 Math TCAP by Proficiency Levels (Criterion-Referenced Portion)



Source: Tennessee Statewide Report Card 2003. See http://evaas.sasinschool.com/tn_reportcard/welcome.jsp. 2004 data provided by the Tennessee Department of Education Center for Research and Policy.

Exhibit 7: 2002-2003 Algebra I Gateway by Proficiency Levels



Note: The 2004 Gateway data could not be included because the Tennessee report card now presents the percentage of students scoring proficient and the percentage scoring advanced as a composite, which prevents comparisons to previous years.

Source: Tennessee Statewide Report Card 2003. See http://evaas.sasinschool.com/tn_reportcard/welcome.jsp.

Tennessee's schools raised students' math achievement between 2003 and 2004. However, the state's improved performance on NCLB is also the result of changes in how it calculates AYP. In 2004, Tennessee (among several other states) began using a "confidence interval" to calculate AYP. A confidence interval provides more flexibility in meeting the AYP benchmarks because it allows a range of results around the benchmarks to qualify as achieving them.

Tennessee fares even less well on NAEP; Tennessee and most Southeastern states have consistently ranked below the national average on recent NAEP assessments. Given the recent Brookings Institution report that asserts the math NAEP exams assess below grade-level content, Tennessee's relatively low performance is especially striking. The report found that the mean grade level was 3.1 for the 4th grade NAEP and 3.4 for the 8th grade NAEP.[78] However, the Brookings study focused only on the arithmetic content of NAEP problem solving test items, and it used Singapore's math textbook program to determine the grade level of test items. The National Assessment Governing Board, which sets the test content, has strongly disagreed with the report's findings, stating they are skewed because the U.S. teaches math differently than does Singapore.[79]

On the 2003 4th grade NAEP math assessment, only 23 percent of Tennessee students performed at or above the proficient achievement level, compared to 33 percent of students nationally. (See Exhibit 8.) However, Tennessee's achievement has improved over time: In 1992, only nine percent of Tennessee students performed at or above proficient, which increased in 2000 to 18 percent.

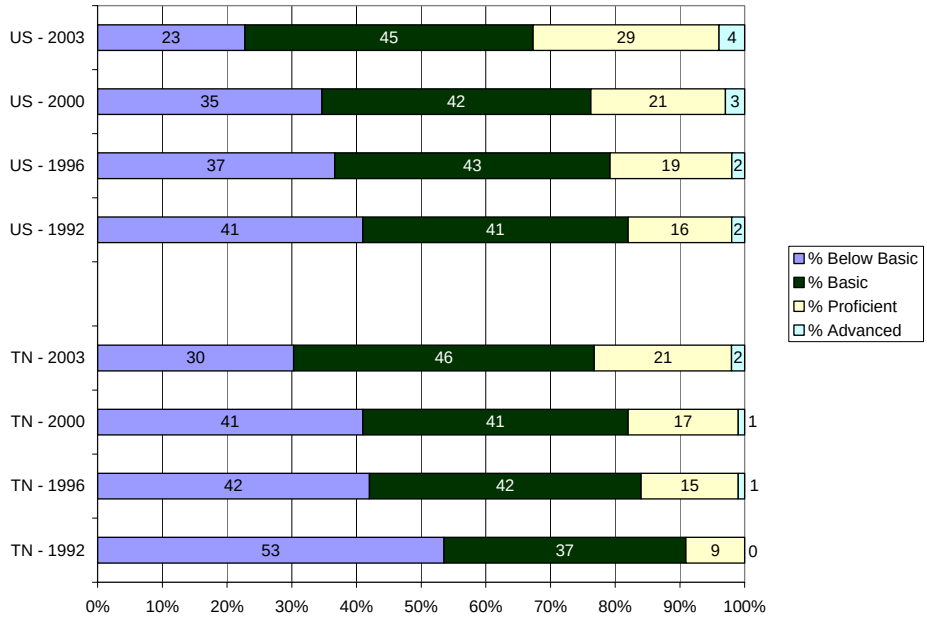
In 8th grade, fewer Tennessee students perform at or above the proficient level. On the 2003 8th grade NAEP math assessment, only 21 percent of Tennessee students performed at or above proficient compared to 28 percent of students nationally. (See Exhibit 9.) This percentage also represents an improvement: In 1992, only 12 percent of Tennessee students performed at this level, and in 2000, 16 percent.

Examining Tennessee's achievement comparatively, 36 states had a higher percentage of students at or above proficient on the 2003 4th grade NAEP mathematics assessment than did Tennessee, 10 states had approximately the same percentage of students at or above proficient, and three states – Mississippi, Alabama, and New Mexico – had a lower percentage of students at or above proficient. (See Exhibit 10, page 23.)

For 8th grade, 33 states had a higher percentage of students at or above proficient on the mathematics NAEP than did Tennessee, 12 states had approximately the same percentage of students at or above proficient, and four states – Mississippi, Alabama, New Mexico, and Hawaii – had a lower percentage of students at or above proficient. (See Exhibit 11, page 24.)

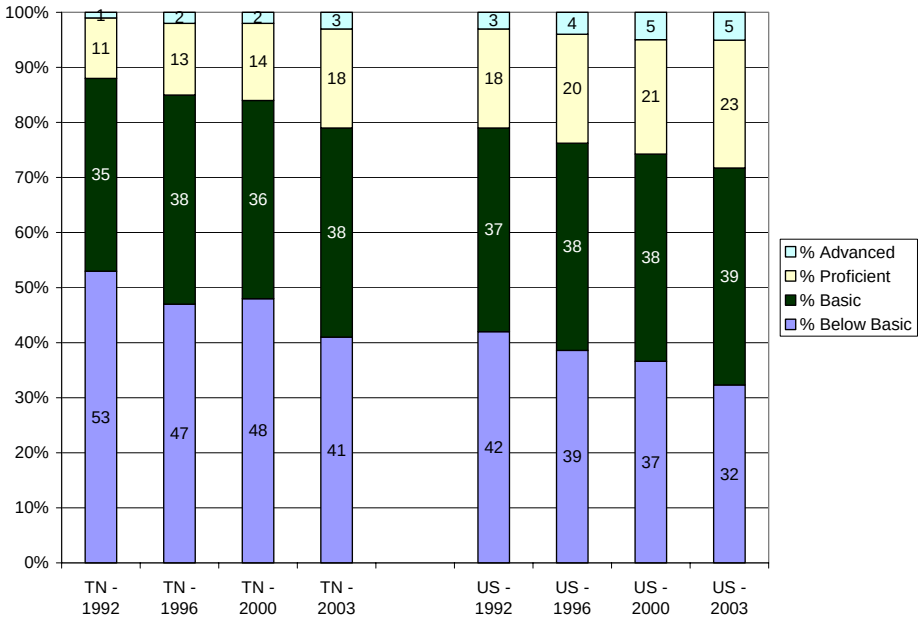
[78] Tom Loveless, The Brookings Institution, "How Well Are American Students Learning?," November 2004. See http://www.brook.edu/gs/brown/bc_report/2004/2004report.pdf.
[79] Ben Feller, "Study calls national math test a no-brainer," *The Detroit News*, November 18, 2004. See http://www.detnews.com/2004/schools/0411/18/A14-8508.htm.

Exhibit 8: Percent of Students at Each Achievement Level on 4th Grade Math NAEP, Tennessee and the US[80]



Source: National Center for Education Statistics, "The Nation's Report Card." See http://nces.ed.gov/nationsreportcard pdf/stt2003/2004457TN4.pdf and http://nces.ed.gov/nationsreportcard/mathematics/results2003/natachieve-g4.asp.

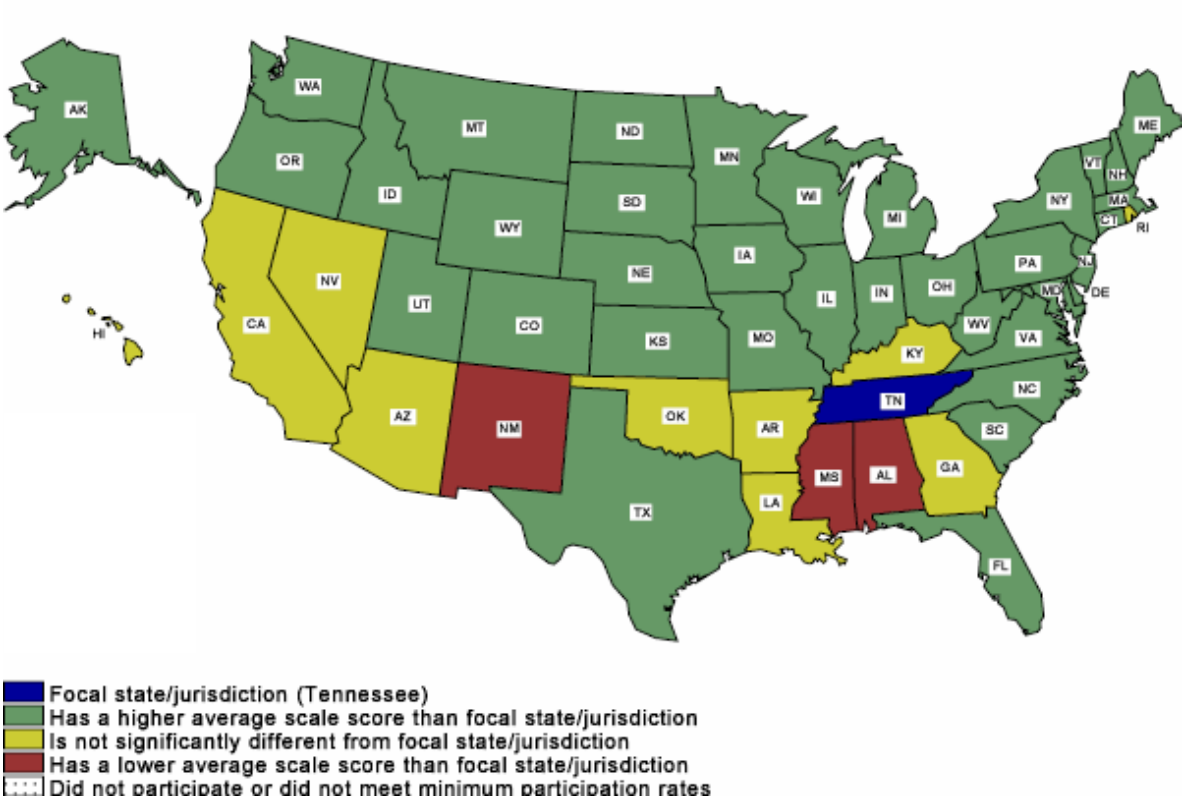
Exhibit 9: Percent of Students at Each Achievement Level on 8th Grade Math NAEP, Tennessee and the US[81]



Source: National Center for Education Statistics, http://nces.ed.gov/nationsreportcard/pdf/stt2003/2004457TN8.pdf and http://nces.ed.gov/nationsreportcard/mathematics/results2003/natachieve-g8.asp.

[80] Accommodations were not permitted for the TN and US assessments in 1992 and for the TN assessment in 1996.
[81] Accommodations were not permitted for the TN and US assessments in 1992 and for the TN assessment in 1996.

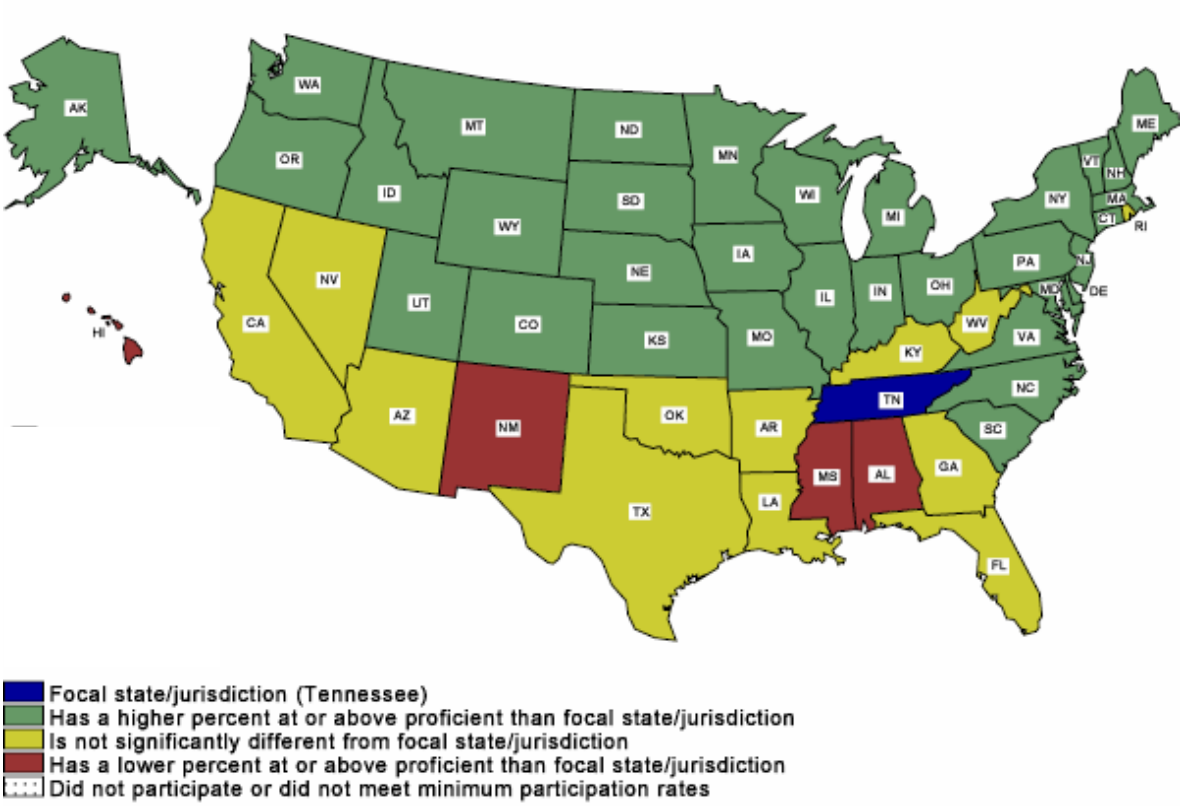
Exhibit 10: 2003 4th Grade NAEP Mathematics Composite, Percent At or Above Proficient Compared to Tennessee



Source: National Center for Education Statistics, Cross-State Comparisons. See http://nces.ed.gov/nationsreportcard/states/statecompare.asp.

The potential effects of Tennessee's low mathematics performance as measured by NCLB and NAEP are far reaching. Tennessee misses the NCLB math benchmark for several student subgroups at the elementary and high school levels. Because state performance is an aggregate of district and school performance, schools across the state will be placed on the targeted and high priority schools lists for their low math achievement. The number of targeted and high priority schools will only increase as the NCLB benchmarks increase towards 100 percent proficiency in 2014. These schools will require additional technical assistance from the state to improve their performance and may have to provide supplemental tutoring and/or face the loss of their students to other schools under the choice provision. Given the wide disparity between student performance on Tennessee tests and external assessments, Tennessee students may not be prepared adequately for K-12 math classes in other states or for college-level math in either Tennessee or other states.

Exhibit 11: 2003 8th Grade NAEP Mathematics Composite, Percent At or Above Proficient Compared to Tennessee



Source: National Center for Education Statistics, Cross-State Comparisons.
See http://nces.ed.gov/nationsreportcard/states/statecompare.asp.

Tennessee students who earned respectable grade point averages in high school often still require additional assistance in mathematics when they enter college. Many of the state's lottery scholarship recipients are likely to require a developmental class in math. Students may qualify for the basic lottery-funded scholarship (Tennessee HOPE) based on either their ACT score or grade point average.

According to The College Board, scoring a 22 or higher on the math section of the ACT indicates that a student likely can handle a freshman credit-bearing college algebra course. Nationally, only 40 percent of 2004 ACT-tested graduates scored a 22 or higher on the math section. In Tennessee, an even lower proportion – 32 percent – attained this score.[82] Starting in 2005, the ACT composite score required to earn a lottery-funded scholarship will increase from 19 to 21, raising it above the 2004 state average of 20.5.

In 2004, Tennessee's lowest subject area score on the ACT college entrance exam was in mathematics, with an average of 19.7. To earn a score of 19 on the math portion of the ACT, a student must answer only half the 60 mathematics questions correctly. Students entering a Tennessee public college or university who scored less than 19 in the subject areas of reading, writing, or math must be placed in a Developmental Studies Program (DSP) or assessed further.[83] According to the Tennessee Higher Education Commission, students who have basic remedial

[82] ACT, "Measuring College Readiness: The Tennessee Graduating Class of 2004," 2004.
[83] Tennessee Board of Regents, Basic/Developmental Studies Program (DSP) Operational Guidelines.

skills but "lack the ability to write coherent paragraphs and do algebraic computations"[84] require developmental coursework.

At Middle Tennessee State University (MTSU), DSP mathematics courses include Elementary Algebra, Intermediate Algebra, and Basic Geometry. Like many colleges and universities in Tennessee, MTSU provides pre-college-level coursework to a significant percentage of freshmen, over a third with high school grade point averages of at least 3.0.

Exhibit 12: Middle Tennessee State University Developmental Studies Student Profile

	First-Time Freshmen		% of DSP students in Math	% of DSP students in Writing	% of DSP students with ≥2.5 GPA[85]	% of DSP students with ≥3.0 GPA
Year	MTSU	DSP				
2004	3150	1103 (35%)	59	22	72	40
2003	3038	1055 (35%)	64	20	71	35
2000	2837	1706 (60%)	70	22	67	27
1998	2583	1106 (43%)	91	29	59	23

Source: MTSU Developmental Studies Profiles. See http://mtsu32.mtsu.edu:11063/profile/Studentprofpage.htm.

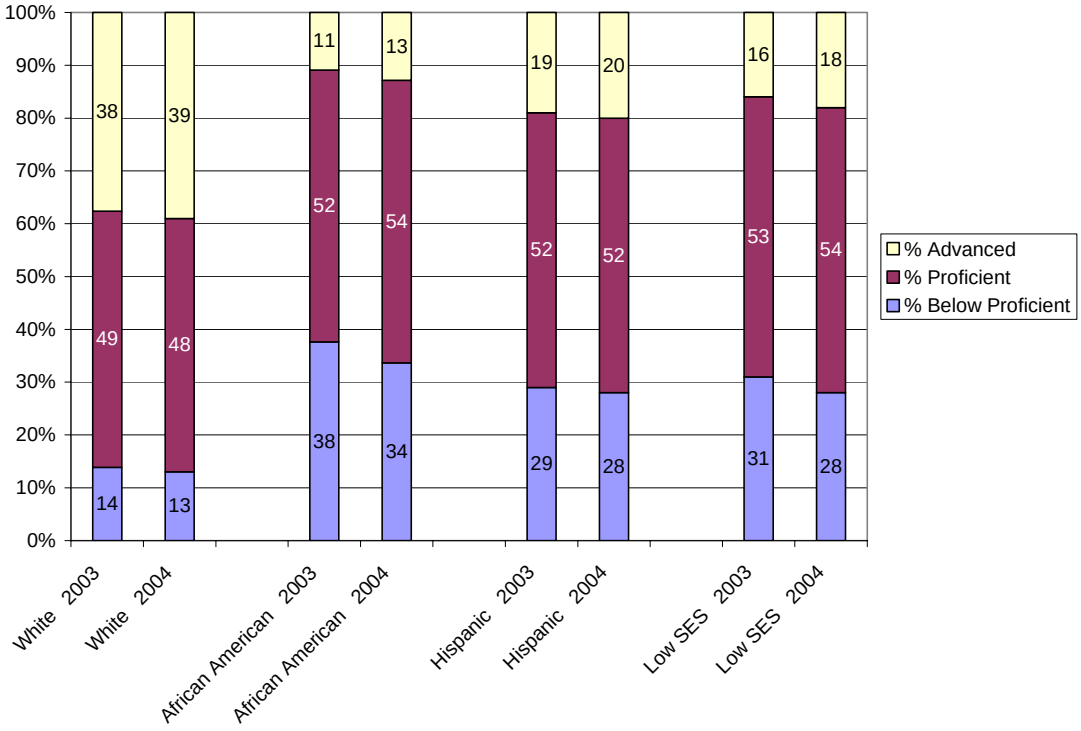
Tennessee students can qualify for lottery-funded scholarships with a 3.0 high school GPA, regardless of their ACT scores. More students are expected to qualify for the scholarship based on GPA than on ACT scores. Given the percentage of students at MTSU in developmental studies who had a high school GPA of 3.0 or higher, many lottery scholarship recipients are likely to require a developmental class in math. Providing developmental classes for scholarship students amounts to state dollars paying for the same instruction twice: once in high school (assuming the student attended public school) and again in college.

A likely cause of the disparity between Tennessee students' grade point averages and their ACT scores is the low rigor of high school mathematics courses, which allows students to earn relatively high grades without acquiring the knowledge and skills needed to be prepared for college math coursework. As a result, Tennessee students receiving HOPE scholarships will have access to college, but many will spend a portion of their time there learning mathematics they should have been taught in high school. This delays their opportunities to take credit-bearing college courses. Other scholarship recipients who aren't required to take developmental courses may still struggle academically, which increases their likelihood of dropping out.

At the elementary and high school levels, and on both state and national mathematics assessments, Tennessee has significant, persistent achievement gaps between white students and students of color and between students of lower and higher socioeconomic status (SES). These gaps have far-reaching consequences for subgroups' college readiness and employability. On the criterion-referenced portion of the 2003 TCAP math exam, 87 percent of white students scored proficient or advanced, compared to 63 percent of African American students, 71 percent of Hispanic students, and 69 percent of economically disadvantaged students. (See Exhibit 13.) In 2004, the performance gap slightly decreased because a higher percentage of African American students, Hispanic students, and economically disadvantaged students scored at or above proficient. (See Exhibit 14.)

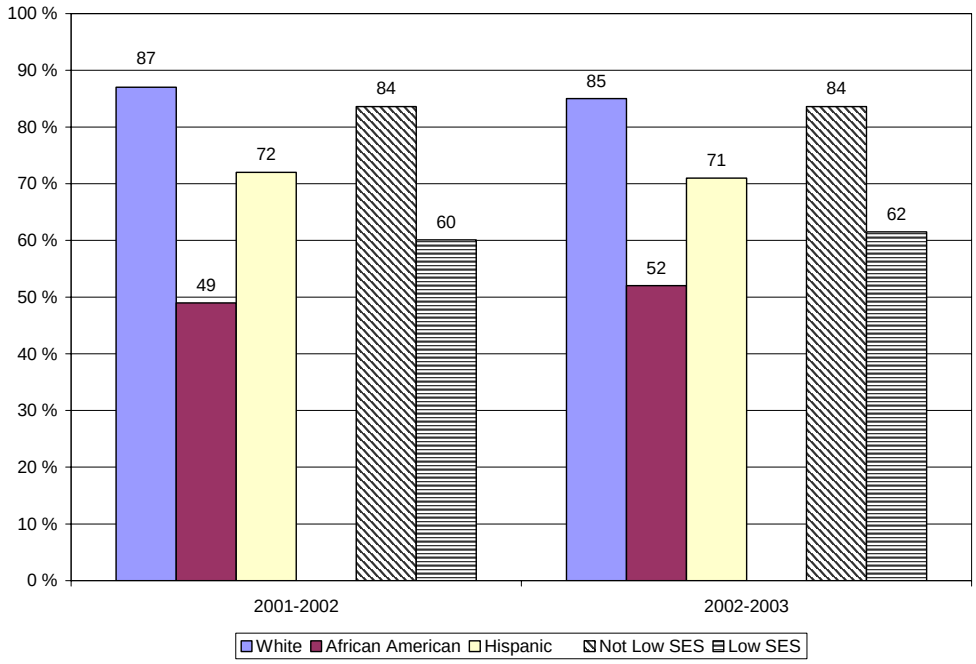
[84] Brian Noland, Tennessee Higher Education Commission, "Subject: Remedial and Developmental Education," Memorandum to Will Burns, March 4, 2003.
[85] These are B and C students in Tennessee's public schools.

Exhibit 13: 2003-2004 Math TCAP by Achievement Level and Student Subgroup (Criterion-Referenced Portion)



Source: Information provided by the Tennessee Department of Education Center for Research and Policy.

Exhibit 14: Algebra I Gateway, Percent of Students Scoring Proficient or Above by Ethnicity and Socioeconomic Status



Source: Tennessee Department of Education, "Gateway Test Results: SY 2001-2002" (See http://www.state.tn.us/education/testing/02tsgwstatewide.pdf) and "Gateway Test Results: SY 2002-2003."

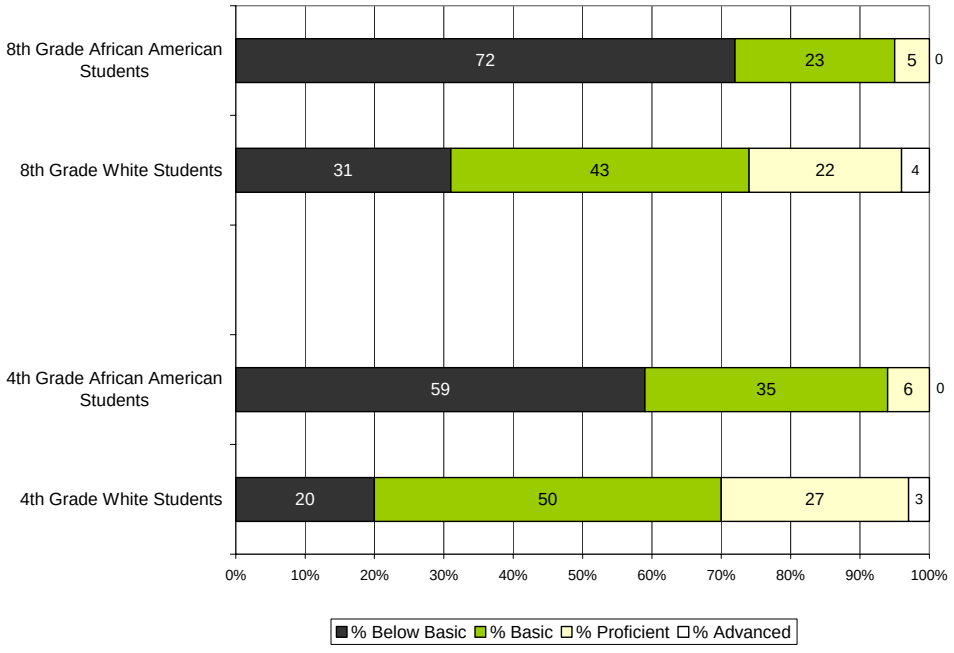
Achievement gaps by ethnicity and SES on the Gateway Algebra I assessment are even greater. In 2003, 85 percent of white students reached proficiency, compared to 52 percent of African American students – a 33 percent gap. By SES, 84 percent of students who were of higher SES reached proficiency, compared with 62 percent of students of low SES – a 22 percent gap. (See Exhibit 15.)

In 2004, Tennessee missed five mathematics benchmarks under NCLB, all due to insufficient performance by student subgroups. For grades K-8, the following student subgroups in Tennessee did not meet the benchmark for the percent of students scoring proficient or advanced (as measured by the criterion-referenced portion of the TCAP math achievement test): African Americans, Students with Disabilities, and Limited English Proficient Students.

In grades 9-12, the following student subgroups in Tennessee did not meet the benchmark for the percent of students scoring proficient or advanced (as measured by the Gateway Algebra I achievement test): African Americans and Students with Disabilities.[86]

The mathematics achievement gaps in Tennessee are the most striking as measured by NAEP. There are large gaps on the mathematics NAEP in Tennessee by ethnicity and SES, and the gaps grow larger from 4th to 8th grade. In 4th grade in 2003, 30 percent of white students, but only six percent of African American students, scored at or above proficient; 59 percent of African American students scored in the below basic category. In 8th grade, 26 percent of white students – compared to five percent of African American students – scored at or above proficient; 72 percent of African American students scored in the below basic category.

Exhibit 15: 2003 Math NAEP by Achievement Levels and Student Ethnicity



Source: National Center for Education Statistics, "The Nation's Report Card." See http://nces.ed.gov/nationsreportcard/pdf/stt2003/2004457TN4.pdf and http://nces.ed.gov/nationsreportcard/pdf/stt2003/2004457TN8.pdf.

[86] Tennessee Statewide Report Card 2004. See http://www.k-12.state.tn.us/rptcrd04/.

North Carolina: Making Strides to Close the Achievement Gap

North Carolina has made significant progress in closing the mathematics achievement gap on its state assessment while continuing to raise the achievement of all student groups. Between 1998 and 2004, North Carolina narrowed the gap between the percent of white and the percent of African American 4th grade students scoring at or above grade level by 18 points. In 8th grade, the state reduced the gap by eight points while increasing the percent of African American students at or above grade level by 15 points.

North Carolina's increased parity of mathematics achievement has not happened by accident. The state has a targeted *Closing the Achievement Gap* initiative which includes numerous integrated programs and strategies to address factors that influence the gap. All components of the initiative align with the 11 recommendations issued by the state's *Advisory Commission on Raising Achievement and Closing Gaps.*
A few highlights of the initiative:

- **The state provides school systems and schools gap-related technical assistance:** The NC Department of Public Instruction (DPI) offers training sessions in the four core content areas, including specific skill development and instructional strategies that promote student achievement. It also provides multicultural/diversity training and training to heighten teachers' awareness of their perceptions and expectations of students.
- **The state serves as a clearinghouse for best practices and research concerning the achievement gap:** The DPI regularly performs data analysis of the state's achievement gap and conducts studies to assess school equity factors that may affect the gap. It also compiles and disseminates (via its website) best classroom practices designed to close the achievement gap as well as academic research on the issue.
- **The state has increased its commitment to provide educators professional development**: In 2001, the NC General Assembly revised the language regarding the State Board of Education's (SBOE) professional development responsibilities. Under the new legislation, the SBOE must identify state and local needs for professional development based on the state's educational priorities for improving student achievement and recommend strategies for addressing these needs. The strategies must be research-based, proven in practice, and designed for data-driven evaluation.
    - In agreement with the NC State Board of Education, the Center for School Leadership Development created a comprehensive school-level program designed to improve educational practice and eliminate the achievement gap. The program is being piloted in 18 schools throughout the state and will be evaluated on the basis of student performance on standardized assessments and other indicators of school success.

Sources: The Education Trust, Inc. 2004. See http://www2.edtrust.org/NR/rdonlyres/6DD3F93E-43FE-4F53-9353-EE4ED313C44A/0/NorthCarolinafinal.ppt.
North Carolina Department of Public Instruction, "Reports of Supplemental Disaggregated State, School System (LEA) and School Performance Data for 2002-2004." See http://disag.ncpublicschools.org/2004.
Closing the Achievement Gap Division of the School Improvement Division of the NC Department of Public Instruction, "NC Initiatives." See http://www.ncpublicschools.org/schoolimprovement/closingthegap/initiatives.

Tennessee is certainly not the only state with sizeable achievement gaps among its student subgroups. However, the prevalence of disparate student achievement does not make these gaps acceptable, nor does it absolve the state of responsibility to attempt to reduce them. Several potential factors may produce the achievement gaps in Tennessee. Certain subgroups of students may be taught by less qualified teachers; they may be exposed to less rigorous math content and poorer quality materials; these students' teachers may have lower expectations of their math achievement. In addition, research substantiates that various sociological factors (e.g., SES and parents' level of education) are highly correlated with student achievement.

The Tennessee Department of Education has taken some steps to address the achievement gap issue. In 2003, it created the *Closing the Gap Work Group*, which Deputy Commissioner Keith Brewer charged with determining means of closing the achievement gap for at-risk students and empowering schools to help all students succeed. In January 2004, the group produced a report, *Closing the Achievement Gap: All Students, Our Students*, which contains three main recommendations and 10 strategies.[87] However, this report is not featured prominently on the department's website (it is located solely under the Special Education Division) and the extent of its impact is unclear.

Regardless of the causes of Tennessee's math achievement gap, students who are not proficient in elementary and high school math will not be prepared for college math courses and will have limited employability, especially in fields requiring math knowledge and skills. Because the students not reaching math proficiency are disproportionately poor and students of color, the math achievement gap potentially will worsen the state's preexisting economic disparities.

U.S. 4th and 8th graders perform well in mathematics compared to their international peers. However, U.S. high school students lag behind the majority of industrialized nations in their ability to apply mathematical knowledge and skills. As a result, the U.S. likely will become less competitive in industries requiring math, especially high growth, high wage industries such as technology and engineering. For further discussion of this issue, see the "Mathematics is a filter for employment" section, pages 4-6.

Forty-six nations participated in the 2003 TIMSS, which assessed the mathematics performance of 4th and 8th grade students. Results indicate that U.S. 4th graders scored an average of 518, which exceeds the international average of 495. They outperformed their peers in 13 countries, and performed lower than their peers in 11 countries. U.S. 8th grade students also scored above the international average with an average score of 504, which exceeded 25 countries and fell below nine countries.[88] (See Exhibit 16.)

Between 1995 and 2003, there were no measurable changes in the average TIMSS mathematics scores for U.S. 4th graders. However, relative to the other 14 countries that participated in the assessments, the performance of U.S. 4th graders was lower in 2003 than it was in 1995. U.S. 8th graders not only improved their average math performance between 1995 and 2003, they also had higher performance relative to the other 21 countries that participated in TIMSS.[89]

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[87] See http://www.state.tn.us/education/speced/sectag.doc.
[88] National Center for Education Statistics, "Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003." See http://nces.ed.gov/pubs2005/2005005.pdf.
[89] National Center for Education Statistics, "TIMSS 2003 Assessment Results." See http://nces.ed.gov/timss/Results03.asp?Quest=2 and http://nces.ed.gov/timss/Results03.asp?Quest=4.

Exhibit 16: Average scores of the U.S. and select other countries participating in 2003 TIMSS mathematics assessments for 4th and 8th grades

Country	Average Math Score 4th grade
Singapore	594
Hong Kong	575
Japan	565
Netherlands	540
Latvia	536
United States	***518***
Italy	503
Scotland	490
Norway	451
Philippines	358
International Average	**495**

Country	Average Math Score 8th grade
Singapore	605
Hong Kong	586
Japan	570
Netherlands	536
Hungary	529
United States	***504***
Italy	484
Norway	461
Philippines	378
South Africa	264
International Average	**466**

Source: National Center for Education Statistics, "TIMSS 2003 – Tables." See http://nces.ed.gov/timss/TIMSS03Tables.asp.

TIMSS has not tested 12th graders since 1995, when U.S. 12th graders scored below the international average and among the lowest of the TIMSS nations in both general mathematics knowledge and advanced mathematics. On the most recent international assessment of mathematics achievement, the 2003 Program for International Student Assessment (PISA), U.S. 15-year-olds performed below their peers in 20 out of 30 participating industrialized countries. The PISA results are especially salient to the United State's future economic competitiveness because this assessment focuses on real-world applications of math knowledge and skills. A comparative study of TIMSS and PISA found that TIMSS has a greater focus on factual knowledge and multiple choice items. In contrast, PISA requires students to problem solve, critically evaluate mathematics scenarios, and provide extended responses.[90] (See page 32 for more information on PISA.)

Research has identified multiple causes of U.S. high school students' low relative mathematics achievement. For example, in 1995, U.S. students in their final year of secondary school were less likely to take mathematics than were their counterparts in other countries. Only 66 percent of U.S. students were taking mathematics, compared to an average of 79 percent in the other nations participating in TIMSS.[91]

In addition:

- Teacher preparation in mathematics generally does not provide new teachers sufficient content knowledge and skills to teach math effectively at high levels.
- U.S. math classes often emphasize process over conceptual understanding and focus on lower-level skills.

[90] National Center for Education Statistics, "Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003." See http://nces.ed.gov/pubs2005/2005005.pdf.

[91] National Center for Education Statistics, "Highlights from TIMSS: Overview and Key Findings Across Grade Levels." See http://nces.ed.gov/pubs99/1999081.pdf.

- U.S. mathematics curricula frequently include a plethora of topics, which limits the depth of coverage teachers can provide on each one.

Furthermore, there is often a gap between teachers' beliefs about and practices regarding the rigor and alignment of the content they teach to state standards. For example, the South Carolina Department of Education collected a week's worth of classroom assignments in four core subjects from several hundred K-8 schools. It found that students in grades 3 through 8 were being taught mostly below grade level in mathematics and the assignments did not provide instruction and practice that would help students become proficient in the South Carolina mathematics standards.[92] (See page 36 for more information.)

If left unchecked, U.S. high school students' low mathematics achievement compared to other nations is likely to cause the United States to become less competitive in industries that depend upon high level mathematics knowledge and skills. U.S. and international corporations will have to look outside the U.S. to find highly skilled workers, thus adversely affecting the nation's economy.

Educators interviewed indicated that U.S. culture dictates that it is acceptable to be "bad at math," a major obstacle to improving students' math achievement. Many draw a comparison to literacy, accurately noting that few would admit publicly to being "bad" at reading. Disparaging remarks about math abound not only in school, but outside school – on television, in public forums, and (perhaps most damaging of all to students' developing attitudes about school) within students' families.

Although the often self-deprecating remarks are not delivered with intent to harm, the result has been widespread "math anxiety" among U.S. students and even some math teachers. Clearly, if students perceive a subject as too difficult and see no practical reason for trying to learn it, most will opt not to learn it or will learn only as much as they need to pass a test. In addition, a teacher with a negative view of his or her own math ability is unlikely to encourage a positive view of math in students. Such a mindset, especially developed in one's early years, can affect a child's academic future, career, and daily life. Collectively, it can result – and has resulted – in poor student achievement on tests that compare U.S. students to those of other nations. Long-term results could be even more damaging to the U.S. economy in future years.

Like many other states, Tennessee does not set high expectations for potential teachers, including those who must be knowledgeable about mathematics. Requirements for education majors vary among the state's higher education institutions. For example, education majors at the University of Memphis must have a minimum grade of "C-" in all courses related to the content areas (math, science, social science, English, and fine arts) of elementary and middle grades and the core courses for the major, but they must maintain a cumulative GPA of 2.5. Similarly, education majors at Middle Tennessee State University and Tennessee Technological University must maintain a GPA of at least 2.5. Students at the University of Tennessee at Knoxville must attain a cumulative GPA of 2.3 for admission into the Early Childhood Education concentration;

[92] *South Carolina Mathematics Focus* handout from Southern Regional Education Board conference, October 7-8, 2004.

Mathematics Students in the United States: Passing but Not Prepared

Results from the latest international math assessment indicate U.S. students continue to lag behind most of their international peers in mathematics. Every three years, the Organization for Economic Cooperation and Development (OECD) – an intergovernmental organization of 30 highly industrialized countries – conducts the Program for International Student Assessment (PISA). PISA gauges 15-year-olds' preparedness to meet the challenges of today's knowledge society. In 2003, 20 of the OECD countries, and three non-OECD countries (Hong Kong-China, Liechtenstein, and Macao-China) outscored the U.S., which performed on par with Latvia.

Unlike multiple-choice items on NAEP and TIMSS that assess students' mastery of specific curriculum, PISA assesses students' ability to perform real-world applications of math knowledge and skills. It requires students to move beyond problem-solving; they must "interpret, validate, and communicate the results."[93] PISA ranks mathematics literacy from Level 1 to Level 6, with Level 6 being the highest level of proficiency. At Level 1, students are able "to carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are obvious and follow immediately from the given stimuli."[94] Over 25 percent of U.S. students were unable to complete tasks above Level 1; 10 percent scored below Level 1.[95]

Even the highest achieving U.S. students were outperformed by their OECD counterparts. Only 10 percent of U.S. students scored in the top two levels of proficiency – a performance below the OECD average of 15 percent and well below the 31 percent in Hong Kong.

Despite low scores on PISA's math assessment, U.S. students reported the highest percentage of good grades. Seventy-two percent of U.S. students agreed with the statement, "I get good marks in mathematics."[96] The discrepancy between international performance and assigned course grades illustrates the low rigor of mathematics curriculum in the United States, which covers numerous topics but without sufficient depth, and reflects the rote, procedural focus of math instruction.

PISA's international perspective on student performance reveals a widening gap in countries' preparedness for the knowledge economy. U.S. students' poor performance foreshadows a growing disadvantage in the global economy.

[93] Organization for Economic Cooperation and Development, "Top-performer Finland Improves Further in PISA Survey as Gap Between Countries Widens," 2004.
[94] Organization for Economic Cooperation and Development, *Learning for Tomorrow's World: First Results from PISA 2003*, 2004, p. 47.
[95] National Center for Education Statistics, *International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results from the U.S. Perspective*, 2004.
[96] Organization for Economic Cooperation and Development, *Learning for Tomorrow's World: First Results from PISA 2003*, p. 134.

earn a minimum grade of "C" in all Education courses; and attain a minimum cumulative GPA of 2.7 for admission to the Teacher Licensure Program.[97]

The Educational Testing Service (ETS) develops and administers the Praxis II exams for beginning teachers seeking licensure, but does not set a passing score for the tests. Instead, each state sets its own passing score. In Tennessee, the State Board of Education sets the passing scores for each Praxis test it requires. Potential teachers seeking a 7-12 math endorsement must achieve a minimum scale score of 136 on the Mathematics: Content Knowledge test. The possible score range for this assessment is 100-200, and the national performance median is 143.[98] In 2003, only 48 percent of Tennessee test-takers passed.[99] Sixty percent of nationwide test-takers would have passed the test given Tennessee's minimum score.[100]

The state has set a minimum scale score of 140 out of a possible 200 for the Praxis II Elementary Education: Content Knowledge (which includes mathematics questions). Only one state has a lower minimum score – Alabama. This score is well below the national median of 163 and below the national average performance range of 150-175.[101] Therefore, based on 2002-03 national data, 86.9 percent of all test takers across the country achieved Tennessee's 2004 minimum score. However, 100 percent of Tennessee's 1,168 test-takers passed this test in 2003 because no minimum passing score had been set. [102]

Department of Education staff indicate that it is routine to require no minimum passing score for the first year a test is given. Resulting scores help a designated committee determine and recommend an appropriate pass score for future Tennessee test-takers. However, this means that the basis for determination of pass rates is how Tennessee candidates score on the test, not what they *should* score if expected to perform at a high level.

Although ETS does not set passing scores, it designates target scores for an achievement it calls "Recognition of Excellence (ROE)" for some selected tests, including the Mathematics: Content Knowledge Test – the ROE is 165 of 200 and Tennessee's passing score for that test is 136. ETS' ROE for the test titled Elementary Education: Content Knowledge is 181 of 200; Tennessee's passing score is 140 for that test. ETS states that the "Recognition of Excellence is not a criterion for licensure, hiring, or promotion decisions. It is a means of recognizing outstanding individual performance on the Praxis tests." [103]

While Tennessee requires the Praxis II strictly for licensing purposes, the individual institutions decide when candidates will take the test and if it is an advancement criterion in the program. However, Praxis passing rates annually reported from the higher education institutions to the Department of Education are limited to the performance of program completers. Because 25 of the 40 teacher education programs in the state now require students to pass the Praxis II prior to entering student teaching, candidates may take the Praxis II Mathematics Content Knowledge well before completing the program and may not pass until the second or subsequent attempts.

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[97] Curriculum guidelines and progression standards from departments of education.
[98] ETS, "Understanding Your Praxis Scores 2004-05." See http://ftp.ets.org/pub/tandl/09706PRAXIS.pdf .
[99] ETS, Passing Rate Summary Report for Tennessee, 2003.
[100] ETS, Total Examinees Summary Report, Mathematics: Content Knowledge, 2003.
[101] ETS, "Understanding Your Praxis Scores, 2004-05."
[102] ETS, Passing Rate Summary Report for Tennessee, 2003.
[103] ETS, "Understanding Your Praxis Scores, 2004-05."

Requiring passage of Praxis II for advancement within the program eliminates those that fail from the list of "program completers" and inflates the reported pass rates.[104] For example, most universities report pass rates above 90 percent for Praxis II tests. (See Exhibit 17 and Appendix C for a complete list of universities' pass rates.)

Exhibit 17: Praxis II Examinations, Institutional Pass Rates

Institution	Number with Praxis Scores	Number Passed	Number Failed	Percent Passed
East Tennessee State University	225	219	6	**97.33%**
University of Tennessee – Knoxville	312	302	10	**96.79%**
Austin Peay State University	170	163	7	**95.88%**
University of Tennessee – Chattanooga	176	168	8	**95.45%**
University of Tennessee – Martin	131	125	6	**95.42%**
Tennessee Technological University	244	228	16	**93.44%**
Tennessee State University	134	125	9	**93.28%**
Middle Tennessee State University	307	278	29	**90.55%**
University of Memphis	368	331	37	**89.95%**
Remaining 22 accredited programs	508	494	14	**97.24%**
State Totals	3153	2985	168	**94.67%**

Source: State Board of Education Summary Report, "2002-2003 Teacher Education Graduates, Institutional Pass Rates, Praxis II Examinations."

However, the Passing Rate Summaries provided by ETS are more telling. (See Exhibit 18.) In 2003, only 48 percent of Tennessee test-takers, and only 27 percent of the African-American test-takers in the state, passed the Mathematics: Content Knowledge test. (See Appendix C for additional Praxis scores.)

Exhibit 18: Praxis II Content Area Endorsements, Pass Rates

		Total Group	African-American	White
MATHEMATICS CONTENT KNOWLEDGE Passing Score = 136	Total N	143	44	91
	Mean	135	123	142
	Median	134	125	140
	Number Pass	68	12	54
	Pass Rate	**48**	**27**	**60**

Source: ETS, Passing Rate Summary Report for Tennessee, 2003.

In 2004, ETS published "Where We Stand on Teacher Quality: An Issue Paper from ETS," which recommended that states "re-evaluate their existing teacher licensure programs and begin work on raising the standards for those entering the profession."[105] According to the report, "ETS is committed to working with states to reduce differences in passing scores on Praxis tests across states. States can begin by reviewing existing standards required for demonstration of subject matter knowledge, including the passing scores required on those assessments."[106]

Policymakers in several states have debated the appropriate passing scores for teachers taking the Praxis tests. When states began moving from the older teacher assessments known as the National Teacher Examinations to the newer Praxis test series, which debuted in 1993, some set higher

[104] Information provided by Martin Nash, Director of Teacher Education and Accreditation, and Vance Rugaard, Director of Teacher Licensing, Tennessee Department of Education.
[105] ETS, "Where We Stand on Teacher Quality: An Issue Paper from ETS," Teacher Quality Series 2004, p. 8.
[106] Ibid.

cutoff scores in an effort to increase standards for teachers.[107] However, many states, like Tennessee, set passing scores at or below the 25th percentile, "meaning that a teacher candidate can score just above the worst one-fourth of students and still be certified."[108]

If the Praxis II tests are meant to help ensure a teaching candidate's knowledge and teaching abilities, setting low scores seems counter to that goal. Allowing some to enter the teaching profession who may lack the necessary skills to provide quality instruction appears to perpetuate a cycle of poor student achievement. Also, even with some of the nation's lowest minimum scores, Tennessee faces a shortage of federally recognized "highly qualified" teachers.

The pipeline producing math-knowledgeable teachers is inadequate.[109] Sixty percent of all new graduates hired in Tennessee from 1992 to 2001 majored in elementary, early childhood, multidisciplinary studies, or special education. During that time, Tennessee public colleges and universities prepared 9,714 elementary school teachers. In contrast, few graduates are prepared to teach subject areas in secondary schools. At the same time, these institutions prepared only 70 mathematics education majors, 39 of whom entered teaching. Of the 180 mathematics majors seeking licensure, 112 began teaching in Tennessee classrooms. [110]

Approximately three-fourths of the new graduates hired to teach in Tennessee's public school system each year graduated from Tennessee's colleges and universities. However, among new teachers in Tennessee who have no previous experience, 35 percent leave within the first four years of teaching and an additional six percent leave by the end of the fifth year. Two out of five teachers who enter the profession in Tennessee are active for five years or less. For this reason, the distribution of potential teachers limited by content area is a matter of concern.

Tennessee is "finding it especially difficult to staff middle grades with teachers who have the necessary content knowledge."[111] From 1992 to 2001, 47 percent of middle school teachers and 38 percent of junior high school teachers who graduated from Tennessee's colleges and universities majored in multidisciplinary studies. An additional 30 percent of middle school teachers and 18 percent of junior high teachers majored in elementary education.[112]

Tennessee's "reserve pool" – educators who have credentials to teach but are currently not hired in the Tennessee public school system – contains a limited number of teachers endorsed in subject areas. For example, 7,652 teachers in the reserve pool have endorsements in elementary school teaching, but only 824 have endorsements in mathematics.

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[107] Jeff Archer, "States Raising Bar for Teachers Despite Pending Shortage," *Education Week*, March 25, 1998.
[108] Associated Press article, "Report: Teacher certification overhaul needed," CNN.com, June 11, 2002. Available 9/7/2004 at www.cnn.com/2002/fyi/teachers.ednews/06/11/teacher.training.ap.
[109] "More Math, Please: The Surprising Consensus on Math Among Parents, the Public, and Business Leaders in Two 'New Economy' States," The Mass Insight Education and Research Institute, April 2004.
[110] Southern Regional Education Board, *2003 Study of Teacher Supply and Demand in Tennessee*.
[111] Ibid., p. 8.
[112] Southern Regional Education Board, *2003 Study of Teacher Supply and Demand in Tennessee*.

South Carolina: Taking a Closer Look at Classroom Content

South Carolina has created an innovative state-level initiative that addresses one of the generally unexamined aspects of education reform: how well state-level standards and raised expectations are implemented in the classroom.

Named "Curriculum Calibration," the program analyzes classroom assignments for their rigor and degree of alignment with state standards. Over two school years, 761 schools have been involved in the initiative: In 2002-03, elementary and middle schools participated, and in 2003-04, high schools were added.

How the process works:

- Teachers collect all student assignments from a high, medium, and low performing student in each of the four core subject areas for a one-week period.
- DataWorks Educational Research (the organization that designed Curriculum Calibration) staff perform five analyses of the assignments:
  1. Percentages of assignments above, below, and on grade level;
  2. Breadth of coverage (content strands/areas);
  3. Types of assignments (teacher guided, independent, homework, etc.);
  4. Source of assignments (textbook, commercial worksheets, teacher created, etc.);
  5. Grades given to the higher, medium, and low performing students.
- Each participating school faculty is given a presentation of the analyses' findings.

Curriculum Calibration has several benefits for schools: it informs teachers about whether their assignments are aligned to grade-level standards; it provides a baseline to measure improvement of curriculum alignment; and it helps schools focus on teaching students at higher levels.

The South Carolina Department of Education has created state-level composite and summary reports of the analyses' findings and trends (posted on its website). This information can potentially (and should) inform and influence the professional development and other technical assistance the state provides to schools.

In elementary math, South Carolina found,"…mathematics assignments were on grade level in K-1 and then progressively slipped further behind at each higher grade." Some of the misalignment to grade-level standards was due to assignments aligned to standards higher than the assigned grade level. However, as the summary report notes, "Alignment to standards for any other grade level, whether higher or lower, is still misalignment and may result in redundancies or gaps in teaching or learning across grades." Of the assignments collected from regular-level Algebra I classes, only 69 percent aligned with the state's standards for this course.

Source: South Carolina Department of Education, Curriculum Calibration overview. See http://www.myscschools.com/Offices/CSO/enhance/curriculumcallibration-overview.htm.
Summary Report of 2002-2003 Curriculum Calibration for 362 South Carolina Schools (K-8). See http://www.myscschools.com/Offices/CSO/enhance/curriculumcalibrationsummaryreport02-03.htm.
2003-2004 School Composite Report. See http://www.myscschools.com/Offices/CSO/enhance/documents/2004SchoolReport.pdf.

Additionally, because individuals can have more than one endorsement, taking half of the endorsements reported provides a rough estimate of the number of reserve teachers per specialization.[113] Tennessee, therefore, has approximately 412 reserve mathematics educators. While this "excess" of mathematics teachers might seem adequate at first glance, "studies show that teachers rarely return to the classroom after an absence of a year or more."[114]

Given the lack of content specialization, districts with high demand for subject area teachers continue to have higher percentages of teachers who have waivers or permits, rather than full teaching credentials. Further, many teachers certified in another subject have a waiver to teach math. A permit allows a local education agency (LEA) to employ an individual with a Bachelor's degree in cases of extreme hardship. This means that "an authorized official from the local education agency must verify that no licensed educator is available for the type and kind of position in which a vacancy exists."[115]

Less than four percent of Tennessee's educators have waivers or permits, but the number of waivers and permits in mathematics increased from 161 in 1999-2000 to 204 in 2001-02.[116] During the 2003-04 school year, there were 134 under-qualified math teachers statewide – 109 permits and 25 waivers. Waivers particularly affect schools that serve large populations of high poverty students because higher-credentialed teachers with more years of teaching experience frequently do not teach at these schools. Davidson County employed 40 under-qualified math teachers – 36 permits and four waivers; eight were in one school alone. Memphis City had 34 under-qualified math teachers – 29 permits and five waivers.[117] (See Appendix D for a complete list of waivers and permits by school system.)

As of November 2004, the Department had issued 42 math permits for the 2004-05 school year. While this number will increase by the end of the school year, a recent push for alternate licensure is responsible for the decrease. A person teaching on a permit is not considered highly qualified under NCLB. Therefore, the Department of Education encourages educators to enter one of three routes to Alternative Teacher Licenses – a credential that meets the "highly qualified" benchmark of NCLB.[118]

Still, prior to this year, many students, at both the middle school and high school levels, have been taught by teachers who were not qualified to teach math. In addition, many school systems do not have a licensed mathematics educator available. In September 2004, the department announced the allocation of funds for a new teacher recruitment center and pointed to a shortage of math teachers in the state.[119]

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[113] Southern Regional Education Board, *Educator Supply and Demand Statistical Report for the State of Tennessee*, December 2003. There are 28,347 endorsements shared among 17,555 individuals or approximately 2 endorsements per person in Tennessee.
[114] Southern Regional Education Board, *2003 Study of Teacher Supply and Demand in Tennessee*, p. 8.
[115] Tennessee Department of Education. See http://www.state.tn.us/education/lic_perm.htm.
[116] Southern Regional Education Board, *Educator Supply and Demand Statistical Report for the State of Tennessee*, December 2003.
[117] Data provided by the Office of Teacher Licensing and the Office of Improvement, Innovation, and Accountability, Tennessee Department of Education.
[118] Educator's with at least a Bachelor's degree in the content area to be taught may receive an Alternative Type A, Type C, or Type E License. Types A and C licensing routes lead to completion of a teacher education program. See http://www.state.tn.us/education/lic_alt.htm.
[119] Diane Long, "Recruitment center aims to stem state's teacher shortage," *Tennessean*, September 26, 2004.

Research indicates that many elementary teachers lack deep understanding of the fundamental principles underlying school mathematics, which in turn disadvantages their students. A 2001 report titled *The Mathematical Education of Teachers* states:

> There is evidence of a vicious cycle in which too many prospective teachers enter college with insufficient understanding of school mathematics, have little college instruction focused on the mathematics they will teach, and then enter their classrooms inadequately prepared to teach mathematics to the following generations of students.[120]

This cycle, if not broken, could have long term negative consequences for Tennessee students. Students who lack good mathematical understanding and reasoning ability face limited opportunities in the future. Some may drop out of high school. Those who attend college may require remedial or developmental instruction.

An OEA survey of Tennessee's public college officials found wide agreement that students majoring in elementary education may be ill-equipped to teach mathematics. One respondent noted often hearing that prospective teacher candidates selected elementary education as a career because they are not "good" at math or science. Another said that teacher candidates frequently indicate they were not taught to appreciate or enjoy mathematics. One survey respondent commented:

> Most of our future K-8 teachers, especially future mathematics teachers, have only a procedural understanding of mathematics. Instead of regarding mathematics as a sense-making endeavor, they assume that it is a subject consisting of facts and procedures to be memorized. Their ability to use mathematical reasoning, think creatively about quantitative solutions, and solve problems is undeveloped. In addition, some of these students also have weak math skills, especially with regard to fractions and percents. There is a great need to raise expectations about what these future teachers should know and be able to do mathematically.[121]

Teachers' knowledge about mathematics comes from their own K-12 education, their postsecondary training, and the support and continuing education opportunities they experience once they are hired to teach. Each is clearly important in developing a teacher's ability to affect student learning. Many current teachers "learned mathematics within the same system that so many are seeking to improve."[122] Most would have attended school prior to issuance of the first National Council of Mathematics Teachers (NCTM) standards in 1989 and 1991, and thus have not seen math instruction modeled to reflect the progressive nature of the NCTM standards.

Partly because elementary education teacher candidates must prepare to teach a variety of subjects, the number of mathematics courses required of them is limited. In Tennessee, many institutions appear to require two mathematics courses for elementary education teacher candidates in addition to the one core math course usually required of students in all majors. Of these, one course may be a content course taught within an institution's Department of Mathematics and the other may be a course focused on pedagogy, or methods of classroom instruction, taught within an institution's

[120] *The Mathematical Education of Teachers,* American Mathematical Society, 2001, p.5.
[121] Survey response from a questionnaire sent to some of the state's higher education institutions regarding teacher education.
[122] RAND Mathematical Study Panel, p. 18.

Department of Education. *The Mathematical Education of Teachers* report suggests that prospective elementary grade teachers should be required to take at least nine semester-hours on fundamental ideas of elementary school mathematics, with emphasis on number, algebra, geometry, measurement, and data analysis and probability, and that such courses should "focus on a thorough development of basic mathematical ideas" rather than a "superficial coverage of many topics."[123]

In addition, Tennessee state law has different content expectations for teachers according to the level of instruction they are to provide – some early childhood teachers may not be required to take any mathematics. T.C.A. 49-5-5622 mandates that "all courses taken toward meeting the requirement for a teacher endorsement shall be selected from those courses required for an academic major in the various fields…This requirement shall not apply to standard methods courses or other courses designed especially for training elementary teachers." Therefore, the Early Childhood Education programs at the University of Memphis and East Tennessee State University do not require mathematics classes beyond the general education requirement of three hours.

Knowing that few mathematics courses are required of many prospective elementary education teachers may lead to proposed requirements for more classes. Research, however, is not clear that this is effective. One study found that taking more than four to six courses had no significant effect on student achievement.[124] "Several studies found that education coursework, including subject-specific methods courses, is useful…In another study, the researcher found that courses in undergraduate mathematics education contribute more to student gains than do courses in undergraduate mathematics."[125] Unfortunately, current research also is not conclusive about the effectiveness of the different parts of teacher pre-service (subject matter, pedagogy, and clinical experiences). Washington University's Center for the Study of Teaching and Policy and RAND Corporation have both called for more in-depth study of this issue.

In the 2004 *Master Plan for Tennessee Schools*, the State Board of Education outlines two strategies for reaching the Teacher Education goal by increasing communication between teacher preparation institutions and local schools:

- to "[p]rovide data to teacher preparation institutions on the effect of their graduates on student learning."
- to "[s]upport the efforts of higher education teacher preparation programs to follow graduates into the profession. Assess program completers' ability to transfer program knowledge and skills into successful classroom practice. Use information to improve pre-service programs."[126]

Given the lack of conclusive research on effective elements of teacher education programs, such an evaluation system has the potential to inform the structural and curricular components of pre-service preparation.

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[123] *The Mathematical Education of Teachers*, p. 8.
[124] D. H. Monk, "Subject Area Preparation of Secondary Mathematics and Science Teachers and Student Achievement," *Economics of Education Review*, 13(2), pp. 125-145.
[125] Suzanne M. Wilson, Robert E. Floden, and Joan Ferrini-Mundy, *Teacher Preparation Research: Current Knowledge, Gaps, and Recommendations*, Center for the Study of Teaching and Policy, March 2001, p. 12.
[126] State Board of Education, *Master Plan for Tennessee Schools: Meeting the Challenges of the 21st Century*, 2004, p. 9.

Teachers' professional development, including that related to teaching mathematics, varies widely across Tennessee. Research emphasizes the need for teachers to be lifelong learners. The report *The Mathematical Education of Teachers* notes that international studies, such as the Third International Math and Science Study (TIMSS) have "highlighted the importance of continuing study as an integral part of a teacher's weekly duties. Thus, college mathematics courses should be designed to prepare prospective teachers for the lifelong learning of mathematics, rather than to teach them all they will need to know in order to teach mathematics well."[127] The TIMSS study showed that in countries where students performed well in mathematics, teachers benefit from well-planned, sustained professional development opportunities embedded within the school day.

The state's funding formula for education, the Basic Education Program (BEP), does not generate monies specifically for teacher professional development, though systems can choose to use some of the funds for that purpose. Larger systems with access to greater resources, such as Memphis City and Metro Nashville, provide a variety of course offerings for teachers. Smaller, more rural systems have more difficulty consistently providing such opportunities.

According to the NCTM standards, which inform much of Tennessee's mathematics curriculum,

> Effective teaching requires continuing efforts to learn and improve. These efforts include learning about mathematics and pedagogy, benefiting from interactions with students and colleagues, and engaging in ongoing professional development and self-reflection…The work and time of teachers must be structured to allow and support professional development that will benefit them and their students.[128]

Tennessee's Mathematics Curriculum Standards acknowledge that they represent "systemic changes in mathematics education that will require extensive staff development and necessitate new forms of assessment that reflect the emphasis on higher order thinking."[129] The 2004 *Master Plan for Tennessee Schools* establishes the goal that "[t]he teaching profession will attract qualified individuals who complete strong professional preparation programs and continue to grow professionally."[130]

The State Board of Education's Professional Development Policy, which relies heavily on the National Staff Development Council (NSDC) standards, states, "[e]ducators need to update their knowledge and skills continually throughout their careers."[131] Research indicates that high-quality professional development is necessary to effect change in schools and improve instruction and that it:

- Focuses on the intersection of content and pedagogy.
- Includes opportunities for practice, research, and reflection.
- Is embedded in educators' jobs and takes place during the regular school schedule.
- Is sustained over time.
- Reflects the principles of adult learning theory in its content and format.

[127] *The Mathematical Education of Teachers*, p. 6.
[128] National Council of Teachers of Mathematics, 2000, p. 17.
[129] Tennessee State Board of Education, Mathematics Curriculum Standards, Grades 9-12, "Philosophy, History, and Process Standards."
[130] Tennessee State Board of Education, Master Plan for Tennessee Schools, 2004, p. 9.
[131] Tennessee State Board of Education, Professional Development Policy, p. 1.

- Includes and fosters elements of collegiality and collaboration among teachers and principals.[132]

Tennessee's Department of Education concentrates most of its professional development efforts on those in district and school leadership positions rather than on teachers. This is perhaps a reasonable use of resources given the state's limited funding for teacher training and the critical need to build district- and school-level capacity for long-term improvement. However, providing professional development to make administrators better instructional leaders is (at best) an indirect means of improving classroom pedagogy and is not likely to influence teachers' content knowledge. The Department employs staff dedicated to working with educators for whom Tennessee state law (T.C.A. 49-5-5703) mandates training: principals; assistant principals; supervisors or coordinators of instruction, special education, Title I, federal programs, or Education Edge; curriculum coordinators; and instructional coordinators. (Other positions may also require the training, as determined by the superintendent or director of schools.) The purpose of the training, provided through the Tennessee Academy of School Leaders (TASL), "is to provide professional development opportunities for educational leaders to continue their growth as educators who actively shape organizational cultures to promote high student performance and learning."

Although the Department provides more opportunities for school leaders, it also administers 20 teacher study councils across the state, "dedicated to professional growth among teachers." In addition, the Department organizes some professional development activities for teachers, often accessing federal funds to do so. In the summer of 2004, for example, the Department coordinated five-day professional development academies across the state for 900 7th and 8th grade middle school mathematics teachers using Title II federal funding under the NCLB "highly qualified teacher" provisions. The Department targeted training for those teachers because many had been certified under the state's K-8 license, which required less content knowledge training than NCLB now requires for 7th and 8th grade teachers.

Tennessee teachers are not alone in the lack of consistent access to quality professional development. According to the Education Commission of the States:

> …there are few, if any, states or districts that use professional development as an effective vehicle for improving teachers' ability to teach to student content standards and to work toward school and district improvement goals. Instead, teachers patch together a career-long curriculum of professional development in odd and assorted ways. Some teachers pursue any opportunity to learn with passion, while others only attend workshops when mandated to do so. Districts are just beginning to incorporate professional development into their larger school improvement strategies.[133]

According to ECS, teachers' professional development opportunities may also be affected by:

- School culture – including whether schools encourage collegiality, reflection, and collaborative problem solving.

[132] Education Commission of the States, ECS Issue Site: Teaching Quality—Professional Development—Pros and Cons, "What Does the Evidence Say?," available at www.ecs.org.
[133] Ibid.

- Time made available for professional development – outside the school workday, which is often when training is scheduled, separates the training from teachers' actual work, making it less effective.
- Ability to access providers of high-quality professional development – particularly difficult for rural and urban districts.[134]

Despite adoption of math standards that mirror the National Council of Teachers of Mathematics (NCTM) standards, researchers suggest that many teachers still teach math much as it has been taught for decades. NCTM's *Principles and Standards* recognizes that rote memorization and procedural knowledge are not enough. "In today's world students' basic arithmetic skills must include the ability to choose what numbers to use and what operation is appropriate for carrying out the computation, deciding if the results make sense, and then making a decision about what to do next. Having both computational skills and conceptual understanding will enable students to solve problems that they encounter in their daily lives."[135]

A 2001 report by the Maryland Mathematics Commission found that after that state revised its math standards to reflect the NCTM standards, instruction became more "authentic and performance based." However, the study also found that the "actual delivery of instruction varies."[136] OEA analysts did not document Tennessee teachers' approaches to teaching mathematics. However, interviews with higher education faculty, principals, and some K-12 math teachers confirm that Tennessee is much like other states – still in the process of an attempted cultural change among its math teachers.

Mathematics teachers in the United States have used quite consistent, predictable teaching methods for nearly a century. This description of mathematics classrooms in 1978 could also describe classrooms in 1954 or 2004:

> First, answers were given for the previous day's assignment. A brief explanation, sometimes none at all, was given of the new material, and problems were assigned for the next day. The remainder of the class was devoted to students working independently on the homework while the teacher moved about the room answering questions. The most noticeable thing about math classes was the repetition of this routine.[137]

NCTM acknowledges in the introductory portion of its *Principles and Standards* that the standards represent an ideal that has not yet been realized in most classrooms in the U.S. According to research from the TIMSS study, U.S. teachers are "highly aware" of the NCTM-advocated reforms and most (70 percent) claimed to be implementing those reforms.

> But this is where the good news ends. When we looked at the videos, we found little evidence of reform, at least as intended by those who had proposed the reforms. Looking at the situation as a whole, one might even argue that Japanese lessons better exemplify current U.S. reform ideas than do U.S. lessons. Japanese lessons, for example, emphasized

[134] Ibid.
[135] National Council of Teachers of Mathematics, "Answers to Frequently Asked Questions about Principles and Standards for School Mathematics," 2002, p. 3. See http://www.nctm.org/about/pdfs/mathed/pssm_faq.pdf.
[136] Maryland Mathematics Commission, *Keys to Math Success: A Report from the Maryland Mathematics Commission,* Baltimore, MD: Maryland State Department of Education, June 2001, p.30.
[137] Hiebert, p. 11.

> student thinking and problem solving, multiple solution methods, and the kinds of discourse described in U.S. reform documents to a greater extent than U.S. lessons did.[138]

TIMSS researchers concluded that U.S. teachers believed they were implementing reforms because they had changed some "surface features" in their approach to teaching by using calculators, manipulatives, group work, and writing – their basic approach to teaching math, however, did not change.[139]

The authors of NCTM's *Principles and Standards* argue that teaching using a constructivist approach is more difficult and requires far more of teachers than using the old "kill and drill" method, likely one reason some teachers cling to the old approach. Another reason may stem from the recent emphasis on high-stakes assessments, which researchers say can influence the content and instructional approach teachers select for their classes. At the extreme, some teachers may resort to "teaching to the test" in an effort to maximize student scores. Such an approach may fit in more with the traditional method of teaching mathematics – emphasizing rote learning and memorization rather than teaching for deeper understanding.

It is also possible that prospective teachers do not see a more progressive style of teaching modeled by higher education instructors in their pre-service programs. Some research suggests that teacher preparation programs themselves are "symptomatic of the educational status quo. They replicate the reliance on teacher-centered, textbook-driven, and fact-based forms of teaching."[140]

According to research, "fruitful opportunities to learn new teaching methods share several core features":

> (a) ongoing (measured in years) collaboration of teachers for purposes of planning with (b) the explicit goal of improving students' achievement of clear learning goals, (c) anchored by attention to students' thinking, the curriculum, and pedagogy, with (d) access to alternative ideas and methods and opportunities to observe these in action and to reflect on the reasons for their effectiveness.[141]

Thus, without high-quality, well-planned, consistent professional development and a work environment that encourages and schedules time for teacher collaboration, teachers may have little understanding of how to alter their teaching methods most effectively.

Some Tennessee school systems and schools employ mathematics specialists who can help teachers improve classroom instruction. Some larger and mid-size systems in the state – including Davidson County, Knox County, Oak Ridge, and Shelby County – employ one or more math coordinators, consultants, or similarly titled individuals whose time is dedicated exclusively to mathematics at the district level. Their responsibilities include curriculum alignment, improving

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[138] James W. Stigler and James Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom*, The Free Press: New York, 1999, pp. 105-106.
[139] See also David K. Cohen, "A Revolution in One Classroom: The Case of Mrs. Oublier," *Educational Evaluation and Policy Analysis*, Fall 1990, Vol. 12, No. 3, pp. 311-329.
[140] Dan W. Butin, "The Foundations of Preparing Teachers: Are Education Schools Really 'Intellectually Barren' and Ideological?," *Teachers College Record*, 2004.
[141] Hiebert, p. 15.

instructional strategies, professional development, and test data analysis. A few systems also identified specific schools that employ math specialists to facilitate math instruction.

The 2001 *Mathematical Education of Teachers* report suggests that elementary school mathematics instruction should be directed by mathematics specialists beginning in 5th grade. According to the National Council of Teachers of Mathematics (NCTM), improving the opportunities for elementary students to learn math requires the expertise of teachers with specialized knowledge. A 1989 National Research Council report recognized that:

> Expecting elementary teachers to have this specialized knowledge in mathematics, as well as every other subject they teach, simply is unrealistic…The United States is one of the few countries in the world that continues to pretend – despite substantial evidence to the contrary – that elementary school teachers are able to teach all subjects equally well. It is time that we identify a cadre of teachers with special interests in mathematics and science who would be well prepared to teach young children both mathematics and science in an integrated, discovery-based environment.[142]

The Maryland Mathematics Commission recommended developing a certification program for elementary mathematics specialists similar to the state's already-established reading specialist certificate. The report proposed that the program should be at the graduate level and include a prerequisite of three years of successful classroom teaching at the elementary level, and should include study of advanced mathematics so that specialists would understand and consider where elementary students are headed mathematically.[143]

OEA analysts identified some systems and schools in Tennessee already using math specialists in various ways. Knox County Schools, for example, employs a Supervisor of Mathematics K-12 and a Mathematics Specialist K-8, in addition to two mathematics data coaches funded through NCLB who work with teachers and principals to help them understand math testing data and how to use it to inform instruction. The Supervisor of Mathematics provides the leadership to develop, coordinate, and evaluate all phases of mathematics education in Knox County Schools; advises and assists teachers, math consultants, elementary generalists, supervisors, coordinators, and other administrative personnel with regard to mathematics content, methodology, textbooks, support materials/technology, and the initiation of desirable change; and assists in the implementation of directives and requirements coming from coordinators, the superintendents, the Board of Education, and the Tennessee Department of Education.

Davidson County employs a Mathematics Coordinator who is responsible for handling math issues for grades K-12, including providing professional development for math teachers to maintain their skills and improve their content knowledge and pedagogy; implementing standards-based instruction; developing curriculum alignments; developing assessments; and supporting teachers in improving their efforts to facilitate student learning. The district also employs three math specialists, two of which are responsible for assisting middle school teachers in Title I schools with planning, classroom management, pedagogy, and content. The other is a Mathematics Mentor Specialist who travels to any requesting school to help with planning,

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[142] National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, Washington, D.C.: National Academy Press, 1989, p. 64.
[143] Maryland Mathematics Commission, pp. 36-37.

modeling lessons, and providing content or classroom management advice. All three provide staff development across the county for math teachers.

In Oak Ridge, the system employs an Elementary Math Coordinator and one elementary school employs a Math Specialist. The Math Specialist, supervised by the school principal, carries out three major areas of service: diagnosing and prescribing assistance for students having difficulties with math, providing corrective and remedial instruction to students, and consulting with the principal and teachers in matters related to the math program and students' needs.

Officials in some smaller systems, including Henry and Hamblen Counties, said that in years past they had employed math specialists, but no longer do so. An official in Rutherford County indicated that their system employs a math/science specialist whose responsibilities include: coordinating math instruction with middle school and high school coordinators, evaluating test results from state tests and recommending improvements, working with administrators to strengthen mathematics instruction at the school level via school-based or system in-service recommendations, consulting with struggling math teachers, and coordinating math initiatives with higher education. Montgomery County employs a math consulting teacher who provides staff development for teachers and works on the mathematics curriculum.

Cleveland School officials noted that "time has been spent on reading and reading issues," and the system is beginning to look closely at the math curriculum. The system is using a math consultant in elementary schools. Johnson County Schools has freed a high school math teacher to work half-days with middle school and elementary teachers to improve math instruction. Officials define the teacher's responsibilities to include helping math teachers map and align curriculum, improve teaching strategies that accommodate different learning styles, and provide staff development for math teachers.

The presence of math specialists within a school system should ensure that professional development for math teachers matches schools' and teachers' needs and that mathematics instruction receives the emphasis it deserves. Math specialists may also help some systems overcome their difficulties with accessing quality and continual professional development for math teachers.

Anecdotal evidence from Tennessee mathematics and education professors suggests the need for improved cooperation and communication among faculty who prepare future K-12 math teachers. *The Mathematical Education of Teachers* report emphasizes the need for mathematics faculty and mathematics education faculty to develop strong partnerships. Absent such a partnership, the education of mathematics teachers is unlikely to improve:

> Some aspects of mathematical knowledge for teaching…may seem to mathematicians to fall into the domain of methods courses in education. However, education faculty generally see these issues to be more appropriately addressed in mathematics courses, and so such issues often remain unaddressed in teacher preparation. This state of affairs is one of many reasons why efforts to improve the mathematical education of teachers require a partnership between faculty in mathematics and mathematics education.[144]

[144] *The Mathematical Education of Teachers,* p. 4.

The report makes two related recommendations about the cooperation among the parties involved in teacher education:

- The mathematical education of teachers should be seen as a partnership between mathematics faculty and mathematics education faculty.…The reality today is that there is considerable distrust between mathematics faculty and mathematics education faculty both within institutions and through public exchange.
- There needs to be more collaboration between mathematics faculty and school mathematics teachers.[145]

Tennessee higher education institutions are making great strides, but responses from the OEA higher education survey indicate that the degree of cooperation between the two departments varies greatly among the state's public institutions. Some described an excellent collaborative relationship; others indicated that philosophical differences about departmental responsibilities had been a source of friction. Examples follow from institutions that have developed promising practices.

The University of Memphis

Input and advice from the faculty in the Mathematics Department at the University of Memphis resulted in the inclusion of another mathematics content class within the elementary education major, Integrative Studies, designed in 1998. Collaboration on program and course design is intended to increase pre-service teachers' conceptual understanding of mathematics content. Faculty members of the two departments have collaborated on several recent grants. Each group is beginning to "trust" the other in their unique functions.

East Tennessee State University

Collaboration between the Department of Mathematics and the Department of Curriculum and Instruction in the College of Education has led to the strengthening of the mathematics requirements for elementary teachers and the mathematics content for secondary mathematics teachers.

- The Department of Mathematics has a representative serving on the Teacher Education Advisory Council.
- The chair of the Department of Mathematics serves on the Secondary Education committee in the Department of Curriculum and Instruction.
- Before revising the content of the requirements leading to secondary mathematics or elementary licensure, the Department of Curriculum and Instruction confers with the Department of Mathematics.
- The undergraduate level secondary mathematics program is housed in the Department of Mathematics and the graduate level is housed in the College of Education's Master of Arts in Teaching program.
- The Department of Mathematics has a newly hired mathematics education faculty member who will be working closely with the mathematics educators in the Department of Curriculum and Instruction.
- The faculty of the two departments have collaborated on several Improving Teacher Quality grants from the Tennessee Higher Education Commission (THEC) and have begun work on a National Science Foundation K-12 proposal.

[145] Ibid., pp. 9-10.

Middle Tennessee State University
Mathematics educators are housed in the Department of Mathematical Sciences, helping to facilitate close collaboration between the mathematicians and the mathematics educators. Courses and activities related to mathematics teacher education, which are often housed in the department of education at other universities, are housed in the Department of Mathematical Sciences. Responsibilities of the Department of Mathematical Sciences include:

- Mathematics content courses taken by the pre-service elementary teachers.
- The middle school mathematics methods course.
- The secondary school mathematics methods course.
- Supervision of student teachers (7-12 mathematics).
- The master's program for mathematics teachers with emphasis in middle or secondary grades mathematics.
- A member of the department sits on the Teacher Education Council in order to enhance communication and collaboration between the College of Education and the Department of Mathematical Sciences.

As a reciprocal service to the Department of Mathematical Sciences, the Department of Educational Leadership offers a minor in Professional Education required of mathematics majors seeking 7-12 licensure. In addition, mathematics educators in the Department of Mathematical Sciences and faculty from the College of Education have collaborated on a number of grant-funded teacher enhancement projects for in-service K-12 teachers of mathematics.

The University of Tennessee – Knoxville
A member of the College of Education faculty serves on the Mathematics Department's education committee charged with monitoring the courses aimed toward education. Members of the Mathematics Department serve on search committees for mathematics education faculty and vice versa. Any proposed changes that impact future teachers are discussed in both directions. The Mathematics Department is receptive to needs communicated by the College of Education.

Recommendations

Legislative

The General Assembly may wish to reconsider the qualifying criteria for lottery scholarships given this report's finding that some recipients require developmental instruction in mathematics. The Tennessee Higher Education Commission is collecting data on the incidence of lottery scholarship recipients taking developmental courses and expects to report on the issue in the future. Providing developmental classes for scholarship students amounts to state dollars paying for the same instruction twice: once in high school (assuming the student attended public school) and again in college.

Administrative

The Tennessee Department of Education should include annual information on each High School Report Card about the number of graduates who require developmental instruction upon entering college, when it is readily available. The Tennessee Higher Education Commission is collecting this information, which it supplied to high schools across the state for the first time in 2004. The information should also be part of the annual report cards to give parents and the general public a more complete picture of schools' success rates.

The Tennessee Department of Education should consider making closing the achievement gap one of the state's top educational priorities and developing a comprehensive, collaborative initiative to address this issue. Tennessee has significant, persistent disparities in academic achievement between white and minority students and between students of different socioeconomic status (SES). Improving the learning opportunities for these currently underserved students—and hence increasing their potential for both employment and higher education—is critical to the state's standard of living and economic welfare. The state should develop a strategic plan and an implementation plan with concrete objectives, goals, and action steps for all responsible parties.

The initiative should include long-term, meaningful collaboration among the Tennessee Department of Education, the State Board of Education, the Tennessee Higher Education Commission, higher education teacher preparation programs, and public schools. As part of the planning process, each stakeholder group should create a set of goals and associated action steps to close the achievement gap. The state should coordinate the efforts of the involved parties to ensure all aspects of the initiative are aligned and not redundant. The State Department of Education should look to North Carolina's *Closing the Gap* initiative as a model (see page 28); the North Carolina initiative may not exactly fit Tennessee's needs or available resources, but Tennessee should aim for its initiative to be similarly focused, action-oriented, and comprehensive.

The Department of Education, the State Board of Education, and perhaps Tennessee Tomorrow, along with other education-related organizations, should launch a public campaign to urge students to consider math-related careers, including teaching math, and to inform parents about the importance of math to their children's future educational and economic welfare. Advertising can be a powerful tool capable of reaching and motivating large audiences. The same techniques used to promote commercial goods and services could be used to inform and motivate the public about issues important both to individuals and society. Children and adults frequently hear the message that "it's okay to be bad at math." A well-designed, targeted public campaign could effectively challenge that notion.

The BEP Review Committee should recommend that the General Assembly include teacher professional development in the funding formula. Teachers, researchers indicate, need to be "life-long learners" to continually improve their teaching practices. Prepared only to *begin* teaching once they complete their pre-service programs, teachers, like their students, require ongoing study to add to their knowledge both about their subject matter and how to teach it. Research demonstrates a lack of content knowledge particularly among elementary educators in the subject area of mathematics. Praxis II test scores and results reveal that even some with a math major lack deep understanding of their chosen subject area. Tennessee's Department of Education cannot provide adequate training for every teacher in Tennessee and some systems are not financially well-equipped to provide or access quality training to their teachers. Teacher learning is not a luxury, but a necessity to improve Tennessee student achievement.

The Tennessee Higher Education Commission (THEC) and the State Board of Education should consider hosting a forum inviting representatives from the Department of Education and Tennessee's K-12 and higher education communities to discuss issues including:

- Improving elementary teachers' content knowledge and understanding of fundamental mathematical principles, including Praxis assessments used for teacher licensure.
- Providing mathematics teachers access to results-driven professional development on a continuing basis and encouraging LEAs to develop research-based mentoring programs for new mathematics teachers.
- Improving classroom instruction in mathematics.
- Narrowing the wide achievement gaps in mathematics scores on state and national assessments.
- Improving collaboration among higher education faculty who prepare future K-12 math teachers and between higher education and K-12.
- Creating a long-term task force to address the needs identified.

These issues have no easy answers – nevertheless, for student achievement in mathematics to improve and for the benefit of the state's economic future, state policymakers must face them head on. Open discussion among those closely involved with the teaching of mathematics could lead to some workable strategies.

The Department of Education should improve its dissemination of best practices and research findings about the teaching of mathematics so that all Tennessee educators can benefit from the information. The State Board of Education's Professional Development Policy states that one of the roles of state leadership is to "identify effective educational and professional development practices and provide information about them to school personnel." The Internet is one means of distributing information that all Tennessee schools can access. The Department should consider creating a web site devoted to the teaching of mathematics that could provide links to research results from reputable sources as well as links to web sites that provide useful information to math teachers. The various math-science partnerships scattered throughout Tennessee may provide useful information since they are working in the state's schools.

The State Board of Education may want to consider establishing a mathematics specialist certificate similar to the reading specialist certificate. Such positions may be difficult to fill, given the shortage of qualified mathematics teachers, but placement of individuals with such expertise could extend a system's or school's ability to provide meaningful ongoing training for teachers.

Appendix A
Excerpts from Tennessee State Board of Education's Professional Development Policy

The role of state leadership is to:

- Implement a coherent statewide professional development system that targets resources, programs, and personnel to identified needs of school systems and schools.
- Identify effective educational and professional development practices and provide information about them to school personnel.
- Allocate adequate resources to professional development and mentoring of teachers.
- Create opportunities to build learning communities across the state among educators from pre-kindergarten through higher education (P-16). Examples of this are below.

The role of the school system leadership is to:

- Allocate sufficient resources for professional development.
- Focus professional development to enhance educator knowledge of the subject content related to state curriculum standards and use of data and assessments to inform classroom practice.
- Establish a system to regularly evaluate the impact of professional development on increased teacher effectiveness and improved student learning.
- Develop partnerships with institutions of higher education to further the growth and development of pre-service and experienced teachers. Examples of this are below.

The role of the school leadership is to:

- Provide time and resources for teachers and administrators to collaborate on common goals; observe examples of good practice both within and outside the schools and school system; and reflect on their practice.
- Ensure that professional growth and development is continuous, ongoing, and job-embedded and includes follow-up and support for further learning.

The role of the individual educator is to:

- Deepen content knowledge related to the state curriculum standards in the subjects they teach and seek professional development opportunities to access additional strategies to provide effective instruction to their students.
- Reflect on their own professional practices and continually evaluate the effect their instruction has on students; use the information to modify instruction accordingly.

Appendix B
Grants and Partnerships Targeting Mathematics

Many professional development opportunities for Tennessee's K-12 mathematics teachers are funded by Tennessee Higher Education Commission (THEC) Improving Teacher Quality Grants (ITQ). Other opportunities are available through National Science Foundation (NSF) Mathematics and Science Partnerships (MSP) and miscellaneous grants.

Improving Teacher Quality Grants

Formerly known as Dwight D. Eisenhower Teacher Professional Development Grants, THEC's Improving Teacher Quality Grants operate under the NCLB legislation to increase teacher content knowledge and enhance instructional methodology. Representing "the largest federal initiative for using professional development to improve teaching and learning,"[146] ITQ grants are awarded to colleges, universities, and nonprofit institutions to develop and implement workshops for K-12 mathematics, science, and humanities teachers. THEC funds four Capacity Building Projects, designed to create "coalitions that would plan, implement, and evaluate professional development in an ongoing manner," and 15-20 general projects designed to provide "professional development opportunities aligned with the state's curriculum framework objectives."[147]

Middle Tennessee State University

Since 1992, Middle Tennessee State University's Department of Mathematical Sciences has received $600,000 from THEC through 14 Improving Teacher Quality (ITQ) grants to provide professional development for K-12 teachers of mathematics. The teacher enhancement projects resulting from two such capacity building grants in 2001-2002 ($97,000) and 2002-2003 ($125,000) provided training for approximately 500 teachers in at least 25 counties in Tennessee.

Four of the ITQ grants since 2001 have been collaborative projects between the Department of Mathematical Sciences and the Tennessee Mathematics, Science, and Technology Education Center (TMSTEC) at MTSU. Ongoing projects of the center currently include (1) coordinating the Tennessee Linking Leaders Program which brings leaders from education, industry, and government to influence the state's mathematics agenda; (2) partnership with Rutherford County Schools, Rutherford Chamber of Commerce, and the Jennings Jones Foundation to develop and deliver summer institutes for teachers on applications of mathematics and science; and (3) collaboration with other universities in the state to develop a statewide middle school mathematics contest.[148]

East Tennessee State University

Through funding from THEC's Improving Teacher Quality grants, East Tennessee State University provided professional development to 60 teachers in the summer of 2003. ETSU funded a project to work with K-8 math teachers in Unicoi County and has routinely provided

[146] Richard G. Rhoda, Executive Director, Tennessee Higher Education Commission, "Subject: Improving Teacher Quality Grants, Request for Proposals," Memorandum to Chancellors, Presidents, Deans and Faculty (Education/Arts and Sciences) of Tennessee Institutions of Higher Education and Chief Administrative Officers of Non-Profit Organizations Providing Instructional Services, July 28, 2004, p. 1.
[147] Ibid., p. 2.
[148] Information provided by the Mathematics Education Faculty in the Department of Mathematical Sciences, Middle Tennessee State University.

professional development for approximately 20 teachers through a course sponsored by Sullivan County Schools each spring. In addition, the university facilitates Appalachian Educational Laboratory sponsored workshops each year for math and science teachers. Since 2001, these workshops have served over 250 teachers, of whom approximately 70 percent are math teachers.[149]

East Tennessee

Project Math and Science Synergy (Project MaSS), the result of an NSF Urban Systemic Program grant in Hamilton County, aims to improve K-12 mathematics and science performance, provide a qualified instructor in every mathematics and science classroom, and strengthen partnerships with local higher education institutions.

First objective: student achievement. Project MaSS piloted a summer program in Algebra I for 8th graders identified as at risk for making the transition to high school. The project encourages high schools to increase the number of and enrollment in Advanced Placement courses. The project brings local community and business leaders together, through the Coalition for Mathematics and Science Excellence, to discuss how business and education communities work together to ensure that Hamilton County young people will be prepared for future careers.

Second objective: teacher quality. Most of the NSF grant funds professional development, with the goal of having a qualified instructor in each classroom. The NSF goal is 75 percent of teachers with 60+ hours of professional development within a single year. Hamilton County has reached 50 percent of teachers at this level. In addition, the project is attempting to increase the number of math credits required of education majors.

Third objective: partnerships with higher education institutions. The University of Tennessee at Chattanooga (UTC) allows district students to take the university-level math placement test in 11th grade. If students place into a developmental course, they have the 12th grade year to catch up. The Project has also increased the number of UTC faculty conducting summer institutes for math teachers.

In addition, the Hamilton County School Board has approved a "Single Path Diploma," which increases the graduation requirements for all students to a minimum of four math credits including Algebra I, Geometry, and Algebra II starting with the freshman class of SY 05. Stemming from the Single Path Diploma, career academies in Health Science, Talents Unlimited, Business and Technology, and Construction developed in the district's 15 high schools. In each academy, math and science courses are enhanced by real-life applications to capitalize on student interest and the needs of the career field.[150]

[149] Information provided by Hal Knight, Dean of the College of Education, East Tennessee State University.
[150] Information provided by Dr. Barbara Fulmer, Co-Director, and Stacey Roddy, Internal Evaluator, Project Mathematics and Science Synergy; Project MaSS Annual Report, September 1,2002-August 31, 2003; and "MaSS Objectives and Goals." See http://hcschools.org/projectmass/Project_Goals.htm.

University of Tennessee – Knoxville

The University of Tennessee – Knoxville serves as the state's Appalachian Rural Systemic Initiative (ARSI) Resource Collaborative.[151] Bringing higher education, local school districts,[152] and teachers together, the collaborative provides local professional development opportunities for communicating math, improving students' problem-solving skills, and developing specific strategies for adapting instructional materials, aligning curricula, and analyzing students' needs based on mathematics assessment results.[153]

In 2002, ARSI submitted a proposal for a National Science Foundation (NSF) Mathematics and Science Partnership (MSP) grant with the University of Kentucky as the lead institution. The resulting Appalachian Mathematics and Science Partnership (AMSP) includes school districts in Virginia, Kentucky, and Tennessee.[154]

Built on ARSI's foundation, AMSP focuses on developing higher education mathematics courses for pre-service teachers and summer institutes for in-service teachers. "In regard to teacher preparation, the nine [Institutions of Higher Education] involved in this partnership have spent a great deal of time working with K-12 agencies to gain a better understanding of 'what it is' teachers need to know, specifically in math and science."[155]

AMSP considers solid understanding of mathematics content the absolute minimum requirement for teacher expertise. The AMSP initiative in Johnson County, for example, is beginning to move teachers "beyond the curriculum framework and into the realm of adopting necessary mindsets and predisposed beliefs about how and why students learn mathematics."[156]

Through the assistance of AMSP, Johnson County has "committed to the long-term goal of making clear, precise connections for our teachers when looking at how the K-8 curriculum funnels into the three Gateway subjects at our high school. We are encouraging the concept that all of our teachers are Gateway teachers and that everything we do, especially in mathematics instruction, is interwoven with a student's completion of his K-12 career and successful graduation from high school." Kindergarten teachers in Johnson County "frequently call on the consulting teachers for assistance with lessons to ensure specific correlations to performance indicators and, ultimately, the Gateway standards."[157]

West Tennessee

The Memphis Urban Systemic Program was first funded in 1995 by the National Science Foundation to help the urban school district "develop the capacity to improve student achievement, specifically in mathematics and science."[158] The program is entering into the final year of its second five-year grant. Rather than creating a few special enrichment or remediation

[151] Resource Collaboratives are located at higher education institutions throughout the region.
[152] Campbell, Cocke, Fentress, Johnson, and Scott Counties, Oneida City, and the Alvin C. York Agricultural Institute in Fentress County participate in this six-state partnership created in 1995.
[153] Information provided by Wimberly Royster, AMSP Project Director.
[154] Anderson, Campbell, Cumberland, Grainger, Johnson, and Scott Counties, Harriman City, Oneida Special School, and the Alvin C. York Agricultural Institute in Tennessee.
[155] Information provided by Dr. David Timbs, Supervisor of Instruction, Johnson County Schools.
[156] Ibid.
[157] Ibid.
[158] Information provided by Dr. Alfred Hall, Director, Memphis Urban Systemic Program.

programs for a small portion of the student population, the program changes the way the school system delivers mathematics instruction to all students. The goal is to bring about positive changes in what is taught, how it is taught, and how student progress is assessed in order to provide graduates with a high degree of mathematical literacy.

Through the National Science Foundation, the program,

- Established district-wide curriculum and goals. The program encourages vertical alignment (i.e., teachers at each grade level know what is taught at other grade levels). School Improvement Plans for all Memphis City Schools must include the Memphis USI goals and objectives.
- Provides teacher content-specific training and workshops all year at all grade levels. Some target elementary school teachers who rarely get much content-specific instruction during their pre-service program. Average monthly attendance for the Teaching and Learning Academy, a professional development center, is 4,000 teachers (accessing all courses).
- Seeks to improve communication with the higher education community about what is expected of new teachers.
- Monitors student achievement and provides programs beyond the school year. The Program developed standardized assessments that teachers can use every six-weeks to determine where to alter their instruction. Also, prior to the test offering, students who are re-taking the Gateway can take classes each of the three Saturdays leading up to the test date.[159]
- Spreads awareness of the importance of higher level mathematics.
- Provides professional development activities related to mathematics education reform for principals in all schools.

In addition to the Memphis Urban Systemic Program, the Memphis Mathematics and Science Partnership (MMSP) at the University of Memphis serves Memphis City School teachers. The immediate goal of the MMSP is "to provide a vehicle by which to increase, by approximately 100, the number of Memphis City School Teachers 'highly qualified' – under Federal NCLB guidelines – to teach middle school science and mathematics."[160] This is done by offering graduate credit coursework that prepares the teachers to pass the relevant Praxis II exam and which can be counted towards the minimum number of graduate credit hours required for the "highly qualified" designation.

The MMSP courses "examine the fundamental concepts of mathematics with an emphasis on the conceptual understanding needed for effective teaching, and thus are ultimately aimed at improving the mathematics knowledge of Memphis City Schools students."[161] Members of the university community hope the Partnership spurs more broad-based collaboration between the department of mathematics and the department of education.

Upper Cumberland Region

The Upper Cumberland Middle Grades Mathematics Partnership consists of Putnam County Schools as the lead organization and fiscal agent, Tennessee Technological University's (TTU) Department of Mathematics and Rural Education Research and Service Consortium, and 10 small

[159] Ibid.
[160] Information provided by Dr. Donald Franceschetti, Physics Professor, University of Memphis, August 20, 2004.
[161] Ibid.

rural school districts – Bledsoe, Clay, DeKalb, Fentress, Jackson, Overton, Pickett, Van Buren, Warren and White Counties.

Educators in the Upper Cumberland region recognized that very few middle grade math teachers were "highly qualified" in math. Furthermore, most teachers had no more than the math courses minimally required for elementary licensure, and few teachers participated in math content professional development. Prior to the implementation of the Middle Grades Partnership, "only 20 teachers in the eleven counties [had] taken and passed the Middle Grades math Praxis."[162]

The driving vision of the partnership is to increase the number of teachers highly qualified for teaching math in grades 7-8, to emphasize standards-based, inquiry-oriented teaching, and to increase student achievement in mathematics. Tennessee Technological University's Rural Education Research and Service Consortium, Department of Curriculum & Instruction, and Department of Mathematics work together in providing professional development for area teachers and developing, implementing, and revising licensure programs.

Professional Development Teams in Appalachian Middle and High Schools

The Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics (ACCLAIM) offers courses and other professional development activities to assist math teachers across Appalachia. There are four ACCLAIM partnerships in Tennessee:

- Alvin C. York Institute in Jamestown, Tennessee and Tennessee Tech University
- Oneida High School in Oneida, Tennessee and The University of Tennessee at Knoxville
- T.A. Dugger Junior High school in Elizabethton, Tennessee and East Tennessee State University
- Soldiers Memorial Middle School in Tazewell, Tennessee and Walters State Community College

ACCLAIM approaches professional development of both pre-service and in-service mathematics teachers through partnerships between teacher education programs and the mathematics faculty of middle or high schools. Each resulting Mathematics Professional Development Team (PDT) includes a minimum of 80 percent of the mathematics teachers in a particular school, a group of pre-service teachers from an area teacher preparation institution, and a postsecondary faculty member.

Each team identifies the professional development and resource needs of the mathematics department as well as the professional development needs of each individual. The PDT partners craft a mathematics professional development plan to prepare pre-service and in-service mathematics faculty to meet the learning needs of diverse populations.[163]

More than 200 ACCLAIM partner schools across Kentucky, Tennessee, Virginia, West Virginia, and Ohio have implemented an assessment process known as the Mathematics Program Improvement Review (MPIR). MPIR evaluations include a one-day site visit to the school in

[162] Information provided by Dr. Sandra Koczwara, Director, Upper Cumberland Middle Grades Mathematics Partnership.

[163] Steve Henderson, "Professional Development Initiative," *Rural Mathematics Educator*, February 2003, Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics. See http://www.acclaim-math.org/docs/html_rme/rme3/02.01our_profession.html.

which an assessment team examines all aspects of the program; interviews with teachers, the school administrator, students, and parents; careful review of the school's curriculum and all related documents; and analysis of the school's mathematics assessment data. The report and recommendations are given to the school principal and serve as the basis for program reforms and professional development.[164]

[164] Ron Pelfrey, "Using the Mathematics Program Improvement Review for Planning and Evaluation," *Rural Mathematics Educator*, April 2003, Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics.

Appendix C

2002-2003 Praxis II Examinations, Institutional Pass Rates

Institution	Number with Praxis Scores	Number Passed	Number Failed	Percent Passed
Aquinas College	19	19	0	**100%**
Austin Peay State University	170	163	7	**95.88%**
Belmont University	21	20	1	**95.24%**
Bethel College	11	9	2	**81.82%**
Bryan College	14	14	0	**100%**
Carson-Newman College	95	93	2	**97.89%**
Christian Brothers University	91	83	8	**91.21%**
Crichton College	22	22	0	**100%**
Cumberland University	29	27	2	**93.1%**
David Lipscomb University	50	47	3	**94%**
East Tennessee State University	225	219	6	**97.33%**
Fisk University	2	2	0	**100%**
Free Will Baptist Bible College	14	14	0	**100%**
Freed-Hardeman University	68	68	0	**100%**
Johnson Bible College	12	12	0	**100%**
King College	13	13	0	**100%**
Lambuth University	23	22	1	**95.65%**
Lane College*	0	0	0	**0%**
Lee University	141	137	4	**97.16%**
LeMoyne-Owen College	7	7	0	**100%**
Lincoln Memorial University	69	69	0	**100%**
Martin Methodist College	19	18	1	**94.74%**
Maryville College	31	30	1	**96.77%**
Middle Tennessee State University	307	278	29	**90.55%**
Milligan College	60	58	2	**96.67%**
Peabody College of Vanderbilt University	85	84	1	**98.82%**
Rhodes College	16	16	0	**100%**
Southern Adventist University	30	30	0	**100%**
Tennessee State University	134	125	9	**93.28%**
Tennessee Technological University	244	228	16	**93.44%**
Tennessee Wesleyan College	26	25	1	**96.15%**
Trevecca Nazarene University	17	17	0	**100%**
Tusculum College	40	29	11	**72.5%**
Union University	58	58	0	**100%**
University of Memphis	368	331	37	**89.95%**
University of the South	3	3	0	**100%**
University of Tennessee – Chattanooga	176	168	8	**95.45%**
University of Tennessee – Knoxville	312	302	10	**96.79%**
University of Tennessee – Martin	131	125	6	**95.42%**
State Totals	**3153**	**2985**	**168**	**94.67%**

* No graduates with scores.

Source: State Board of Education Summary Report, "2002-2003 Teacher Education Graduates, Institutional Pass Rates, Praxis II Examinations."

ETS Summary Report for the State of Tennessee Praxis Passing Rate, 2002-2003

Praxis I – Pre-Professional Skills Test: Mathematics[165]

		Total Group	African-American	White
C-PPST: Mathematics	Total N	405	157	219
Passing Score = 173	Mean	175	172	178
	Median	176	172	179
	Number Pass	257	72	167
	Pass Rate	**63**	**46**	**76**
PPST: Mathematics	Total N	247	80	144
Passing Score = 173	Mean	174	170	176
	Median	173	170	177
	Number Pass	138	27	103
	Pass Rate	**56**	**34**	**72**

Praxis II – Content Area Endorsements

		Total Group	African-American	White
MATHEMATICS CONTENT KNOWLEDGE	Total N	143	44	91
	Mean	135	123	142
Passing Score = 136	Median	134	125	140
	Number Pass	68	12	54
	Pass Rate	**48**	**27**	**60**
MATHEMATICS PEDAGOGY	Total N	97	26	68
Passing Score = 125	Mean	132	124	136
	Median	130	125	135
	Number Pass	68	14	53
	Pass Rate	**70**	**54**	**78**
ELEMENTARY EDUCATION: CURRICULUM, INSTRUCTION, & ASSESSMENT	Total N	1134	275	780
	Mean	166	152	172
	Median	169	153	174
	Number Pass	827	121	661
Passing Score = 159	**Pass Rate**	**73**	**44**	**85**

[165] Praxis I PPST: Mathematics is one of three tests required for admission to teacher preparation programs. C-PPST and PPST are two versions of the same test – one computer, one paper and pencil.

Praxis II – Principles of Learning and Teaching[166]

Test		Total Group	African-American	Asian	Hispanic	White
PRINCIPLES OF LEARNING & TEACHING K-6 Passing Score = 155	Total N	1209	236	11	12	68
	Mean	171	160	172	165	136
	Median	173	161	177	164	135
	Number Pass	1064	161	9	10	53
	Pass Rate	**88**	**68**	**82**	**83**	**78**
PRINCIPLES OF LEARNING & TEACHING 5-9 Passing Score = 154	Total N	136	41			84
	Mean	165	153			171
	Median	168	154			175
	Number Pass	105	27			75
	Pass Rate	**77**	**51**			**89**
PRINCIPLES OF LEARNING & TEACHING 7-12 Passing Score = 159	Total N	691	136		10	512
	Mean	169	160		168	172
	Median	170	162		168	173
	Number Pass	553	76		8	445
	Pass Rate	**80**	**56**		**80**	**87**

[166] Required for endorsement in selected grade level.

Appendix D: Mathematics Permits and Waivers Issued During the 2003-04 School Year

School System	Permits	Waivers	Total Under-Qualified Math Teachers
Bedford	3	0	3
Benton	0	1	1
Bradley	1	0	1
Davidson	36	4	**40**
Dickson	1	0	1
Giles	0	1	1
Fayette	2	0	2
Franklin	1	0	1
Grainger	1	0	1
Hamilton	10	2	**12**
Hawkins	1	2	3
Haywood	1	0	1
Henderson	1	0	1
Henry	0	1	1
Hickman	1	0	1
Jackson County	0	1	1
Macon	0	2	2
Marion	0	1	1
Memphis City	29	5	**34**
Montgomery	1	0	1
Rhea	3	0	3
Robertson	1	1	2
Rutherford	0	1	1
Sumner	3	0	3
Tipton	10	1	**11**
Trousdale	1	0	1
Union	0	1	1
Van Buren	0	1	1
Warren	1	0	1
Wilson	1	0	1
State Totals	**109**	**25**	**134**

Tennessee Schools with the Highest Number of Mathematics Permits and Waivers, 2003-2004

School System	School	Total Under-Qualified Math Teachers
Davidson	Antioch High	8
Tipton	Brighton High	5
Davidson	Hunters Lane High	4

Appendix E
List of Persons Interviewed/Contacted

Dr. Beverly Anthony, Undergraduate Advisor
Department of Instruction & Curriculum Leadership
University of Memphis

Dr. Bill Austin, Professor
University of Tennessee – Martin
Department of Mathematics and Statistics

John Beam
Office of Improvement, Innovation, & Accountability
Tennessee Department of Education

Dr. Deborah Boyd, Executive Director
Office of Curriculum and Instruction
Tennessee Department of Education

Dr. Herbert Burhenn, Dean
College of Arts and Sciences
University of Tennessee – Chattanooga

Dr. Lynn Cagle, Associate Dean
College of Education, Health and Human Sciences
University of Tennessee – Knoxville

Dr. Paul Cobb
Department of Teaching and Learning
Peabody College
Vanderbilt University

Cory Curl, Director
Center for Research and Policy
Tennessee Department of Education

Dr. Taft Davis, Teacher
Nashville School of the Arts
Metro-Nashville Public Schools

Dr. Scott Eddins, Math Consultant
Tennessee Department of Education

Kim Finch, Principal
Wright Middle School

John Fine, Principal
Unaka High School
Carter County Schools

Dr. Donald Franceschetti, Professor
Department of Physics
University of Memphis

Art Fuller, Research Associate
Tennessee State Board of Education

Dr. Barbara Fulmer, Co-Director
Project Mathematics and Science Synergy

Dr. Alfred Hall, Director
Memphis Urban Systemic Program
Memphis City Schools

Dr. Mary Lee Hall, Dean
The College of Education and Behavioral Sciences
University of Tennessee – Martin

Dr. Jeanetta Jackson
College of Arts and Sciences
Department of Physics and Mathematics
Tennessee State University

Dr. W. Hal Knight, Dean
College of Education
East Tennessee State University

Dr. Sandra Koczwara, Director
Upper Cumberland Middle Grades Mathematics
Partnership

Dr. Richard Lehrer
Department of Teaching and Learning
Peabody College
Vanderbilt University

Dr. Sheryl A. Maxwell, Associate Professor of
Math Education
College of Education
University of Memphis

Dr. L. Diane Miller, Interim Associate Dean
College of Basic and Applied Sciences
Middle Tennessee State University

Martin Nash
Director of Teacher Education and Accreditation
Tennessee Department of Education

Erik Ness
Associate Director of Policy, Planning, and Research
Tennessee Higher Education Commission

Matthew Pepper, Policy Analyst
Tennessee Department of Education

Dr. Bonnie Peterson, Math Teacher
Hendersonville High School
Sumner County Schools

Stacey Roddy, Internal Evaluator
Hamilton County Schools

Dr. Wimberly C. Royster, Project Director
Appalachian Math and Science Partnership

Vance Rugaard, Director
Office of Teacher Licensing
Tennessee Department of Education

Dr. Sandra Scheik
College of Arts and Sciences
Department of Physics and Mathematics
Tennessee State University

John Scott, Assistant Commissioner for Teaching and Learning
Tennessee Department of Education

Laura Tew, Director of Stakeholder Relations
Arch Chemicals

Dr. David J. Timbs, Supervisor of Instruction
Johnson County Schools

Richard Tucker
Associate Director of Assessment and Evaluation
Tennessee Higher Education Commission

Malinda Tuttle, Program Manager
TCAP Achievement Test
Tennessee Department of Education

Pat Tyree, Curriculum Specialist and Teacher
Williamson County Schools
(also former Presidential Award Winner for Excellence in Teaching Mathematics, Grades 7-12)

Sharon Walker, Licensing Consultant
Office of Teacher Licensing
Tennessee Department of Education

Dr. Deborah Williams, Director of Secondary Education
Tennessee Department of Education

Gary Williams, Principal
Cocke County High School

Linda Woodruff, M.S.
College of Arts and Sciences
Department of Physics and Mathematics
Tennessee State University

Appendix F
Agency Responses to Report Review

STATE OF TENNESSEE
DEPARTMENT OF EDUCATION
6TH FLOOR, ANDREW JOHNSON TOWER
710 JAMES ROBERTSON PARKWAY
NASHVILLE, TN 37243-0375

PHIL BREDESEN
GOVERNOR

LANA C. SEIVERS, Ed.D.
COMMISSIONER

December 14, 2004

Ms. Ethel R. Detch, Director
Office of Education Accountability
505 Deaderick Street, Suite 1700
Nashville, TN 37243-0268

Dear Ms. Detch:

We appreciate the opportunity to review the draft report on math proficiency in Tennessee. Your staff is to be commended for the comprehensiveness of the report they have written.

At your request, below you will find the Department's response to each of the Conclusions and Recommendations that pertains to our agency.

CONCLUSIONS

OEA: Tennessee students have significantly higher achievement on state math assessments than they do on national math assessments.

TDOE: We are encouraged by the NAEP assessment results, which show that Tennessee students' math achievement has been growing over the past decade. However, we are concerned that Tennessee still lags behind the national average on this assessment. Tennessee students need a math education that will make them competitive nationally and internationally, not only for their own success but for the benefit of the state and nation as a whole. The Department will study the alignment between the Tennessee curriculum and the NAEP assessment.

OEA: Tennessee students who earned respectable grade point averages in high school often still require additional assistance in mathematics when they enter college. Many of the state's lottery scholarship recipients are likely to require a developmental class in math.

TDOE: Tennessee students should be exposed to a rigorous math curriculum in high school to prepare them for demanding college math courses. The G.P.A. doesn't reflect the rigor of the course of study.

OEA: At the elementary and high school levels, and on both state and national mathematics assessments, Tennessee has significant, persistent achievement gaps

between white students and students of color and between students of lower and higher socioeconomic status.

TDOE: We are extremely concerned about these achievement gaps and the motivation to eradicate them drives everything we do. We provide extensive professional development to teachers of English language learners and special education students. Our efforts to close achievement gaps between white and African-American and Hispanic students, and between low SES and high SES students, are also extensive. Our Urban Education Specialist focuses on fostering collaboration between urban schools, community resources, and institutions of higher education and on facilitating communication of research-based best practices on improving student achievement. Our pre-kindergarten pilot program provides economically disadvantaged children with access to the early childhood education that will give them the foundation for achievement throughout K-12. We offer Understanding Poverty workshops for district teams to learn how to train teachers in understanding economic class differences that make both teaching and learning more challenging. In 2005, our Teaching and Learning Division is focusing on family and community engagement, to engage families in student achievement regardless of economic or ethnic background, and differentiated instruction, to engage teachers in recognizing learning styles of individual students.

OEA: As U.S. students progress through school, their mathematics performance in comparison to other nations deteriorates. By 12th grade, U.S. math achievement is among the lowest of all nations participating in the TIMSS.

TDOE: Tennessee students, as well as students across the nation, should be exposed to a rigorous math curriculum in high school. All students entering high school beginning in 2005-06 will be required to complete one of the following: Algebra II, Technical Geometry, Geometry, or Integrated Math II. Currently, all students on the university path to high school graduation in Tennessee must complete Algebra I, Algebra II, and Geometry or another advanced course. Schools should also encourage students to exceed these requirements.

OEA: Educators interviewed indicated that U.S. culture dictates that it is acceptable to be "bad at math," a major obstacle to improving students' math achievement.

TDOE: One strategy schools could adopt is to establish partnerships in the community to improve students' perceptions of the value of math achievement. These partnerships could be especially effective in encouraging girls to enroll in the advanced math courses required for college and career success.

OEA: Like many other states, Tennessee does not set high expectations for potential teachers, including those who must be knowledgeable about mathematics.

TDOE: Tennessee sets high expectations for all teachers. All new middle and high school mathematics teachers may show competency in math by holding a graduate degree or undergraduate major in the field, completing academic coursework equivalent to an academic major, holding other advanced certification such as that offered by the National Board of Professional Teaching Standards, or by passing the Praxis test. The Praxis cut scores are determined regularly by an independent panel which evaluates Tennessee results over multiple years. As the report indicates, given these cut scores, Tennessee had a 48% pass rate in 2003.

A large number of potential teachers are not given the opportunity to teach in Tennessee based on their performance on the Praxis exam.

OEA: The pipeline producing new math-knowledgeable teachers is inadequate.

TDOE: Students interested in and people who work in math-related careers have many attractive career paths to consider, including business, law, engineering, information technology, medicine, pharmaceuticals, and others, in addition to education. Many of these people would value the opportunity to spread their enthusiasm for math to young people. Our Teach Tennessee initiative is designed to recruit such individuals to the teaching profession.

OEA: Research indicates that many elementary teachers lack deep understanding of the fundamental principles underlying school mathematics, which in turn disadvantages their students.

TDOE: It may be beneficial to require prospective elementary teachers to complete more math courses. However, as the report indicates, research is inconclusive about whether this is a successful strategy for enhancing elementary teachers' understanding of mathematics.

OEA: Teachers' professional development, including that related to teaching mathematics, varies widely across Tennessee. Research emphasizes the need for teachers to be lifelong learners.

TDOE: It is absolutely essential for teachers to obtain professional development throughout their careers. We appreciate the report's support of our efforts in this area, such as our professional development for school instructional leaders and our "highly qualified" institutes for teachers.

OEA: Despite adopting the math standards that mirror the National Council of Teachers of Mathematics (NCTM) standards, researchers suggest that many teachers still teach math much as it has been taught for decades.

TDOE: We provide continuous professional development to encourage systemic change in the way teachers address math skills and problem solving.

OEA: Some Tennessee school systems and schools employ mathematics specialists that teachers can access to help them improve classroom instruction.

TDOE: The fiscal impact of employing mathematics specialists in districts across the state would be significant, but there are other strategies districts may pursue in focusing on math improvement. Many smaller districts employ a supervisor of instruction who may focus on improving specific areas of the curriculum as necessary. Another strategy would be for districts to allow certified math teachers some release time to assist math instruction throughout a school.

OEA: Anecdotal evidence from Tennessee mathematics and education professors suggests the need for improved cooperation and communication among faculty who prepare future K-12 math teachers.

TDOE: Education faculty could create meaningful partnerships with faculty from engineering, business and economics, and the sciences to enhance math education preparation programs. P-16 Councils across the state aim to facilitate such partnerships.

RECOMMENDATIONS

OEA: The Tennessee Department of Education should include annually on each High School Report Card information about the number of graduates who require developmental instruction upon entering college, when it is readily available.

TDOE: We will explore the possibility of including this information from the Tennessee Higher Education Commission on the report card.

OEA: The Tennessee Department of Education should consider making closing the achievement gap one of the state's top educational priorities and developing a comprehensive, collaborative initiative to address this issue.

TDOE: The Department's top priority is to improve achievement of all students, especially students with disabilities, English language learners, and economically disadvantaged students. We offer extensive professional development for special education teachers and teachers of English language learners. Our Teaching and Learning division has dedicated the next year to encouraging differentiated instruction and family engagement to improve educational outcomes among economically disadvantaged students and minority students. The Department's Urban Education Specialist is also dedicated to this goal, bringing together leaders from the state's urban school districts to share best practices. The state's pilot pre-kindergarten program provides economically disadvantaged four year-olds with the educational foundation necessary for achievement in school.

OEA: The Department of Education, the State Board of Education, and perhaps Tennessee Tomorrow, along with other education-related organizations, should launch a public campaign to urge students to consider math-related careers, including teaching math, and to inform parents about the importance of math to their children's future educational and economic welfare.

TDOE: We encourage schools to create meaningful partnerships in their communities to make math studies and math careers compelling to young people and their families. As a Department we would certainly collaborate with any organizations in an effort to make such partnerships possible. Schools could also spark an interest in the math teaching profession by identifying students who are strong in math and encouraging them to tutor or mentor other students.

OEA: The Department of Education should improve dissemination of best practices and research findings about the teaching of mathematics so that all Tennessee educators can benefit from the information.

TDOE: We are currently developing a website to share promising strategies and research findings on a number of education issues, paralleling our urban initiative to facilitate communication of research-based best practices.

Again, thank you for your office's work in compiling this report. We hope that this research and the conversation it generates will contribute to our efforts of improving mathematics education and achievement in Tennessee.

Sincerely,

Lana C. Seivers

DR. GARY L. NIXON
EXECUTIVE DIRECTOR

PHIL BREDESEN
GOVERNOR

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STATE BOARD OF EDUCATION
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January 5, 2005

Ms. Ethel Detch
Offices of Research and Education Accountability
Suite 1700, James K. Polk Building
505 Deaderick Street
Nashville, TN 37243-0268

Dear Ms. Detch:

We have reviewed the draft report on math proficiency in Tennessee. The State Board of Education endorses the conclusions and recommendations of the Office of the Comptroller. In particular, the BEP Review Committee identified in its 2004 report the need for funding for quality professional development.

On the issue of a mathematics specialist, local education agencies should be encouraged to employ an outstanding teacher to train and assist other math teachers who need help with instructional strategies. Sustained research-based professional development is needed to improve content knowledge.

Thank you for the opportunity to review this draft report. We look forward to continuing to work with your office in the future.

Sincerely,

Gary L. Nixon, Ed.D.
Executive Director

GLN/pc

RICHARD G. RHODA
Executive Director

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PHIL BREDESEN
Governor

December 22, 2004

Ms. Ethel Detch, Director
Offices of Research and Education Accountability
Comptroller of the Treasury
Suite 1700, James K. Polk Building
505 Deaderick Street
Nashville, TN 37243-0268

Dear Ms. Detch,

Thank you for providing our office with the opportunity to comment on the report your office prepared on math proficiency. The Commission commends your office on this comprehensive analysis of math proficiency in Tennessee. The implications of your report highlight the importance of P-16 collaboration on math education.

The Commission concurs with the conclusions that pertain to the higher education community. The conclusions listed below are familiar concerns to the higher education community and are currently being addressed through the statewide and local P-16 Councils. Additionally, the forthcoming *2005-2010 Master Plan for Tennessee Higher Education* will set goals and benchmarks to gauge improvement in teacher education.

Like many other states, Tennessee does not set high expectations for potential teachers, including those who must be knowledgeable about mathematics.

The pipeline producing new math-knowledgeable teachers is inadequate.

Research indicates that many elementary teachers lack deep understanding of fundamental principals underlying school mathematics, which in turn disadvantages their students.

Anecdotal evidence from Tennessee mathematics and education professors suggests the need for improved cooperation and communication among faculty who prepare future K-12 math teachers.

With regard to the recommendations in your report, the Commission concurs and offers the following comments for the two recommendations related to the higher education community.

Legislative Recommendation – The General Assembly may wish to reconsider the qualifying criteria for lottery scholarships given this report's finding that some recipients require developmental instruction in mathematics.

Our office will be conducting analysis on lottery scholarship recipients taking remedial and developmental courses. Due to the increased ACT requirement from 19 to 21, fewer recipients should require these courses beginning next fall.

Administrative Recommendation – The Tennessee Higher Education Commission (THEC) should consider hosting a forum inviting representatives from Tennessee's K-12 and higher education communities to discuss [issues addressed in the math proficiency report].

Similar discussions are already taking place in the statewide P-16 Council, specifically in the Teacher Education sub-committee of the Council. We will continue to work with P-16 Councils and perhaps co-host the recommended forum with the statewide P-16 Council.

Again, the Commission appreciates the opportunity to review and comment on this report and commends your office for its diligence. We look forward to working with you to develop the best strategies to address the challenges facing mathematics teacher education in Tennessee.

Sincerely,

Richard G. Rhoda
Executive Director

Offices of Research and Education Accountability Staff

Director
◆Ethel Detch

Assistant Director (Research)
Douglas Wright

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◆Phillip Doss

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◆indicates staff who assisted with this project