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ABSTRACT

This paper uses data from the 1990 National Assessment of Educational Progress (NAEP) Trial State Assessment to describe educational opportunities for students in eighth-grade mathematics in 1990. The first section of the paper summarizes the methodology used here and in the 1990 NAEP Trial State Assessment. The second section summarizes findings of the study. The final section discusses implications of the findings for national educational policy and highlights a follow-up study using data from the 1992 NAEP Trial State Assessment. Overall, results showed that a majority of eighth-grade students receive mathematics instruction in traditional classrooms; are assigned to classrooms based on their ability; receive between 2.5 and 4 hours of mathematics instruction by teachers who place heavy emphasis on numbers, operations, facts, and concepts; are more likely to do problems from textbooks than to do reports or problems on mathematics; and few regularly use calculators or computers. Further, it appeared that eighth-grade mathematics teachers who have participated in at least 16 hours of in-service training in mathematics or the teaching of mathematics in the last year are more likely to report using non-traditional methods. Appendices include a listing of states participating in the 1990 NAEP Trial State Assessment and sources of supplementary data. Contains 10 references. (MKR)

CONSORTIUM FOR POLICY RESEARCH IN EDUCATION

Opportunity to Learn:

Instructional Practices in Eighth-Grade Mathematics

Data from the 1990 NAEP Trial State Assessment

Margaret E. Goertz

CPRE
The Policy Center
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Rutgers, The State University of New Jersey
University of Wisconsin-Madison
Harvard University • Stanford University
University of Michigan

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Contents

Abstract

This paper uses data from the 1990 National Assessment of Educational Progress (NAEP) Trial State Assessment to describe educational opportunities for students in eight-grade mathematics in 1990. It presents preliminary analysis of the distribution of these opportunities across the state. Specifically, the paper addresses two questions:

- What kinds of instructional practices and curricular emphases were used in different states to teacher eighth-grade math in 1990? How did these vary across states.

- How and to what extent were differences in instructional practice and curricular emphases related to state characteristics and policies, such as level of spending, demographics and socio-economic characteristics, and state curriculum and testing mandates.

The first section of the paper summarizes the methodology used in the 1990 NAEP Trial State Assessment, and in the analysis reported here. The second section contains findings of the study. The final section discusses implications of the findings for national educational policy and highlights a follow-up CPRE study using data from the 1992 NAEP Trial State Assessment.

The study found that a majority of eighth-grade students receive math instruction in traditional classrooms. They are assigned to classrooms based on their ability, they receive between 2.5 and 4 hours of mathematics instruction by teachers who place heavy emphasis on numbers and operation, facts and concepts. But teachers pay limited attention to geometry and statistics and probability. The students are more likely to do problems from textbooks than to do reports or problems on math, and few students regularly use calculators or computers.

At the state level, however, instructional practices fall into two groups: "traditional" (heavy reliance on textbooks and teaching of numbers and operations) and "non-traditional" (less reliance on textbooks, less emphasis on numbers, more use of manipulatives, small groups, reports, calculators and computers).

Further, it appears that eighth-grade math teachers that have participated in at least 16-hours of in-service training in math or the teaching of math in the last year are more likely to report using non-traditional practices. Although these patterns are based on aggregated data and simple statistical methods, this is the first study to look at relationships among instructional practices. These relationships are worth exploring further using a nation, rather than state-level, database, and at the fourth, as well as eighth-grade level.

Biography

Margaret E. Goertz is a professor in the Bloustein School of Planning and Public Policy at Rutgers University and a senior research fellow with the Consortium for Policy Research in Education. Prior to joining the Rutgers University faculty in 1993, she was a senior research scientist and Executive Director of the Education Policy Research Division of Educational Testing Service.

Goertz is a policy analyst specializing in the fields of education finance and governance. She has conducted extensive research on education finance, state education reform policies, state teacher testing policies, and state and federal programs for special needs students. Her current research activities include studies of systemic reform in selected states in the United States, the implementation of New Jersey's recent school finance reform law, programs to increase the representation of racial and ethnic minorities in the teaching force, and the allocation of resources under Chapter 1, the federal government's program for educationally disadvantaged students. While at Educational Testing Service, Goertz assisted the National Assessment of Education Progress in the design of their teacher and school background questionnaires.

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This study benefited from the contributions of many people. Fred Cline of Educational Testing Service patiently and expertly created databases, defined variables and programmed analyses. Susan Fuhrman of Rutgers University, Allan Odden of the University of Wisconsin-Madison, Paul Barton and Richard Coley of Educational Testing Service, and Marshall Smith of the United States Department of Education provided thoughtful reviews of this work. The author, of course, remains responsible for any errors of fact or interpretation.

Introduction

Since the mid-1980s, state and local policymakers have taken steps to strengthen elementary and secondary curriculum, particularly in the areas of mathematics and science. State legislators and boards of education have increased coursework requirements for high school graduation, developed curriculum standards for K-12 education focusing on conceptual understanding rather than basic skills, sought greater rigor in textbooks and student outcomes, and aligned statewide assessment programs with the more ambitious curriculum standards. Professional organizations such as the National Council of Teachers of Mathematics established standards for a sound curriculum in mathematics (NCTM 1989). We know little, however, about the impact of these activities on curriculum and instructional practices in the classroom, or on student performance.

The push for higher standards, and student accountability tied to these standards, also raises an age-old concern for fairness and equity. Is it fair to tie decisions about high school graduation and entry to either the job market or post-secondary education to more rigorous tests if students don't have an opportunity to learn the new knowledge and skills that are being assessed? Do students have equal access to these opportunities or are they allocated differentially by student race/ethnicity, socio-economic status and/or community? The equity issue has also been advanced by state courts, which are beginning to define educational equity in terms of educational outcomes, rather than educational inputs, such as education expenditures per pupil. For example, the courts in Alabama. Kentucky and Massachusetts have defined the state responsibility for education to include opportunities for students to *attain* sufficient skills in different academic areas to function at a state, national and international level, to be informed citizens, to appreciate their own, and others' cultural heritage, to compete favorably with students in other states, and to live up to their full potential.

This concern for equity has led to a spirited public debate over the concepts of school delivery standards, or opportunity to learn standards. Should schools, school districts and/or states prove they have provided adequate and equal access to appropriate educational opportunities before they can hold students, teachers and schools accountable for student performance? Porter (1993) argues that school delivery/opportunity to learn standards could be used for three purposes: (1) presenting a vision of good practice for educators to aspire to; (2) providing a framework for an indicator system that describes the extent to which schools have implemented good practice; and (3) providing the basis for school accountability.

There is no consensus, however, on what should be included under the heading of school delivery standards or opportunity to learn standards. Many use the two terms interchangeably. Others distinguish the two. Porter (1993), for example, views opportunity to learn standards as a subset of school delivery standards. School delivery standards include such organizational features as school leadership, school goals, parent and community support, and district and state support. Opportunity to learn focuses more narrowly on "the enacted curriculum as experienced by the student" (Porter 1993, p. 7), features of the educational system that best predict student achievement. While Porter and others (1993) have studied the enacted curriculum in high school mathematics and science in a small sample of high schools, little data have been reported on either school delivery standards or opportunity to learn standards across schools and states.

This paper uses data from the 1990 NAEP Trial State Assessment to describe educational opportunities for students in eighth-grade mathematics in 1990, and to present preliminary analyses of the distribution of these opportunities across states. Specifically, the paper address two questions:

- What kinds of instructional practices and curricular emphases were used in different states to teach eighth-grade mathematics in 1990? How, and to what extent, did these practices and emphases vary across states?

- How, and to what extent, were differences in instructional practices and curricular emphases related to variations in state characteristics and policies, such as level of education spending, the demographic and socio-economic characteristics of states and state curriculum policies and state testing mandates?

While the variables included in the NAEP database do not provide the level of detail on curriculum and instruction reported by Porter and others (1993), they provide one set of broad indicators of the extent to which mathematics education reforms are being adopted across the country. 1990 NAEP data also provide a benchmark for tracking reform over time and for relating reform to student achievement.

This paper is divided into three sections. The first section summarizes the methodology used in the 1990 NAEP Trial State Assessment and in the analysis reported here. The second section contains the findings of the study. Section three discusses implications of the findings for national education policy and outlines a follow-up study using data from the 1992 NAEP Trial State Assessment.

Study Methodology

Since 1969, the National Assessment of Educational Progress (NAEP) has served as The Nation's Report Card, regularly collecting and reporting information on the academic knowledge, skills, and attitudes of a national sample of 9-, 13-, and 17-year-olds in a variety of subject areas. Each assessment covers several subjects, many of which are reassessed periodically to monitor trends in achievement. In 1984, NAEP began sampling students in grades 4, 8 and 12, as well as by age. NAEP undertook a voluntary Trial State Assessment in 1990, assessing eighth-grade mathematics in 37 states, two territories and the District of Columbia.[1] The assessment and questionnaire instruments were identical to those used in the 1990 NAEP national assessment of mathematics.

The 1990 NAEP mathematics assessment incorporated a new mathematics objectives framework and new assessment questions, reflecting the *Curriculum and Evaluation Standards for School Mathematics*, developed by the National Council of Teachers of Mathematics (NCTM 1989). The assessment included a broad range of questions that required students to use scientific calculators, provide responses using protractor/rulers, and solve problems in a constructed-response format. It tested five content areas (numbers and operations; measurement; geometry; data analysis, statistics and probability; and algebra and functions) and three mathematical abilities (conceptual understanding; procedural knowledge; and problem-solving). In addition, students, their teachers, and school administrators were asked to complete questionnaires about their background and instruction in mathematics. These questionnaires were designed to provide an educational context for understanding information on student achievement, to identify differences in access to instruction and distribution of services for various types of students, and to track changes in policy-relevant variables over time.

Database

The data reported in this study are drawn primarily from the 1990 NAEP Eighth Grade Mathematics Teacher Questionnaire. This questionnaire, along with those administered to students and school administrators, was developed under the guidance of an Analysis and Use Panel (AUP) composed of policymakers, policy analysts, educational researchers, and other individuals who influence policy. The AUP drafted a policy information framework that guided the process of developing and selecting items for the questionnaires as well as the analysis and reporting of these data (NAEP 1989). Questions on the mathematics teacher questionnaires were developed jointly with the NAEP Mathematics Item Development Panel and were reviewed by state directors of testing, state mathematics supervisors and the National Center for Education Statistics.

The eighth-grade mathematics teacher questionnaire consists of two parts. The first part collects information on the teachers' background, such as academic degrees held,

[1]Participating jurisdictions are listed in Appendix A.

teaching certification, training in mathematics, and availability of instructional resources. The second part requests information on each class they taught that included one or more students who were assessed. These questions cover instructional practices, such as ability grouping, time spent on mathematics instruction, and the use of textbooks, manipulatives, small group activities, and mathematics projects, coverage of mathematical topics, and the use of calculators and computers. Questions on instructional practices were designed to capture "best practice" as well as traditional teaching methods.

Data from the teacher questionnaire were supplemented with information on the characteristics of the states, selected state education policies, and characteristics of students assessed in each state. These additional data included cost-adjusted education expenditures per pupil for 1989-90, average per capita income for each state in 1989, the percent of students receiving free school lunch in each state in 1987, the existence of a state testing program in mathematics, the racial/ethnic composition of the assessed students (percent of students who are White), the number of literacy items in the students' homes (the percent of students reporting four specified reading materials in the home), and the educational achievement of the students' parents (the percent of students whose parents had a high school diploma or less).[2]

1990 Trial State Assessment Sampling

Forty jurisdictions (37 states, two territories and the District of Columbia) participated in the 1990 NAEP Trial State Assessment. A sample of 100 schools was selected in each state, with a sample of 30 students drawn from each school. Schools were stratified based on urbanicity, racial/ethnic composition, and median household income. Approximately 2,500 eighth-grade students were assessed in each jurisdiction. Because the teacher sample is based on participating students, they are not necessarily representative of all eighth-grade teachers in their state. Therefore, responses to the teacher questionnaire are reported using the student as the unit of analysis. Thus, NAEP provides information on the instruction received by a representative sample of students, rather than that provided by a representative sample of teachers (Mullis et al. 1991).

Analysis of Data

Data from the 37 participating states are included in this study. Variables from the eighth-grade mathematics teacher questionnaire were correlated with each other and with the state characteristics. A subset of teacher background and instructional practice items and student demographic variables were also regressed against the state NAEP mathematics scores.

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[2]Sources for each variable are reported in Appendix B.

Major Findings

This section describes the variation in instructional practices, resources, teacher characteristics, and course-taking in eighth-grade mathematics that are captured in the 1990 NAEP questionnaires. It groups the variables into five categories: (1) instructional practices, (2) topic coverage, (3) resources, (4) course-taking, and (5) teacher experience and training. In each category, we describe the range of variation reported across the 37 participating states and then relate this variation to the characteristics of the states and the assessed students. Where appropriate, we also compare the findings of this study to those of a much more detailed look at high school mathematics classrooms, *Reform Up Close* (Porter et al., 1993).[3] Although the latter study focuses on high school courses, it includes information on instructional practices used in basic mathematics and pre-algebra courses, courses which are also taught in the eighth grade. This section begins, however, with a description of state characteristics.

State Characteristics

Table 1 shows the mean and range of state characteristics used in this study. Cost-adjusted expenditures per pupil in 1989-90 ranged from a low of $3,499 in Idaho to a high of $6,994 in New York State, with a national average expenditure of $4,952. State average per capita income (PCI) in the participating states ranged from a low of $12,345 in West Virginia to a high of $24,683 (Connecticut), or with an average PCI of $17,596. Nearly one-quarter of the nation's students participated in the federal free school lunch program in 1987. Louisiana had the largest percentage of students receiving free school lunches in 1987—4[illegible] percent—but six other states participating in the Trial State Assessment had free school lunch percentages of 30 percent or greater. At the other end of the distribution, only 8 percent of New Hampshire's students were in this program. The racial/ethnic composition of the states' eighth-grade students also varied considerably, ranging from a low of 18 percent White students in Hawaii to a high of 94 percent in New Hampshire. Two states in addition to Hawaii—California and Texas—were majority-minority on this measure. In five states—Arizona, California, Florida, Hawaii, and New Mexico—40 percent or fewer of eighth graders reported they had four or more specified reading materials in their homes, in contrast to three states—New Hampshire, Nebraska and North Dakota—where 60 to 61 percent of the students reported this many items. The educational attainment of eighth-grade parents also differed across states. One-quarter of Idaho's eighth graders reported their parents had a high school diploma or had not completed high school. The corresponding percentage was 50 percent in West Virginia.

[3] *Reform Up Close* is a study of state, district and school policies and practices concerning high school mathematics and science instruction. A major component of this project was the collection and analysis of detailed data on the content and pedagogy of instruction in four target classes in each of 18 high schools.

Table 2 presents correlations among these state characteristics and their relationship to whether the state has a state test in mathematics and the average NAEP proficiency score in eighth-grade mathematics. There is a moderate and significant correlation between the average level of education spending in the participating states and the income of their citizens. Measures of socio-economic status clustered across the states: states with high levels of poverty (as measured by the percentage of students receiving free school lunches) had more students from homes with fewer reading materials and less well-educated parents. Low SES states also had larger minority student populations. There was no correlation between state economic and demographic characteristics and the existence of a state mathematics test, due in large part to the large number of states administering such tests (39 in 1989-90[4]). Average state performance on the eighth-grade NAEP assessment, however, is positively correlated with the level of state education spending, the socio-economic status of students in the state, and the racial/ethnic composition of the state's students.

Instructional Practices

The NAEP mathematics teacher questionnaire asked teachers of assessed students to report whether students were assigned to their classes by ability, the amount of time they spend each week on mathematics instruction with each class, and how often students in their classes do a series of activities for mathematics.

Ability grouping. Nationally, almost two-thirds of eighth graders have been assigned to their mathematics class based on some measure of their ability. At the state level, this ranges from a low of 30 percent of students in North Dakota to a high of 93 percent in Hawaii and Maryland (see Table 3). As shown in Table 5, the use of ability grouping across classes is reported more often in high-income states, states with larger minority students populations and in states with statewide mathematics tests.

Time on mathematics instruction. Teachers were asked to report how much time they spend each week on mathematics instruction. Nineteen percent of the nation's eighth graders received less than 2.5 hours of mathematics instruction in a week in 1990, while 30 percent received four or more hours of instruction. Time spent on mathematics instruction varied widely across the states. Only 11 percent of students in Connecticut and New York were in mathematics classes that met less than 2.5 hours a week, compared to nearly half of the eighth-grade students in Oklahoma. Only 9 percent of Iowa students were in mathematics classes than met more than four hours a week, compared to 57 percent in Georgia. Students in high-spending and high-wealth states were less likely to have teachers who reported teaching mathematics either 2.5 hours a week or less, or 4 hours a week or more.

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[4]Coley and Goertz (1990).

States with more low SES students were more likely to report above-average amounts of mathematics instruction, perhaps reflecting the use of extended instruction for compensatory education. This hypothesis is strengthened by the significant negative correlation between the amount of instructional time in mathematics and average NAEP scores.

Mathematics activities. Teachers of eighth-grade students were asked how often students in their classes performed a variety of activities for mathematics, such as solving mathematics problems from textbooks or on worksheets, working in small groups, working with manipulatives, taking mathematics tests, and using calculators and computers. In 1990, teachers made heavy use of problems in textbooks. Nationally, nearly two-thirds of eighth graders had teachers who assigned them problems from textbooks almost every day. This figure was 55 percent in New Hampshire, the state with the lowest reported use of textbook problems. Most eighth-grade students (85 percent) in Alabama and Wyoming were assigned problems from their textbooks on a regular basis.

Many recommendations for the reform of mathematics education advocate the use of small-group work, work with concrete materials, and problem-solving in the context of projects. For example, the *NCTM Standards* recommend that classrooms be equipped with ample supplies of manipulatives and that students work on mathematical projects and prepare reports in mathematics. In 1990, half of the country's eighth graders had teachers who reported they used small groups for mathematics at least once a week. Teachers in Colorado, Wyoming and Oregon were the most likely to use this approach; teachers in Rhode Island the least likely.

Teachers of eighth-grade mathematics were less likely to use manipulatives or to assign their students reports or projects in mathematics. About one-third of eighth-grade students in Colorado, California, Montana and Oregon had teachers who used rulers, counting blocks and geometric shapes in their classrooms. The national average was 22 percent. Forty-three percent of eighth-grade students nationally were never assigned reports or projects. This percentage rose to over 60 percent in Wyoming, Pennsylvania, Delaware and Rhode Island. Over 60 percent of eighth-grade students in North Carolina, Georgia, Kentucky, New Jersey and Virginia, however, were assigned an occasional paper or report in mathematics.

These figures are supported by findings from Porter and others (1993). They found that high school teachers in their study allocated virtually no instructional time in basic mathematics, pre-algebra or Algebra 1 classes to students' writing (zero to one percent) or to lab/field work (zero to 3 percent). Less than 10 percent of instructional time was spent on student presentations or demonstrations in these classes.

Neither calculators nor computers were a fixture in eighth-grade classrooms in most states in 1990. Nationally, only 27 percent of eighth-grade students had teachers who used calculators to teach mathematics at least several times a week. Students in New York State were the least likely to have exposure to calculators, while calculators were used the most extensively in Montana. More than half of all eighth graders were in classrooms where the computer was never used to teach mathematics. Students in Montana again had the greatest exposure to computer use in mathematics, while those in Louisiana had the least exposure. Frequent use of calculators and use of computers were positively correlated with the state NAEP score, however.

Finally, teachers were asked how often they give teacher-generated mathematics tests. Nationally, only 39 percent of eighth-grade students have teachers who test them less than once a week. Students are tested most often in Louisiana, and least often in Oregon.

At the state level, one begins to see instructional practices fall into two groups: "traditional" (heavy reliance on textbooks and little use of other activities) and "non-traditional" (less reliance on textbooks and a greater use of manipulatives, small groups, reports, calculators and computers). As shown in Table 4, for example, students in states where teachers assign mathematics problems from textbooks on a daily basis are less likely to work in small groups, work with manipulatives, write reports or do mathematics projects, or use calculators on a regular basis. Their teachers are also more likely to place a heavy emphasis on the teaching of numbers and operations (see Topic Coverage below). Students in states where teachers use small groups on a regular basis are also more likely to work with manipulatives and calculators. Their teachers place less emphasis on the teaching of numbers and operations, and test them less often. These preliminary patterns are worth exploring using a national, rather than state-level, teacher database, and at the fourth-, as well as eighth-grade level.

Four of the instructional practices are correlated with state characteristics (Table 5). The only activity related to level of spending on education is the use of computers. Teachers in high-spending states are less likely to report they do not use computers at all to teach mathematics. This relationship is not surprising, as the availability of computers in eighth-grade classrooms is also related to state spending levels. Students in states with higher concentrations of low SES students are more likely to be assigned problems from textbooks and tested more often than students in states with more advantaged student populations. Students in states with less advantaged students are also less likely to use calculators and computers on a regular basis. A small, but significant, positive correlation also exists between the existence of a state mathematics test and the frequency with which students are tested.

Topic Coverage

Eighth-grade mathematics teachers were asked to report the emphasis they placed on numbers and operations (e.g., whole number operations, common fractions, decimal fractions, ratio or proportion, and percent), measurement, geometry, data analysis, statistics and probability, and algebra. Nearly half of the nation's eighth-grade students were in mathematics classes that placed a heavy emphasis on numbers and operations (49 percent) and algebra and functions (46 percent). Less emphasis was placed on geometry and data analysis, statistics and probability. The content of eighth-grade mathematics classes varied by state. Teachers in Texas, for example, placed greater emphasis on numbers and operations, while those in Louisiana stressed the teaching of algebra.

These reports are similar to the findings of *Reform Up Close*. That study found that basic mathematics courses in high school spent more than half of their time on arithmetic, and paid little attention to geometry, statistics and probability (Porter et al. 1993). The two studies differ on emphasis on algebra, however. Only 10 percent of instructional time in high school basic mathematics courses in the *Reform Up Close* study was devoted to algebra, while algebra was given heavy emphasis in half of eighth-grade mathematics classes. There are three possible explanations for this difference. First, about 35 percent of eighth-grade students are enrolled in pre-algebra and algebra classes and the instruction they receive is averaged in with the instruction provided in basic eighth-grade mathematics classes. Second, basic eighth-grade mathematics courses, which prepare students for high school mathematics, may contain more algebra than basic mathematics classes in high school, which are more remedial in focus. Third, the *Reform Up Close* study collected much more detailed instructional information from teacher logs and questionnaires. Their definition of what constitutes algebra instruction may be much narrower than that used by teachers in the NAEP questionnaire.

Teachers in the NAEP sample were also asked how much emphasis they placed on four mathematics skills: learning mathematics facts and concepts, learning skills and procedures needed to solve routine problems, developing reasoning and analytic ability to solve unique problems, and learning how to communicate ideas in mathematics effectively. The most emphasis was placed on learning skills to solve routine problems, followed by emphasis on learning facts and concepts. Less attention was paid to learning how to communicate ideas in mathematics, although emphasis varied across the states on all four of these skill areas.

Greater emphasis was placed on numbers and operations and learning facts and concepts in low-income states and states with low student SES, while greater emphasis was placed on geometry and developing reasoning and analytic ability in high-income states. There was no correlation between the content of eighth-grade mathematics courses and the existence of a state mathematics test, with the exception of a moderate, positive relationship with learning how to communicate ideas in mathematics. States that placed a greater emphasis on the teaching of numbers and operations and facts and concepts had relatively lower NAEP scores, as did those that emphasized the development of reasoning and communication skills. States with a strong emphasis on algebra had higher proficiency scores, however.

Resources

Teachers were asked if their school system provides them with all, most, some or none of the instructional materials and other resources they need to teach their classes.

Nearly one-third of the nation's eighth-grade students have mathematics teachers who report they receive none or only some of the resources they need (Table 6). This percentage ranges from a low of 14 percent in Iowa to a high of 58 percent in Louisiana. Teachers in low-spending and low-income states, in states with low-SES students, and in states with large minority student populations were more likely to report a shortage of resources than were teachers in more advantaged states (Table 7). We also found a strong, positive correlation between state average NAEP mathematics scores and teacher reports of the sufficiency of instructional resources.

Eighth-grade mathematics teachers were also asked about the availability of calculators and computers in their schools. Fifty-six percent of eighth-grade students have access to school-owned calculators in their mathematics class, ranging from a low of 29 percent of students in Louisiana to a high of 89 percent of students in California. Only 22 percent of eighth-grade students have a computer available in their mathematics classroom; another 28 percent of students have no access to a computer for use in their mathematics class. Again, the percentages vary across states. Only 7 percent of eighth-grade students in Minnesota have no access to a computer for mathematics class, while more than half (57 percent) of students in Louisiana are without computers. Access to both calculators and computers in the school is positively related to levels of education spending, income and student SES in the states. In addition, computers are less available in states with large percentages of minority students.

Course-taking

Eighth-grade students were asked whether they were enrolled in eighth-grade mathematics, pre-algebra or algebra. Fifteen percent of the students reported they were taking algebra. This percentage ranged from a low of 8 percent in North Dakota to a high of 27 percent in Maryland. Eighth-grade students were more likely to take algebra in high-spending, high-income states. On an individual level, eighth-grade students enrolled in algebra had, on average, higher proficiency scores than those students enrolled in other mathematics courses (Mullis et al. 1991). This relationship did not hold on the state level, however. There was no correlation between the percent of students enrolled in algebra and state average mathematics proficiency scores.

Teacher Experience and Training

NAEP collected information on the training and experience of the mathematics teachers of assessed eighth-grade students. While research has been inconsistent about the relationship between years of teaching experience and degree attainment and student achievement, three variables—years of teaching mathematics, majoring in mathematics and taking a broad range of mathematics courses—are positively related to eighth-grade mathematics achievement at both the individual level (Mullis et al. 1991) and at the state level.

Eighth-grade students nationally are taught by staff who have taught mathematics an average of 14 years. Average mathematics teaching experience ranges from a low of 11 years in six states (Arizona, Arkansas, Idaho, New Mexico, Texas, and West Virginia) to 17 years in three states (Iowa, Minnesota, Wisconsin). Forty-three percent of students are taught mathematics by teachers who majored in mathematics in college. At the state level, this ranges from a low of 15 percent in Arizona to a high of 88 percent in Minnesota. As a measure of breadth of training in mathematics, NAEP reports that 52 percent of students had eighth-grade mathematics teachers who took college courses in at least six of seven mathematics content areas.[5] Again, this percentage ranged from a low of 25 percent in Kentucky to a high of 85 percent in Minnesota. Teachers who were mathematics majors were more likely to report this breadth of training than those who majored in other subjects (correlation of 0.83).

It is also important to track the amount of in-service training that mathematics teachers receive, especially given how long it has been since most teachers completed their formal education. Nearly 40 percent of students were taught by teachers who had completed 16 hours or more of in-service training in mathematics or the teaching of mathematics the previous year. Although this is not a lot of training (only two days), only 16 percent of eighth-grade students in Indiana had teachers with this level of in-service participation. At the high end, 69 percent of students in New Hampshire had teachers with this level of recent training. Although the amount of in-service training is not directly correlated with mathematics achievement, it is correlated with instructional practices when data are aggregated to the state level (see Table 4). Students who had eighth-grade mathematics teachers who received 16 or more hours of in-service education in mathematics or mathematics teaching methods were more likely to be instructed by teachers who used non-traditional instructional practices, such as small groups, manipulatives, report writing and calculators on a regular basis. They were also less likely to be assigned problems from textbooks or have a heavy emphasis placed on the teaching of numbers and operations.

The only teacher training and experience variable related to state education expenditure and state income was the number of years that teachers taught mathematics. However, the demographics of the states' students was positively related to the training and experience of their teachers. States with high percentages of students receiving free lunch and with few reading materials in the home were less likely to have teachers trained in mathematics or who had taught the subject for a long period of time. Students in states with high percentages of minority students were also less likely to be taught by well-trained teachers. There was no relationship, however, between the socio-economic characteristics of the states and the percentage of teachers who spent 16 or more hours in mathematics-related in-service training.

[5]The seven areas are number systems and numeration, geometry, probability and statistics, abstract or linear algebra, calculus, computer science, and computer programming.

Relationship of Instructional Practices and Teacher Characteristics with State NAEP Mathematics Scores

We conducted a series of multiple regressions to examine the relationship between four sets of instructional practices and teacher characteristics with state NAEP mathematics scores: (1) resources, (2) instructional practices, (3) topic coverage, and (4) teacher characteristics.

Resources. The first block included measures of resources available to eighth-grade mathematics classrooms: (1) teachers get some or none of the resources they need; (2) students have access to school calculators; and (3) computers are available for students to use. Taken together, the three variables explain 57 percent of the variance in state NAEP mathematics scores, but only the first variable is statistically significant.

Instructional practices. This block included six measures of instructional practice: (1) teachers use calculators at least several times a week; (2) students work in small groups at least once a week; (3) students are assigned to mathematics class based on ability; (4) students use computers at least once a week, (5) students do problems from textbooks almost every day; and (6) students never write reports or do mathematics projects. This block of variables explain 56 percent of the variance in state NAEP scores, but most of this is explained by the first two variables. In addition, holding the use of calculators constant, the relationship between use of small groups and tested achievement becomes negative.[6]

Topic coverage. In the third block, we regressed the emphasis placed on the five topics and four mathematics skills addressed by the NCTM standards. This block of variables explains 62 percent of the variance of NAEP state mathematics scores, with most of the variance explained by heavy emphasis on learning concepts, algebra, learning to communicate ideas, and numbers and operations.

Teacher characteristics. This block, which included (1) years of teaching mathematics, (2) percent of teachers with only an undergraduate degree, (3) percent of teachers with an undergraduate mathematics major, (4) percent of teachers certified in mathematics, and (5) percent of teachers who spent 16 hours or more on mathematics in-service in the prior year, accounted for 40 percent of the difference in state mathematics scores. Only the first two measures were statistically significant, and accounted for most of the variance.

If is difficult, however, to factor out the influence of student SES on these relationships. As we have seen, there is not only a strong correlation between the percent of low-SES students in a state and NAEP mathematics scores, but a strong correlation between

[6]The correlation between the use of small groups and mathematics achievement is small and insignificant, but is positive.

the SES of a state and many of those educational opportunities that seem to explain differences in state mathematics scores. When one can explain more than 80 percent of the variance in state NAEP scores with three student demographic variables—percent of eighth-grade students living in a two-parent family, the percent of students whose parents have formal education beyond high school, and the percent of students in a state who are White—what is left to be explained by differences in instructional practices? This is the "North Dakota phenomenon," where high NAEP scores can be explained in large part by the homogeneous and stable student population in the state.

One way to explore the explanatory power of different categories of variables is through blockwise regression analysis. The first block of variables entered in the equation was "instructional practices." As discussed above, this block accounted for 56 percent of the variance in NAEP scores across states. The second block we entered was "resources." The availability of resources to teachers and their students explains an additional 24 percent of the variance (see Table 8). Topic coverage accounts for another 9 percent of the variance, when this block of variables is entered into the regression following instructional practices and level of resources. The block of variables measuring the training and experience of teachers adds only another 2 percent to the explanation. Taken together, however, these four blocks account for 91 percent of the difference in average eighth-grade NAEP mathematics scores across the states. The student demographics block does not have much *independent* explanatory power—only 6 percent—but much of the predictive power of the other blocks is correlated with student demographics and the socio-economic characteristics of the states.

Policy Implications and Plans for the Year 2 Study

The data presented in this report can be used by policymakers for three purposes: (1) to determine the extent to which instructional practices recommended by mathematics reformers (such as the NCTM) have been enacted across the states; (2) to examine the degree to which opportunities to learn the "new mathematics" are related to economic and socio-economic characteristics of states; and (3) to track changes in eighth-grade mathematics instructional practices over time.

There are limitations, however, to the use of data aggregated at the state-level data for policy development. While the kinds of analyses presented here allow us to look generally at differences across states, this aggregation may obscure differences across schools within states. One needs to use more sophisticated statistical techniques, such as multi-level linear models, to examine variation in instructional practices *within* states and the interaction of within and across state variations. This approach would enable one to determine, for example, whether and to what extent disadvantaged students living in disadvantaged states are doubly penalized in their opportunities to learn mathematics. Hierarchical linear models could also be used in conjunction with the NAEP database to identify differences among teachers in the same school (cf., Raudenbush, Rowan and Cheong 1993). For example, the use of calculators may vary across classes within schools because of differences in course content (calculators may be used more often in advanced mathematics classes) or differences in teachers' individual practice. The National Center for Education Statistics has issued RFPs for small-scale analyses of the NAEP assessment and questionnaire data. It is hoped that some of these studies will begin to disentangle some of these multi-layered relationships.

The Enactment of New Instructional Practices in Mathematics

This study found that a majority of eighth-grade students receive mathematics instruction in traditional classrooms. They are assigned to their classrooms based on their ability, they receive between 2.5 and 4 hours of mathematics instruction a week by teachers who place heavy emphasis on numbers and operation, and facts and concepts, but pay limited attention to geometry and statistics and probability. The students are more likely to do problems from textbooks than to do reports or projects on mathematics. Few students use calculators in mathematics class on a regular basis, and more than half of the students never use a computer.

At the state level, however, one begins to see instructional practices fall into two groups: "traditional" (heavy reliance on textbooks and little use of other activities and a heavy emphasis on the teaching of number and operations) and "non-traditional" (less reliance on textbook problems, a greater use of manipulatives, small groups, reports, calculators and computers, and less emphasis on numbers and operations). In addition, it appears that eighth-grade mathematics teachers that have participated in at least 16 hours of in-service training in mathematics and/or the teaching of mathematics, in the last year are more likely to report using non-traditional instructional practices. Although these patterns are based on aggregated data and fairly simple statistical methods, this is the first study to examine relationships among instructional practices. To date, reports published using the NAEP data have focused only on the relationship of discrete instructional practices and NAEP test score data (cf., Mullis et al. 1991; CCSSO 1993). Relationships among instructional practices are worth exploring further using a national, rather than a state-level, data base, and at the fourth, as well as eighth-grade level.

Differences in Instructional Practices Across States

The 1990 NAEP Trial State Assessment shows that there is wide variation in instructional practices across the states, and that students' experiences in their classrooms are often related to the characteristics of their states. For example, students living in high-spending states are more likely to have access to calculators and computers, have teachers with adequate instructional resources, and have more experienced teachers. Students in high-spending states are also more likely to take algebra in eighth grade. Students in states with a higher proportion of disadvantaged students are less likely to have access to calculators and computers, more likely to be taught using traditional instructional practices (e.g., do problems from a textbook on a daily basis, have heavy emphasis placed on numbers and operations and facts and concepts, and be tested at least weekly), and less likely to have experienced teachers or teachers with considerable training in mathematics (e.g., an undergraduate major in mathematics and/or course work in several areas of mathematics). They are also less likely to be enrolled in algebra in eighth grade.

When groups of variables are regressed against the state NAEP proficiency score, it appears that resources available to teachers and certain instructional practices, such as use of calculators and emphasis on different mathematics topics and skills explain considerable variance in state NAEP scores. It is difficult, however, to factor out the influence of student SES on these relationships. For example, one can explain more than 80 percent of the variance in state NAEP scores with three student demographic variables: (1) percent of eighth-grade students in the state living in a two-parent family, (2) the percent of students whose parents have formal education beyond high school, and (3) the percent of students in a state who are White. This is the "North Dakota phenomenon," where high NAEP scores can be explained in large part by the homogeneous and stable student population in the state. While student demographics do not have much independent explanatory power, they are highly correlated with other blocks of factors that explain much of the variation in test scores across the states.

Tracking Changes in Instructional Practices

This study provides a baseline for tracking changes in instructional practices in eighth-grade mathematics. The *NAEP 1992 Mathematics Report Card for the Nation and States* provides detailed information on student tested achievement, but none on teacher or school policies and practices. The second phase of this project, scheduled for 1994, will examine changes in eighth-grade mathematics instructional practices and NAEP test scores between 1990 and 1992 in those states that participated in the State Trial Assessment in both years. Using data on state characteristics, we will identify the characteristics of the states that have changed the most, and the impact of these changes on equity in the opportunity to learn mathematics and tested achievement. Have instructional practices changed as teachers, schools and states respond to the NCTM standards? Has the relationship between instructional practices and state wealth, expenditures and SES lessened? What are the implications of these changes for students of different social, economic and racial backgrounds?

Table 1
Distribution of State Characteristics across the 37 Participating States

	National Average	Lowest State	Highest State
Cost-adjusted Expenditures Per Pupil, 1989-90	$4,952	$3,499 Idaho	$6,994 New York
Per Capita Income, 1989	$17,596	$12,345 West Virginia	$24,683 Connecticut
% of Students on Free School Lunch, 19°7	24%	8% New Hampshire	46% Louisiana
% of Students Who Are White, 1990	70%	18% Hawaii	94% New Hampshire
% of Students with 4 of 6 Reading Materials in the Home	48%	35% Hawaii	61% New Hampshire
% of Students Whose Parents Have High School Education or Less	35%	25% Idaho	50% West Virginia

Table 2
Correlation among State Characteristics and with Average NAEP Proficiency Score for Eighth graders

	Exp/ Pupil	**Per Capita Income**	**Free Lunch**	**% White**	**Materials in Home**	**Low Parent Education**	**State Test**	**Adj. Math Score**
Exp/Pupil	1.00	.432**	-.287	.403*	.485**	-.100	.164	.328*
Per Capita Income	.432**	1.00	-.457**	-.178	.186	-.411*	.191	.070
Free Lunch	-.287	-.457**	1.00	-.519**	-.664**	.586**	-.080	-.711**
% White	.403*	-.178	-.519**	1.00	.814**	-.134	-.158	.724**
Materials in Home	.485**	.186	-.664**	.814**	1.00	-.307	-.149	.823*
Low Parent Education	-.100	-.411*	.586**	-.134	-.307	1.00	-.129	-.630**
State Test	.164	.191	-.080	-.158	-.149	-.129	1.00	-.113
Adj. Math Score	.328*	.070	-.711**	.724**	.823*	-.630**	-.113	1.00

* Significant at .05 ** Significant at .01

Table 3
Distribution of Teacher Responses across the 37 Participating States

	National Average	Lowest State	Highest State
Use Ability Grouping	63%	30% North Dakota	93% Hawaii, Maryland
Less than 2.5 Hours of Math Instruction	19%	11% Connecticut, New York	46% Oklahoma
4.0 or More Hours of Math Instruction	30%	9% Iowa	57% Georgia
Textbook Problems Daily	62%	55% New Hampshire	85% Alabama, West Virginia
Small Groups Weekly	50%	27% Rhode Island	70% Oregon, Wyoming
Use Manipulatives	22%	11% Indiana, Pennsylvania	37% Montana
No Reports/Projects	43%	35% North Carolina	63% Rhode Island
Teachers Tests Rarely	39%	12% Louisiana	60% Oregon
Use Calculators Often	27%	6% New York	60% Montana
Never Use Computer	54%	37% Montana	81% Louisiana
Emphasis on Numbers and Operation	49%	34% Oregon	61% Texas
Emphasis on Geometry	28%	14% Idaho	40% New York
Emphasis on Data Analysis, Statistics, and Problems	14%	4% Indiana	24% Georgia
Emphasis on Algebra and Functions	46%	29% Hawaii	59% Louisiana
Emphasis on Facts and Concepts	55%	47% Minnesota	72% Kentucky
Emphasis on Problem-Solving Skills	67%	56% Montana, Oregon	75% Pennsylvania, West Virginia
Emphasis on Reasoning Ability	45%	33% North Dakota	53% Maryland
Emphasis on Communicating Ideas in Math	37%	24% Wisconsin	52% Georgia

Table 4
Correlation among Teacher Instructional Practices in Eighth-grade Mathematics

	Do Text Problems Daily	Small Groups	Use Object	Never Assign Report	Tests Rarely	Use Calculators Often	No Computer Use	Numbers and operate	16 or More Hours In-Service
Do text problems daily	1.00	-.424**	-.507**	.331*	.021	-.337*	.322	.627**	-.484**
Use small groups	-.424**	1.00	.781**	-.167	.373*	.630**	-.254	-.459**	.440**
Use objects	-.507**	.781**	1.00	-.378*	.365*	.729**	-.327*	-.566**	.541**
Never assign reports	.331*	-.167	-.378*	1.00	.256	-.0063	.266	.050	-.418*
Tests rarely	.021	.373*	.365*	.256	1.00	.567**	-.159	-.376*	-.146
Use calculators often	-.337*	.630**	.729**	-.006	.567**	1.00	-.410*	-.666**	.329*
No computer use	.322	-.254	-.327*	.266	-.159	-.410*	1.00	.499**	-.082
Numbers and operate	.627**	-.459**	-.566**	.050	-.376*	-.666**	.499**	1.00	-.378*
16 or more hours in-service	-.484**	.440**	.541**	-.418*	-.146	.329*	-.082	-.378*	1.00

* Significant at .05 ** Significant at .01

Table 5
Correlation between Teacher Instructional Practices and State Characteristics and Test Scores

	Exp/ Pupil	Per Capita Income	Free Lunch	% White	Materials in Home	Low Parent Education	State Test	Adj Math Score
Ability group	.155	.614**	-.254	-.353*	-.216	-.108	.355*	-.344
Less 2.5 hrs. math	-.384*	-.557**	.019	.159	-.139	-.068	.402*	.109
4.0 hrs. or more math	-.370*	-.362*	.415*	-.220	-.357*	.375*	.149	-.384*
Text problem	-.280	-.631**	.430**	.164	-.106	.536**	-.095	-.171
Test rarely	-.212	-.217	-.372*	.304	.158	-.423**	-.334*	.483**
High calculator use	-.139	-.036	-.499**	.483**	.473**	-.5[illegible]6**	-.201	.694**
No computer use	-.376*	-.259	.448**	-.243	-.455**	.25[illegible]	-.119	-.457**
Numbers and operate	-.301	-.465**	.642**	-.277	-.474**	.607**	.188	-.483**
Geometry	.292	.416*	.100	-.186	.102	-.157	-.035	.125
Algebra	.302	-.020	-.007	.233	.329*	-.281	.043	.377*
Facts/concepts	-.113	-.085	.452**	-.286	-.347*	.646**	254	-.516**
Reasoning	.199	.433**	.060	-.392*	-.257	-.001	.279	-.342*
Communication skills	.115	.262	.235	-.387*	-.331*	.209	.414*	-.506**

* Significant at .05   ** Significant at .01

Table 6
Distribution of Teacher Responses across the 37 Participating States

	National Average	Lowest State	Highest State
Have some or no resources	31%	14% Iowa	58% Louisiana
Access to calculators	56%	29% Louisiana	89% Connecticut
No access to computers	28%	7% Minnesota	57% Louisiana
Take algebra in 8th grade	15%	8% North Dakota	27% Maryland
Years teaching math	14	11 Arizona, Arkansas, Idaho, New Mexico, Texas, West Virginia	17 Iowa, Minnesota, Wisconsin
Have math certification	84%	41% Arizona	98% Minnesota
Undergrad major in math	43%	15% Arizona	88% Minnesota
Number of math areas covered	52%	25% Kentucky	85% Minnesota
16 or more hours in-service in math in last year	39%	16% Indiana	69% New Hampshire

Table 7
Correlation between Resources and Teacher Characteristics and State Characteristics and Test Scores

	Exp/Pupil	Per Capita Income	Free Lunch	% White	Materials in Home	Low Parent Education	State Test	Adj Math Score
Some or no resources	-.437**	-.375*	.695**	-.434**	-.608**	.512**	.066	-.691**
Access to calculators	.327*	.484**	-.499**	-.029	.113	-.339*	.265	.178
No access to computers	-.343*	-.329*	.676**	-.342*	-.565**	.437**	-.037	-.599**
Take algebra	.446**	.423**	-.365*	.060	.145	-.114	.283	-.031
Years teach math	.499**	.439**	-.450**	.342*	.587**	-.288	-.064	.508**
Math certification	.448*	-.122	-.090	.407*	.373*	.199	.146	.235
Math major	.038	-.063	-.367*	.393*	.522**	-.086	-.248	.455**
# Math areas	.115	.030	-.523**	.391	.554**	-.375*	-.124	.568**
16 or more hrs in-service	.023	.229	-.225	.018	.068	-.207	.030	.018

* Significant at .05 ** Significant at .01

Table 8
Predictors of Average State NAEP Scores, 8th Grade Mathematics

Block	R^2
Block 1: Instructional Practices	0.56
Block 2: Resources	0.80
Block 3: Topic Coverage	0.89
Block 4: Teacher Characteristics	0.91
Block 5: Student Demographics	0.97
ONLY Student Demographics	0.81

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Appendix A

States Participating in the 1990 NAEP Trial State Assessment

Alabama
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Florida
Georgia
Hawaii
Idaho
Illinois
Indiana
Iowa
Kentucky
Louisiana
Maryland
Michigan
Minnesota
Montana
Nebraska
New Hampshire
New Jersey
New Mexico
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
Texas
Virginia
West Virginia
Wisconsin
Wyoming

Appendix B

Sources of Supplementary Data

1. Cost-adjusted education expenditures per pupil for 1989-90: Total current expenditures for public elementary and secondary day schools per pupil in average daily attendance, from National Education Association, Estimates of School Statistics, 1990-91, adjusted by a cost index reported in Nelson (1991). Adjusted figures are taken from Barton, Coley and Goertz (1991).

2. Average per capita income for each state in 1989: U. S. Department of Commerce Bureau of Economic Analysis, *Commerce News*, August 1990, as reported in Mullis, Dossey, Owen and Phillips (1991), Table A.4.

3. Percent of students receiving free school lunch in each state in 1987. Calculated from data provided by U.S. Department of Agriculture, Food and Nutrition Service, 1987, and *Statistical Abstract of the United States: 1987*, as reported in Mullis, Dossey, Owen and Phillips (1991), Table A.4.

4. Racial/ethnic composition of the assessed students: 1990 NAEP eighth-grade student questionnaire.

5. Number of literacy items in the students' homes: 1990 NAEP eighth-grade student questionnaire.

6. Educational achievement of the students' parents: 1990 NAEP eighth-grade student questionnaire.

7. State testing mandate: Coley and Goertz (1990).