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Assessing the Impact of *Standards*-Based Middle Grades Mathematics Curriculum Materials on Student Achievement

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This study compared the mathematics achievement of eighth graders in the first three school districts in Missouri to adopt NSF-funded *Standards*-based middle grades mathematics curriculum materials (*MATH Thematics* or *Connected Mathematics Project)* with students who had similar prior mathematics achievement and family income levels from other districts. Achievement was measured using the mathematics portion of the Missouri Assessment Program (MAP) administered to all 8th graders in the state annually beginning in the spring of 1997. Significant differences in achievement were identified between students using *Standards*-based curriculum materials for at least 2 years and students from comparison districts using other curriculum materials. All of the significant differences reflected higher achievement of students using *Standards*-based materials. Students in each of the three districts using *Standards*-based materials scored higher in two content areas (data analysis and algebra), and these differences were significant.

Key Words: Achievement; Curriculum; Middle grades, 6–8; Reform in mathematics education

Concerns about the mathematics achievement of U. S. youth are commonplace and based on evidence from a variety of national and international studies (Beaton et al., 1997; Kilpatrick, 1992, 1997; National Research Council, 1989, 1998; Schmidt, McKnight, & Raizen, 1997; Wu, 1997). General agreement is found that the quality of school mathematics programs must improve to afford all students opportunities to succeed in mathematics. Strengthening and clearly articulating *mathematics curriculum standards* for the K–12 school years and producing *curriculum*

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materials to guide teachers and students are major efforts that are under way to improve school mathematics programs and student learning outcomes.

In this article, we use the term *mathematics curriculum standards* to refer to the set of learning goals articulated across grades that outline the intended mathematics content and process goals at particular points in time (e.g., grades or grade bands) throughout the K–12 school mathematics program. School leaders, textbook authors, assessment developers, and ultimately classroom teachers use curriculum standards as they design products or organize mathematics instruction for students. The National Council of Teachers of Mathematics (NCTM) has provided a set of mathematics curriculum Standards (NCTM, 1989, 2000).

Curriculum materials (e.g., textbooks) provide guidance and structure to teachers as they enact the intended school mathematics curriculum. Research has documented a strong influence of textbooks on the mathematics content that is taught and learned (Driscoll, 1980; Porter, 1989; Robitalle & Travers, 1992; Schmidt, McKnight, & Raizen, 1997; Schmidt et al., 2001). If mathematical content is not included in curriculum materials, then teachers are unlikely to present the content. Likewise, the instructional approach suggested by the materials often influences teachers' pedagogical strategies. Indeed, the implemented curriculum often closely mirrors the content and pedagogical approach presented in textbooks.

Beginning in 1990, the National Science Foundation (NSF) funded several mathematics curriculum development projects to respond to the need for curriculum materials to be more closely aligned with the NCTM's *Standards*. Curriculum development teams consisted of mathematics educators, mathematicians, and classroom teachers. The curriculum materials were extensively field-tested and revised on the basis of feedback from teachers and evidence of student learning (Senk & Thompson, 2002). Final versions of the materials were published and distributed by commercial vendors beginning in the mid 1990s (Reys, Robinson, Sconiers, & Mark, 1999). In this article, we refer to curriculum materials that are aligned with the content and pedagogical expectations articulated in the NCTM's *Standards* documents and developed with support from the NSF as "Standards-based curriculum materials." A summary of the characteristics of *Standards*-based curriculum materials can be found elsewhere (e.g., Trafton, Reys, & Wasman, 2001).

Information about the impact of *Standards*-based mathematics curriculum materials on student learning is clearly needed. This kind of research is difficult to conduct for many reasons, including gaining access to schools, documenting the fidelity of implementation of curriculum materials, gathering data over a substantial period of time, identifying appropriate comparison groups, and accessing valid measures of student performance (Hiebert, 1999; Schoenfeld, 2000; Usiskin, 1999). Despite these difficulties, two recently published studies provide evidence of the positive impact of middle grades *Standards*-based curriculum materials as well as the need to embed curriculum reform within a larger systemic effort that includes attention to professional development of teachers.

Riordan and Noyce (2001) compared the mathematics achievement of students from two groups of schools on the Massachusetts state-mandated assessment of mathematics. One group included students from every school in Massachusetts that had adopted a *Standards*-based textbook in the fourth or eighth grade for at least 2 years. The other group included students from Massachusetts schools carefully selected to match the first group on two important predictors of achievement—prior achievement and socioeconomic status. The results indicated that students using *Standards*-based curriculum materials as their primary textbook performed significantly better on the state-mandated mathematics assessment than did students in schools using traditional textbooks. The differences were consistent across various content strands, assessment problem types, and student subpopulations. Additionally, in schools that had used the materials for longer periods of time (i.e., at least 4 years), performance gains were more dramatic. Their research is consistent with other studies showing the benefits of *Standards*-based curricula to students of varying abilities, including those at the higher and lower achieving levels (Briars, 2001; Griffin, Evans, Timms, & Trowell, 2000).

The Third International Mathematics and Science Study-Repeat (TIMSS-R) study conducted in 1999 offers additional evidence of the impact of *Standards*-based middle grades mathematics curriculum materials. Two groups of students from Michigan participated in TIMSS-R. The first group, the Michigan state sample, included students from a set of schools randomly selected by TIMSS researchers. The second group included students from an "invitational" group of schools that met the following criteria: use of *Standards*-based instructional materials, a well-articulated district curriculum, the use of assessment data to inform instructional decisions, professional development to support teachers, and good communication with the community. The invitational group consisted of 21 schools representing rural, suburban, and urban environments. Although the Michigan state sample was the highest performing state group among the 12 states participating in TIMSS-R (average score of 517), the Michigan invitational group performed significantly higher than the Michigan state sample (average score of 532) indicating the positive effect of *Standards*-based reform efforts within these schools (Mullis et al., 2001).

Studies investigating the impact of elementary or secondary *Standards*-based curriculum materials report similar findings. For example, Fuson, Carroll, and Drueck (2000) found that students learning from *Everyday Mathematics* (*EM*), an elementary *Standards*-based curriculum, scored as well as or better than students studying from traditional materials on standard topics including place value and computation. In addition, the *Standards*-based group had opportunities to study a wider range of curriculum topics (e.g., geometry, fractions, algebra) typically not given much attention in traditional materials, and evidence was found that this opportunity led to increased learning. For example, the *EM* group significantly outperformed students in the National Assessment of Educational Progress sample on geometry items.

Huntley, Rasmussen, Villarubi, Sangtong, and Fey (2000) investigated the impact of the Core-Plus Mathematics Project (CPMP) curriculum materials on the growth of student understanding, skills, and problem solving in algebra. Their findings underscore the need to clearly articulate desired learning outcomes because different types of curriculum materials tend to focus on different priorities. On the one hand, researchers found that *Standards*-based curriculum materials supported the development of the ability to solve algebraic problems within applied contexts when students used graphing calculators. On the other hand, students using conventional algebra curricula were more successful in manipulating symbolic expressions when those expressions were presented free of context and without the aid of graphing calculators.

The study reported here examined the mathematics achievement of eighth-grade students in the first three school districts in Missouri to adopt a *Standards*-based middle grades textbook series. Eighth graders were the focus of this investigation because they were the only group of middle grades students who participated in the state-mandated Missouri Assessment Program (MAP) mathematics exam. Thus, a common measure of mathematics achievement was available for all eighth graders in Missouri. The research was organized to explore the following question: How does the achievement of eighth-grade students who have used *Standards*-based mathematics curriculum materials for at least 2 years (in Grades 6 and 7) compare with that of students using other curriculum materials as measured by the state-mandated mathematics MAP test?

METHODOLOGY

The study was designed to compare the mathematics achievement of students who had studied mathematics using *Standards*-based curriculum materials for at least 2 years (Grades 6 and 7) with the achievement of students who had not used *Standards*-based curriculum materials. Mathematics achievement at the district level prior to implementation of *Standards*-based curriculum materials and the percent of students eligible for free/reduced lunch were the primary factors used to match districts. The measure of mathematics achievement used was the state-mandated MAP mathematics exam.

Participating School Districts

The three districts using *Standards*-based curriculum materials adopted these textbooks and began using them in Grade 6 and 7 in fall 1996. Two districts (one suburban and one small city) implemented *MATH Thematics* (*MT*) (Billstein & Williamson, 1998) and one district (suburban) implemented the *Connected Mathematics* project (CMP) (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1997). In the 1st year of implementation, the *MT* districts used prepublication materials, then purchased the published versions when they became available the following school year.

For the purposes of this study, three districts were selected to serve as comparison districts. Because prior student achievement and socioeconomic level are recognized as strong predictors of student achievement in mathematics (e.g., Riodan & Noyce, 2001), these two variables were taken into account in selecting the comparison districts. In addition, because each of the *Standards*-based school districts used a Grade 6–8 building configuration, this condition was included as a criterion for identifying comparison districts. We did so primarily to insure the integrity of the sixth-grade cohort. In districts where sixth graders are part of an elementary building configuration (i.e., K–6 or K–8) more variation tends to occur in curriculum materials used for mathematics, given multiple "feeder" elementary school buildings. Finally, we restricted the comparison districts to the same general geographic region, in part as another means of drawing from common population clusters. Therefore, the comparison districts were selected on the basis of the following variables: Grade 6–8 middle school organizational structure; geographical location (i.e., close proximity to their *Standards*-based comparison district); percent of students eligible for free/reduced lunch; and a history of comparable mathematics achievement in Grade 8.

The MAP mathematics assessment was used as the baseline measure of student achievement for identifying comparison districts. We examined eighth-grade achievement data in spring 1997, the last year before students used *Standards*-based curriculum materials. Although the *Standards*-based school districts began using the curriculum in 1996, none of the eighth graders in spring 1997 had used these new materials.

The Missouri district profile database was used to locate districts comparable on the identified variables to the *Standards*-based districts. In all cases, only one or two districts matched closely each of the *Standards*-based districts. When more than one close match existed, we chose the district that was biased in favor of the comparison district (lower free/reduced lunch percentage and/or higher district MAP scores) to ensure that no advantage would be given to the *Standards*-based district.

The comparison districts used a variety of mathematics textbooks in Grades 6 through 8, but through spring 1999 none used a *Standards*-based middle grades mathematics textbook series. Appendix A provides a summary of the demographics of each district, including the mathematics course organization and curriculum materials used in Grades 6, 7, and 8.

Comparison 1. One of the *MT* (*MATH Thematics*) districts (denoted as SB1) includes two middle schools enrolling a total of approximately 2,000 students with about 30% of these students eligible for free/reduced lunch. The district is located in a city with a population of about 36,000. All sixth and seventh graders were enrolled in a course using *MT*. In this district, 75% of eighth-grade students are typically enrolled in a prealgebra course. The remaining students are enrolled in an algebra I course. The comparison district (denoted as C1) enrolled approximately 800 students in one middle school with 24% eligible for free/reduced lunch. The district is located in a city with a population of about 20,000. In sixth grade, students were enrolled in one of two courses with approximately 20% in the accelerated course. In both seventh and eighth grade, students are typically enrolled in one of three courses designed for varying ability levels. These courses used different texts.

Comparison 2. The second district using *MT* (SB2) included two middle schools enrolling approximately 1,000 students with about 25% eligible for free/reduced lunch. The district is located in a suburb of a metropolitan area with a population of about 2 million people. All sixth and seventh graders were enrolled in a course using *MT.* In eighth grade, 50% of the students were in a course using *MT,* whereas the others were enrolled in an algebra I course. The comparison district (C2) is an adjacent suburban district. The student population for C2 was approximately 1,000 with about 20% of the students eligible for free/reduced lunch. At each grade level, two mathematics courses were offered. About 20% of the students in each class were placed in an accelerated course sequence. The remaining 80% were enrolled in a regular mathematics course.

Comparison 3. The district using CMP (Connected Mathematics Project) (denoted SB3) enrolled approximately 600 middle grades students in one building with about 13% eligible for free/reduced lunch. The district is located in a suburb of the same metropolitan area as SB2 and C2. In sixth grade, all students in the district were enrolled in a course using CMP. In seventh and eighth grades, approximately 75% of the students continued using CMP as their primary text. The other 25% of the students were enrolled in an accelerated program and used CMP as a supplement to an algebra I text. Located in a suburban community in the same large midwestern city, the comparison district (C3) had a middle school student enrollment in one building of approximately 800 students with about 11% eligible for free/reduced lunch. In Grades 6 and 7, every student was enrolled in the same mathematics course. In Grade 8, students were placed in either a prealgebra course (40%) or an algebra I course (60%).

As noted in Appendix A, none of the school districts used a single curriculum series for all students throughout the middle grades. Thus, the middle school mathematics curriculum materials used by these districts can be characterized as a hybrid curriculum. However, in the *Standards*-based districts, all sixth and seventh graders in two districts and 75% in the third and at least 50% of the eighth graders in two districts used NSF *Standards*-based curriculum materials. Consequently, *Standards*-based curricula represent a significant learning tool for middle grades students within the three *Standards*-based school districts.

Student Sample

The student sample for this study consisted of eighth-grade students from the six school districts completing the Missouri Assessment of Performance (MAP) mathematics exam in 1997 and 1999. In the two suburban districts that used NSF *Standards*-based curricula (SB2, SB3), the researchers were able to examine individual student records. From these records, the researchers identified students who had completed at least 2 years of the NSF *Standards*-based curriculum. Data from students who had recently moved into the district and had, therefore, not studied from *Standards*-based curricula were deleted from the sample. In the small city district (SB1) and the three comparison districts (C1, C2, C3), data from individual student records were not available. Instead, data on the entire eighth-grade class for each of these four districts were used in the analysis.

Teacher Professional Development and Program Implementation

A growing research base is documenting the challenges of implementing *Standards*-based mathematics curricula (Ball, 1996; Clark, 1995; Clarke, 1993; Henningsen & Stein, 1997; Lambdin & Preston, 1995; Tetley, 1998). The challenges include teaching unfamiliar content, higher cognitive expectations for students, different roles for teachers and students, and new assessment tools. These factors individually and collectively influence the manner in which mathematics curricula are implemented (Bay, Reys, & Reys, 1999). New content and new instructional and assessment techniques require increased professional development for teachers implementing *Standards*-based mathematics curricula.

Teachers using a *Standards*-based curriculum in this study had participated in professional development designed to help them understand the rationale for the changes in curriculum materials and prepare to use the materials. These teachers were among nearly 200 teachers from 23 school districts who participated in the Missouri Middle Mathematics (M^3) Project, a 3-year NSF teacher-enhancement project (1995–1998) that used the examination of *Standards*-based middle grades mathematics curricula as a vehicle for professional development (Reys & Reys, 1997). Although districts involved in the M^3 Project were not obliged to adopt a *Standards*-based curriculum, the three *Standards*-based districts in this study chose to adopt and implement either CMP or *MT*.

None of the teachers in the comparison schools participated in the M^3 Project. However, teachers in these districts were involved in professional development activities sponsored by their district and by the state department. These professional development activities were guided by the state Show-Me Standards, which were influenced by, and aligned with, the NCTM's *Standards*. For example, the Missouri Department of Elementary and Secondary Education sponsored workshops throughout the state focusing on the mandated state assessment (MAP). Because mathematics was the first discipline addressed in the state-mandated assessment, the MAP mathematics test, including its content and expectations regarding student response formats, was the focus of these workshops. In addition, summer institutes for middle school mathematics teachers were offered each year through a state-sponsored grant. These workshops focused on improving opportunities for middle grades students to develop as problem solvers. Middle school teachers from each of the comparison districts participated in these summer workshops, although the extent of the influence of these workshops on their teaching is unknown.

No visits were made to comparison schools to determine the extent and manner in which their district-adopted mathematics curriculum was used. However, conversations with school district personnel (curriculum coordinator and/or mathematics department chair) confirm that the middle school teachers in the comparison districts used the district-adopted textbook as their primary instructional guide with regard to the content emphasized and instructional approach used. Observations were made in some, although not all, of the middle grades classrooms in the *Standards*-based schools in two different studies (Bay, 1999; Wasman, 2000). These observations support that teachers were using the district-adopted *Standards*-based curricula as their primary text.

Missouri Assessment of Performance (MAP) Mathematics Exam

Missouri students in Grades 4, 8, and 10 are required to take the mathematics portion of the Missouri Assessment of Performance (MAP) exam at the end of the school year. The MAP was developed by the Missouri Department of Elementary and Secondary Education and CTB/McGraw-Hill Publishing Company to reflect Missouri's *Framework for Curriculum Development in Mathematics, K–12* (Missouri Department of Elementary and Secondary Education, 1996). The framework is designed around six content strands: number sense (including computation); geometric and spatial sense; data analysis, probability, and statistics; algebra; mathematical systems; and discrete mathematics.

The eighth-grade MAP exam in mathematics includes three sections, each administered and completed on separate days. Each of the first two sections of the exam include 8–10 open-ended items requiring student-constructed responses, and calculators are allowed. The third section consists of 31 multiple-choice items drawn from the Terra Nova assessments prepared by CTB McGraw-Hill. The recommended time frame for each of the three sections is 55 minutes. However, MAP is not intended to be a timed test, and teachers are encouraged to allow students adequate time (up to 90 minutes) to complete each of the constructed-response sections of the test. Appendix B contains a description of the content and sample items from each section of the MAP mathematics exam. Table 1 includes

Table 1
Type and Number of Items for Each Content Strand on the 1999 Eighth-Grade MAP Mathematics Exam

	Item type		Total points	Percent of total points
	Constructed response	Multiple choice		
Number Sense	6	11	25	33
Geometric and Spatial Sense	2	8	12	16
Data Analysis, Probability, and Statistics	5	6	16	21
Algebra	3	2	10	13
Mathematical Systems	2	4	8	11
Discrete Mathematics	2	0	4	6
Total	20	31	75	100

Note. Constructed response items are worth either 2 or 4 points, and multiple-choice items are worth 1 point.

information about the eighth-grade MAP mathematics exam by content strand and item type. Additional released and sample items, as well as scoring guides, are available at the Missouri Department of Elementary and Secondary Education Web site at www.dese.state.mo.us/divimprove/assess.

Reports of MAP performance include (a) achievement level, (b) a national percentile score for the Terra Nova portion of the exam, and (c) percent correct by content strand. Responses on all three sections of the exam are used to categorize each student's performance into one of five achievement levels. From the lowest possible category to the highest, these achievement levels are Step 1, Progressing, Nearing Proficiency, Proficient, and Advanced. A description of each of these levels is provided in Table 2. The Missouri Department of Elementary and Secondary Education uses the percentages of students scoring in the top two categories (Proficient and Advanced) and the bottom two categories (Step 1 and Progressing) as important indicators of success in the mandatory state school accreditation and improvement process.

Table 2
Descriptors of the Levels of Achievement on the Eighth-Grade MAP Exam

Level	Descriptor
Step 1	Students perform basic operations with whole numbers; solve simple word problems with whole numbers; identify, describe, compare, and classify geometric figures; read information from tables, graphs, and charts; recognize and extend simple numeric patterns; and order integers.
Progressing	Students perform basic operations of rational numbers; solve simple word problems using rational numbers; use protractor and ruler to measure; identify lines of symmetry; interpret information from tables, graphs, and charts; find measures of central tendency; extend pictorial patterns; solve equations using a replacement set; order rational numbers; and interpret simple Venn diagrams.
Nearing Proficiency	Students solve problems with decimals, percents; identify congruent, similar figures; find elapsed time; convert measurements; find area, perimeter, volume; find probability; use sampling procedure; find measure of central tendency; solve equations; use order of operations; find, order equivalent fractions, decimals, create tree diagrams; generalize patterns; use deductive, inductive reasoning.
Proficient	Students show processes; apply ratios, proportions, percents; use concepts of congruent, similar shapes; show rotations, reflections, translations; apply perimeter, area, volume; predict from data displays; apply measures of central tendency; describe patterns, relationships using algebraic equations; apply properties of real numbers; identify primes, multiples, factors, exponents.
Advanced	Students justify answers; use scale drawings; apply transformation in coordinate grid; compare theoretical and experimental probability; defend data predictions; recognize dependent, independent variables; describe patterns, relationships using algebraic inequalities; use diagrams, patterns, functions in problem solving; apply primes, factors, multiples, exponents; solve problems using strategies.

Data Analyses

For this study, MAP scores were analyzed in the following ways. Comparable prior mathematics achievement between each of the three pairs of districts was established using eighth-grade MAP data archived in 1997, the 1st year of required use of the MAP math exam in that grade. Students taking the 1997 Grade 8 MAP mathematics exam were the last set of eighth graders in the *Standards*-based districts who had not used the new curriculum materials. A chi-square statistic was calculated for each *Standards*-based/comparison district pair to test for possible differences in the percentages of students scoring in three MAP achievement level categories. In addition, *t* tests were used to compare the six content standards and Terra Nova scores between the three *Standards*-based districts and their comparison districts. The *t* tests between *Standards*-based and comparison districts were used on the basis of the mean standardized score for eighth graders in each district. Each standardized score represents the mean percent correct achieved by students in each district for each subtest of the MAP. MAP scores in spring 1999 provided a basis to compare the mathematics achievement of students who had used a *Standards*-based curriculum for at least 2 years with that of eighth graders who had not used such a curriculum. Using 1999 data, three chi-square statistics were computed to test for differences in student MAP achievement levels. Again using 1999 data, *t* tests were used to compare the six content standards and Terra Nova scores between the three *Standards*-based districts and their comparison districts. The *t* tests used the standardized scores reported by the MAP for individual students on the six content standards and Terra Nova.

RESULTS

Table 3 contains the chi-square analyses that compare the number of students scoring in the three MAP achievement levels prior to the use of *Standards*-based curriculum materials (in 1997). A separate chi-square was calculated for each of the three comparisons (i.e., SB1 and C1, SB2 and C2, and SB3 and C3). No statis-

Table 3
Number and Percentage of Eighth Graders Scoring in Each Achievement Level (by District) on the 1997 MAP Mathematics Exam

Comparison districts	Step 1 and Progressing	Nearing Proficiency	Proficient and Advanced	Chi-square
SB1	307 (48%)	211 (33%)	121 (19%)	
C1	124 (50%)	76 (31%)	47 (19%)	4.21 *ns*
SB2	189 (49%)	123 (32%)	73 (19%)	
C2	219 (55%)	111 (28%)	68 (17%)	2.97 *ns*
SB3	51 (34%)	53 (36%)	42 (29%)	
C3	92 (35%)	73 (28%)	97 (37%)	.46 *ns*

Note. SB1, SB2, and SB3 are the districts that implemented *Standards*-based curricula. C1, C2, and C3 are the districts being used as the comparisons for the *Standards*-based districts. *ns* represents a nonsignificant chi-square value ($p > .05$).

tically significant differences were found between any of the *Standards*-based districts and their comparison districts. Therefore, in 1997, prior to the use of *Standards*-based curriculum by these students, each pair of districts had equivalent numbers of students scoring in the different mathematics achievement categories on the MAP.

Table 4 reports *t*-test results for the 1997 Content Standards and Terra Nova scores between *Standards*-based and comparison districts. In 1997, prior to student use of *Standards*-based curriculum materials, no differences in Terra Nova scores were found between any pair of districts. The SB1 district scored significantly higher on Content Standard 3 (Data Analysis, Probability, and Statistics) ($p < .005$)

Table 4
T-Test Comparisons of Standards-Based (SB) and Comparison (C) Districts Based on 1997 MAP Content Standards and Terra Nova Scores

SB1 and C1 Districts

	SB1 (*n* = 681)		C1 (*n* = 256)	
	M	*SD*	*M*	*SD*
Number Sense	60.18	23.71	62.12	22.49
Geometric and Spatial Sense	41.57	23.43	42.29	23.61
Data Analysis, Probability, and Statistics	54.06**	21.72	48.76	21.25
Algebra	50.09	29.26	52.03	31.01
Mathematical Systems	52.73	24.99	53.44	26.02
Discrete Mathematics	54.22	27.98	56.74	31.95
Terra Nova	60.16	26.97	61.68	28.14

SB2 and C2 Districts

	SB2 (*n* = 416)		C2 (*n* = 419)	
	M	*SD*	*M*	*SD*
Number Sense	63.33	24.18	60.77	23.95
Geometric and Spatial Sense	39.75	23.33	38.19	24.46
Data Analysis, Probability, and Statistics	50.21	22.50	47.42	22.57
Algebra	46.43	29.02	46.03	31.17
Mathematical Systems	50.60	24.83	50.79	26.50
Discrete Mathematics	59.26**	32.95	50.48	31.36
Terra Nova	61.05	28.71	59.62	29.40

SB3 and C3 Districts

	SB3 (*n* = 155)		C3 (*n* = 266)	
	M	*SD*	*M*	*SD*
Number Sense	67.94	20.94	72.10*	21.75
Geometric and Spatial Sense	45.10	23.29	49.48	25.86
Data Analysis, Probability, and Statistics	58.87	20.73	60.56	21.62
Algebra	53.87	28.70	58.87	29.64
Mathematical Systems	59.68	21.64	62.07	22.97
Discrete Mathematics	65.65	31.36	67.48	30.87
Terra Nova	68.95	27.36	70.14	27.46

Note. SB1, SB2, and SB3 are the districts that implemented *Standards*-based curricula. C1, C2, and C3 are the districts being used as the comparisons for the *Standards*-based districts.
* $p < .05$. ** $p < .005$.

than its comparison district. Further, SB2 scored significantly higher on Content Standard 6 (discrete mathematics) ($p < .005$). However, the comparison district outscored SB3 on Content Standard 1 (number sense) ($p < .05$). No other differences were noted between *Standards*-based and their comparison districts. These data, in conjunction with the MAP achievement level data reported in Table 3, argue for comparable mathematics achievement between *Standards*-based and their comparison districts at the time that new curriculum materials were introduced in the *Standards*-based school districts.

Table 5 presents chi-square analyses that compare the number of students scoring in the three MAP achievement levels in spring 1999 when the eighth-grade students in three districts had been using *Standards*-based curriculum materials for at least 2 years. Separate chi-squares were calculated for each of the three comparisons (i.e., the *Standards*-based district and their comparison district). No differences were found between the SB2 and C2 districts, as well as the SB3 and C3 districts. However, a statistically significant difference ($p < .02$) was found between SB1 and C1. Results indicated that a greater number of students in the *Standards*-based (SB1) district scored in the highest achievement levels of the MAP (i.e., Proficient and Advanced), whereas a greater number of students in the comparison district C1 scored in the lowest two MAP achievement levels (i.e., Step 1 and Progressing). It is important to note that between 1997 and 1999 the state department changed the cut scores for assigning students to one of the five MAP achievement levels. Unfortunately, this change makes a direct comparison of school- district mathematics-achievement-level scores in 1997 and 1999 impossible.

Table 5
Number and Percentage of Eighth Graders Scoring in Each Achievement Level by District on the 1999 MAP Mathematics Exam

Comparison districts	Step 1 and Progressing	Nearing Proficiency	Proficient and Advanced	Chi-square
SB1	335 (49%)	240 (35%)	112 (16%)	
C1	153 (58%)	83 (32%)	27 (10%)	8.65*
SB2	189 (46%)	148 (36%)	74 (18%)	
C2	219 (51%)	140 (32%)	72 (17%)	1.98 *ns*
SB3	59 (35%)	61 (36%)	51 (30%)	
C3	96 (32%)	100 (34%)	102 (34%)	.96 *ns*

Note. SB1, SB2, and SB3 are the districts implementing *Standards*-based curricula. C1, C2, and C3 are the districts being used as the control comparisons for the *Standards*-based districts.

* $p < .02$

Table 6 reports *t*-test results for the six Content Standards and Terra Nova for SB1 and its comparison district C1 and shows that students using *Standards*-based curriculum (SB1) had statistically significant higher scores than students in C1 in the following content areas: number sense; geometric and spatial sense; data analysis, probability, and statistics; algebra; and discrete mathematics. Also,

Table 6
T-Test Comparisons of 1999 MAP Content Standard and Terra Nova Scores for SB1 and C1 Districts

	SB1 (n = 708)		C1 (n = 274)	
	M	*SD*	*M*	*SD*
Number Sense	64.55***	23.03	57.27	22.99
Geometric and Spatial Sense	49.17**	24.16	43.22	24.30
Data Analysis, Probability, and Statistics	59.27**	22.95	53.79	23.80
Algebra	69.98***	28.54	59.06	29.76
Mathematical Systems	61.52	27.45	63.54	28.44
Discrete Mathematics	45.44*	28.13	40.71	27.98
Terra Nova	63.21***	27.66	56.26	27.84

*$p < .05$. **$p < .01$. ***$p < .005$.

Standards-based students had significantly higher Terra Nova scores than nonusers in the comparison group.

Table 7 presents MAP Content Standard and Terra Nova scores for SB2 and C2 school districts. Results were similar to those reported in Table 6. For example, students using a *Standards*-based curriculum (SB2) outperformed nonusers on the same five content standards. To be more specific, SB2 students had statistically higher test scores than C2 students on Number Sense; Geometric and Spatial Sense; Data Analysis, Probability, and Statistics; Algebra; and Discrete Mathematics. Similarly, SB2 students had significantly higher Terra Nova scores than their C2 counterparts.

Table 7
T-Test Comparisons of 1999 MAP Content Standard and Terra Nova Scores for SB2 and C2 Districts

	SB2 (n = 411)		C2 (n = 440)	
	M	*SD*	*M*	*SD*
Number Sense	66.07**	21.13	62.40	25.21
Geometric and Spatial Sense	53.18*	23.38	47.91	25.55
Data Analysis, Probability, and Statistics	63.63**	20.43	56.35	23.96
Algebra	73.53**	23.62	66.46	30.19
Mathematical Systems	70.52	24.68	69.34	28.07
Discrete Mathematics	55.33**	25.43	47.88	29.65
Terra Nova	67.55**	26.46	60.30	29.84

*$p < .05$. **$p < .01$.

Table 8 shows that students using the NSF *Standards*-based curriculum (SB3) had significantly higher scores than nonusers (C3) on two of the six Content Standard scales: data analysis, probability, and statistics; and algebra. The MAP scores for both of these districts were higher than for the other districts in the study. Their exceptionally strong performance is consistent with the strong academic orientation that has traditionally characterized each district.

Table 8
T-Test Comparisons of 1999 MAP Content Standard and Terra Nova Scores for SB3 and C3 Districts

	SB3 (*n* = 171)		C2 (*n* = 298)	
	M	*SD*	*M*	*SD*
Number Sense	69.54	21.22	70.52	23.65
Geometric and Spatial Sense	60.94	25.51	57.27	25.91
Data Analysis, Probability, and Statistics	69.94*	21.52	64.44	24.92
Algebra	79.80*	23.29	74.25	26.67
Mathematical Systems	70.00	26.12	70.29	27.73
Discrete Mathematics	58.65	24.79	56.04	28.58
Terra Nova	74.96	27.57	72.16	26.93

*$p < .05$

Summary

This research provides empirical evidence that students using the *Connected Mathematics* Project or *MATH Thematics* curriculum materials for at least 2 years in the middle grades equaled or exceeded the achievement of students from matched comparison districts on the mandated state mathematics achievement test. Significant differences on the MAP were identified between students using *Standards*-based curriculum materials and students from comparison districts using other curriculum materials. All the significant differences reflected higher performance for students using NSF *Standards*-based materials. A significantly greater proportion of students in the SB1 *Standards*-based district scored in the highest two MAP achievement-level categories, whereas a greater proportion of students in the comparison district scored in the bottom two achievement-level categories. Students in each of the three districts using *Standards*-based materials scored higher in two Content Standard areas (data analysis, probability, and statistics; and algebra), and these differences were statistically significant. Furthermore, in two districts (SB1 and SB2) students scored significantly better than their comparison district counterparts (C1 and C2) on three other content strands (number; geometric and spatial sense; and discrete mathematics) as well as on the nationally norm referenced Terra Nova assessment. Although critics have chastised NSF *Standards*-based curricula for ignoring basic skills, this research does not support that claim.

DISCUSSION

For the purposes of this study, it would have been ideal to have all students use the same textbook series throughout the middle grades. However, this model is rarely found in the real world and did not exist in the school districts involved in this study. Schools often adopt different curriculum materials at different grades (and sometimes within grades, as occurred in the eighth grade of every school in this study). Each district in this study followed a similar pattern of tracking students at either seventh or eighth grade and used different curriculum materials for different courses at the same grade. Although this school phenomenon is common, it is not clear how using such a hybrid curriculum either strengthens or weakens a school program. Textbook authors make decisions about spiraling mathematics concepts across grades. Therefore, the use of a combination of textbooks from different series may, in fact, interrupt or have other consequences for curriculum coherence and student learning.

Eighth graders in all six districts were enrolled in courses denoted as prealgebra or algebra and most used an algebra textbook. This fact reflects a national trend to enroll most, if not all, eighth graders in an algebra course and is fueled, in part, by a call to make the middle school mathematics curriculum more rigorous and less repetitive. Although *Standards*-based instructional materials were developed to respond to this concern, one frequent complaint about these middle school curricula is that they do not give enough attention to algebra (Wu, 2001). It is worth noting that significant differences occurred across all three groups on the algebra portion of the MAP. In every case, students from districts using a *Standards*-based mathematics curriculum scored significantly higher (at least $p < .05$) on the cluster of algebra items than their comparison group. This evidence contradicts the argument that students using the *Standards*-based middle school mathematics curricula are not learning algebra.

No significant differences were found on all the MAP scores. However, when significant differences were found, they were always in favor of schools using *Standards*-based mathematics curricula. This question is raised: What accounts for the pattern of significant differences on the MAP mathematics assessment?

As indicated earlier, the direct impact of textbooks on student achievement is difficult to establish. Clearly, other variables, including quality of teaching, contributes to mathematics learning. We have no direct information on the quality of teaching in any of these districts and have made no effort to link quality of instruction to student performance. Our assumption is that considerable variability in teaching existed across all schools.

The content and format of assessment instruments can also influence estimates of student achievement. The MAP mathematics exam was not developed to be advantageous to students using any particular set of curriculum materials. Instead, the assessment reflects the *Framework for Curriculum Development in Mathematics, K–12* (Missouri Department of Elementary and Secondary Education, 1996), which articulates the mathematics all Missouri students are expected to learn by the end of Grade 8. The MAP focuses on skills, concepts, and problem solving and includes open-ended and multiple-choice response formats. Thus, the only known factor that was different across the matched pairs of school districts was the mathematics curriculum materials used to guide teaching and learning.

One might ask why the patterns of differences in the third comparison (SB3 and C3) were not similar to the other two comparisons. Recall that significant differences were found (at least $p < .05$) on 5 of 6 subtests and the Terra Nova with two pairs of districts (SB1 and C1, SB2 and C2), but significant differences were seen on only two of the subtests in SB3 and C3. We have at least two explanations, the first of which centers on curriculum. SB3 used CMP for all sixth graders and CMP for about three-fourths of the seventh and eighth graders, with the remaining one-fourth of the students using two different mathematics textbooks. Another explanation relates to the nature of the districts themselves. SB3 and C3 are both wealthy districts, having the two highest average-per-pupil expenditures in the state. The districts pride themselves in being outstanding districts and have a long history of sending a high percent of their students to postsecondary education (over 90%). An examination of Tables 3 and 5 documents that these two districts have a much higher percentage of eighth-grade students in the proficient and exemplary levels than the other districts. They also have the highest scores on the Terra Nova and content subscores. Indeed, they were among the highest in the entire state. The MAP likely provided a low ceiling for students in both districts, thereby curtailing variability and likely accounting for the lack of significant differences.

This examination of mathematics achievement of eighth-grade students who studied from NSF *Standards*-based middle school mathematics materials provides information to those contemplating curriculum reform. More specifically, this research, based on data from six different school districts and involving more than 2,000 students, documents that middle school students using *Standards*-based mathematics curricula for at least 2 years equaled or exceeded the achievement of students from matched comparison groups on the state mandated eighth-grade mathematics test. Just as an artist's picture takes shape with each stroke of the brush, the critical development of a strong research base to investigate the effect of *Standards*-based curriculum materials on student learning will not be established by any single study. The complexity of curriculum implementation demands multiple investigations to uncover key issues for consideration by teachers, district administrators, and policymakers. This analysis requires the contributions of many different research investigations providing a variety of perspectives of the impact of *Standards*-based instructional materials. We offer this study as another stroke for the picture that eventually will emerge.

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APPENDIX A

NSF Curriculum and Comparison District Profiles

District	No. of middle school buildings	No. of middle school students	School percent free/ reduced lunch	Courses by grade	Percent of students in grade in course	Text
SB1	2	2000	30	Gr. 6 Math	100	*MATH Thematics Bk. 1*
				Gr. 7 Math	100	*MATH Thematics Bk. 2*
				Gr. 8 Math	75	*Gateways to Algebra and Geometry*
				Gr. 8, Alg	25	*Algebra I: Explorations and Applications*
C1	1	800	24	Gr. 6 Math	80	*Mathematics: Applications and Connections 1*
				Gr. 6 Math	20	*Mathematics: Structure and Method 1*
				Gr. 7 Math 1	65	*Mathematics: Applications and Connections 2*
				Gr. 7 Math 2	15	*Mathematics: Structure and Method 1*
				Gr. 7 Math 3	20	*Mathematics: Structure and Method 2*
				Gr. 8 Math 1	65	*Mathematics: Applications and Connections 3*
				Gr. 8 Math 2	15	*Mathematics: Structure and Method 2*
				Gr. 8 Math 3	20	*Algebra: Structure and Method*

District	No. of middle school buildings	No. of middle school students	School percent free/ reduced lunch	Courses by grade	Percent of students in grade in course	Text
SB2	2	1000	25	Gr. 6 Math	100	*MATH Thematics Bk. 1*
				Gr. 7 Math	100	*MATH Thematics Bk. 2*
				Gr. 8 Math	50	*MATH Thematics Bk. 3*
				Gr. 8, Alg	50	*Algebra I: Expressions, Equations and Applications*
C2		1000	20	Gr. 6 Math 1	80	*Mathematics: Applications and Connections 1*
				Gr. 6 Math 2	20	*Passport to Mathematics 2*
				Gr. 7 Math 1	80	*Mathematics: Applications and Connections 2*
				Gr. 7 Math 2	20	*Windows to Algebra and Geometry*
				Gr. 8 Math 1	80	*Windows to Algebra and Geometry*
				Gr. 8 Math 2	20	*Algebra: Structure and Method*
SB3	1	600	13	Gr. 6 Math	100	*Connected Mathematics Project*
				Gr. 7 Math 1	75	*Connected Mathematics Project*
				Gr. 7 Prealg	25	*Gateways + Connected Mathematics Project*
				Gr. 8 Math	70	*Connected Mathematics Project*
				Gr. 8 Alg 1	30	*Algebra: Explore, Communication, Apply + Connected Mathematics Project*
C3	1	800	11	Gr. 6 Math	100	*Mathematics: The Path to Success*
				Gr. 7 Math	100	*Middle School Mathematics*
				Gr. 8 Prealg	40	*UCSMP Transitions Mathematics*
				Gr. 8 Alg	60	*Algebra I: Expressions, Equations and Applications*

Note: Complete citations for all textbooks appear in the reference list.

APPENDIX B

Overview of the Mathematics Portion of the Missouri Assessment Program (MAP)

Content strand	Description	Sample item (Grade 8)
Number Sense	The operations of addition, subtraction, multiplication, and division as well as numeration and estimation are included in the number sense strand. Number sense incorporates the applications of these operations and concepts in the workplace and other situations.	Janette, Carl, and Milo are performing a special number in costume during the concert. Each of their costumes will require 3 1/2 yards of material for the outfit and another 1 1/4 yards of material for the hat. How much material is needed in all for the 3 complete costumes? (Show the work done to arrive at your answer.)
Geometric and Spatial Sense	Geometric and spatial relationships involve measurement including length, area, volume, trigonometric relationships, similarity, and transformations of shapes. Geometry involves the study of visual patterns used in representing and describing the world in which we live.	Each square inch of honeycomb contains approximately 25 cells. About how many cells would be found in a honeycomb that measures 8 inches by 12 inches?
Data Analysis, Probability, and Statistics	Collecting, organizing, and interpreting data to make decisions; finding and representing the likelihood that a particular event will occur; making predictions based on experimental data.	The coach keeps records on every player during the season. Study the graph below of the three top players scoring over a six-game period (line graph shown). Which girl scored the most points in all 6 games? How many more points did she score for these 6 games than the lowest scoring player?
Algebra	Recognizing patterns and relationships within and among functions and algebraic, geometric, and trigonometric concepts.	Jim collected $81.00 by selling different sized ads for the school newspaper. He sold 3 jumbo-size ads, 1 large-size ad, and 1 other ad. He misplaced the receipt and needs to determine the cost of the other ad. Jim wrote the following equation to find the cost (*c*) of the other ad: (3 × $20.00) + $12.00 = *c* = $81.00. Use the equation to help Jim find the cost (*c*) of the other ad.

Content strand	Description	Sample item (Grade 8)
Mathematical Systems	Mathematical systems (including real numbers, whole numbers, integers, fractions), geometry and number theory (primes, factors, and multiples).	Your local high school marching band is marching in today's state fair parade. The band, composed of 126 students, usually marches in 21 rows of 6 students each. Due to illness, several band members are unable to march in today's parade. As drum major, you must assist the band director in rearranging the students into rows of equal numbers of students. When you tried 4 students in each row, the last row was 1 student short. The results were the same when rows of 5 and 6 students were arranged. When you arranged the band into rows of 7 students, all rows were complete. Use the information to determine how many students showed up to march in the parade. Show your work and explain the process that you used.
Discrete Mathematics	Discrete mathematics is the study of points, ideas, and object that are separate from each other or distinct. Graph theory, counting techniques, matrices, and the mathematics of decision making are included as part of discrete mathematics.	A group of campers is asked to plan the dinner menus for 15 for an upcoming camping trip. They found that— • 6 people liked only freeze-dried chili, • 4 people liked only backpacker spaghetti, • 5 people liked both the chili and the spaghetti. How many people did NOT like either the freeze-dried chili or the backpacker spaghetti? Draw a Venn diagram to help you solve the problem.