Impact of a Mathematics Intervention on Achievement of Urban Middle School Students

by
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Approval Page

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Abstract

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The problem addressed in this study was that it was necessary to assess the efficacy of the Connected Mathematics Project 2 that was implemented in five middle schools beginning in 2008 to improve the students' mathematics skills. The purpose of this study was to determine the efficacy of the mathematics program at the sixth-, seventh-, and eighth-grade levels using an ex post facto approach with an interrupted time-series design.

To compare the mathematics academic achievement of students before and after implementation of the intervention, pretest and posttest archival data from the state mastery test were analyzed. A questionnaire completed by the middle school mathematics teachers was used to ascertain teachers' perceptions about the new mathematics program, how the program impacted students during the first year of implementation, and perceptions of the professional development teachers received for this intervention.

The results show that implementation of the Connected Mathematics Project 2 improved the overall mathematics achievement of students in Grades 6, 7, and 8 on the state standardized assessments. However, the year-to-year growth of students' performance on the assessment did not improve significantly. Most of the students in specific populations in Grades 6, 7, and 8 also had improved achievement. Furthermore, the achievement gaps between White students and both African American and Hispanic students, as well as the economic achievement gap between economically disadvantaged students and all students, although still significant, were reduced. However, special education students in Grade 7 and English-language learners in Grades 7 and 8 did not experience improvement. Teachers indicated that the professional development they received improved their practice, and they also believed that students benefited from the implementation of the intervention.

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Chapter 1: Introduction

Statement of the Problem

The topic. The topic of this dissertation involved the mathematics skills of students. The acquisition of mathematics skills was not always considered essential for all people. In a classic work regarding the teaching of mathematics in the United States, Cajori (1890) reported that there was little teaching of mathematics in the colonial period. However, after the American Revolution, there was an increase in the number of schools and in the teaching of mathematics (Cajori, 1890). Cohen (2003) claimed that, at this time, there was a new emphasis on an educated citizenry, and learning mathematics was believed to be the way for citizens to have trained minds. Today, the acquisition of mathematics is essential for all people, and those who understand mathematics are able to facilitate advances in medicine, technology, commerce, navigation, defense, and finance (Schoenfeld, 2004; U.S. Department of Education, 2008).

In the past, those who have comprehended mathematics have helped civilizations to understand past mishaps and predict imminent developments. The National Mathematics Advisory Panel (U.S. Department of Education, 2008) stated that, for most of the 20th century, the United States has had incomparable mathematical expertise. This was attributed to the abundance and quality of mathematics specialists, engineers, scientists, and financial leaders, as well as the mathematical education received by the general population. In addition, Schoenfeld (2004) indicated that access to and the knowledge of mathematics has contributed to the social mobility of individuals. The Partnership for 21st-Century Learning (2008) indicated that the importance of the study of mathematics "can be found not only in its ability to help contribute to students' college and career readiness, but it can also help develop individuals as thought leaders who can understand the world better because of their mathematics capabilities" (p. 2). However, members of the National Mathematics Advisory Panel warned that the United States will not remain at the forefront during the 21st century without significant changes to mathematics education.

The research problem. The problem addressed in this study was that it was necessary to assess the efficacy of a program implemented to improve the mathematics skills of middle school students in the target school district. In the 2008-2009 school year, concern regarding the mathematics skills of middle school students in the target school district led educators to implement the program in the five district middle schools with the intent of improving students' academic performance in mathematics.

As shown in Table 1, data from the Spring 2006, Spring 2007, and Spring 2008 administrations of the fourth-generation Connecticut Mastery Test (CMT) in mathematics for the five target middle schools in the district indicated that there were only two subgroups (i.e., Asian American and White) for which over 80% of students achieved at the proficient level, Level 3, or above (Connecticut State Department of Education, 2013). The CMT is a state test that was administered annually to students in Grades 3 to 8 until the spring of 2013. According to Hayes (2010), there are five levels at which students are able to achieve for the CMT: advanced (i.e., exceptional content knowledge), goal (i.e., extensive content knowledge), proficient (i.e., adequate content knowledge), basic (i.e., partially developed content knowledge), and below basic (i.e., limited content knowledge).

Additionally, the data showed that there were minimal increases, and even decreases, in mathematics achievement of some subgroups of students between 2006 and 2008. Assessment data prior to 2006 were not considered because a different generation of tests was initiated in 2006, and there was no correlation between the scores or levels of the third- and fourth-generation CMTs. Table 1 shows the percentage of students at the five target schools achieving at the proficient level or above on the CMT in mathematics in 2006, 2007, and 2008. The information represents the preintervention data for the study.

Table 1

Percentage of Students Achieving Proficient or Above on State Math Test, 2006-2008

	Grade 6			Grade 7			Grade 8		
Group	2006	2007	2008	2006	2007	2008	2006	2007	2008
African American	40.9	62.9	64.4	47.3	46.9	60.1	43.0	49.0	49.6
Hispanic	62.8	65.9	69.6	59.6	60.9	68.0	61.4	64.6	62.4
White	87.9	89.8	86.6	87.2	88.5	90.5	88.1	88.5	88.3
Asian American	87.3	84.3	96.2	83.1	85.9	88.6	91.7	82.3	90.5
Free or reduced lunch	50.5	62.5	65.3	51.5	52.6	64.3	54.2	56.1	55.2
Special education	24.0	27.0	26.5	31.4	24.5	32.7	33.0	34.5	23.5
ELL	43.3	38.6	44.7	40.0	34.2	50.5	41.0	46.3	35.3

Note. ELL = English-language learner.

Background and justification. According to the U.S. Department of Education (2013), the achievement gap is defined as the “difference in academic performance between ethnic groups” (para. 1). However, the National Center for Education Statistics (2014a) presented a broader definition that stated the term achievement gap refers to the situation when “one group of students outperforms another group and the difference in average scores for the two groups is statistically significant” (para. 1). In mathematics, this gap exists between students of low socioeconomic status and ethnic minorities when compared to those students who are White and not of low socioeconomic status.

A report from the Connecticut Commission on Educational Achievement (2010) stated that, overall, students in Connecticut score relatively well on national tests. In fact, Connecticut ranks among the top five states in both reading and mathematics. However, according to this same report, when compared to other states in the country, Connecticut also had the largest achievement gap in both reading and mathematics for students of low socioeconomic status in the 2009 and 2011 National Assessment of Education Progress (National Center for Education Statistics, 2011a, 2011b, 2011c). Students are considered to have a low-income status if they are eligible for participation in the National School Lunch Program (U.S. Department of Agriculture, Food, and Nutrition Service, 2012). Under this program, students are provided with nutritious free or low-cost breakfasts or lunches. The income levels that determine student eligibility are calculated by the Secretary of Agriculture.

This large achievement gap in Connecticut is the difference in test scores in both reading and mathematics for low-income public school students when compared to those of more affluent circumstances (Connecticut Commission on Educational Achievement, 2010). Students in Grades 4 and 8 from low-income families are about three grade levels behind in both reading and mathematics when compared to their peers who are not from low-income families. Unfortunately, this gap disproportionately affects primarily African American and Latino children (Causal, 2010; Connecticut Commission on Educational Achievement, 2010; Hayes, 2010).

Moreover, according to the National Center for Education Statistics (2011a), the mathematics scores for students in Connecticut who were eligible for free or reduced-price school meals in 2011 was not significantly different from the 2003 score gap. The Grade 8 mathematics scale scores of students from low-income families on the National Assessment of Educational Progress were 34 points lower than the scale scores in 2003 and 2011 of students who were not from low-income families. This gap was the largest in the nation.

The achievement gap is not limited to the state of Connecticut but is a crisis nationwide (National Center for Education Statistics, 2013; Van der Bergh, Denessen, Hornstra, Voeten, & Holland, 2010). Students who were enrolled in schools in which 50% or more of the population received free or reduced lunch (U.S. Department of Agriculture, Food, and Nutrition Services, 2012) also scored lower than the U.S. national average in the Trends in International Math and Science Study (National Center for Education Statistics, 2014b). Scores from the 2008 Trends in International Math and Science Study showed that African American and Hispanic students in Grade 8 scored lower than the average and also scored lower than the national average for the United States (National Center for Education Statistics, 2014b). Comparing earlier reports to data from the 2008 report showed that overall scores have improved for groups of students, but the gap between subgroups has not decreased (National Center for Education Statistics, 2014b).

Scores from the 2011 National Assessment of Educational Progress show similar results to the Trends in International Math and Science Study (National Center for Education Statistics, 2013). These data show a 29% point difference in mathematics by Grade 8 between students of low socioeconomic status and ethnic minorities when compared to those students who are White and are not of low socioeconomic status (National Center for Education Statistics, 2013). This trend is similar for all the years that information on the National Assessment of Educational Progress has been collected for students who are eligible for free or reduced-price lunch. Nationally, data from 1996 through 2011 showed that there is, on average, at least a 26-point difference in mathematics between Grade 8 students who are eligible for free or reduced-price lunch and those who are not eligible (National Center for Education Statistics, 2014a). The achievement gap exists internationally as well (Van der Bergh et al., 2010). Studies on the achievement of groups of ethnic minorities have been conducted in countries such as the Netherlands, Britain, China, New Zealand, Belgium, and South Africa.

The Intervention

Prior to 2008, there was not a systemic mathematics curriculum for the five target middle schools in the district. Each mathematics teacher within each school was able to choose which mathematical concepts to teach, at what time of year, and what resources, if any, to use to teach these concepts. Additionally, middle school students were separated into four or five academic tracks based on a score from the state test in reading. This resulted in not all students learning grade-level mathematics content because the students placed in the lower tracks were considered below grade level.

The National Staff Development Council (2005) completed an audit of the mathematics and science curriculum, as well as professional development in all the schools in the district. The June 2005 report identified the following challenges:

> 1. Evidence of the existence or use of Pre-K-12 articulation, district-wide curriculum in math and science is absent.
>
> 2. Instruction in math and science is predominantly whole group and didactic rather than inquiry-based while the district touts its implementation of differentiation and inquiry-based instruction.
>
> 3. Facilities, equipment, instructional resources, and time to support math and science instruction vary widely from school to school and among elementary, middle school, and high school.
>
> 4. Variability in teacher content knowledge in mathematics and science impacts the quality of instruction.
>
> 5. Students' opportunity to learn is limited by the predominant practice of ability grouping in mathematics.

> 6. Teachers want and need extensive, ongoing, comprehensive professional development in math and science content and pedagogy.
>
> 7. Key staff development decision makers and practitioners have shallow knowledge about high-quality professional development.
>
> 8. The design of math and science professional development is primarily school- or district-determined, provided by external experts, and depended on a turnkey model to transfer knowledge to other staff for implementation.
>
> 9. Availability of and use of student achievement data at the classroom level is nonexistent.
>
> 10. The district lacks a comprehensive plan for reform in math and science curriculum, instruction, assessment, and professional development. (p. ii)

As a result of this audit, the school district received a $15.3 million, 5-year education grant in 2006 from the General Electric Foundation's Developing Futures in Education program to improve mathematics and science and a $10.3 million, 3-year renewal grant to complete the mathematics and science work and begin literacy work. The grant provided the necessary funds to improve student achievement in mathematics and science. Because of this grant, money was available to pay middle school teachers to participate in a committee to assist in the choosing of a mathematics curriculum, write curriculum handbooks, and develop common, district-wide assessments. Most of the funds went to providing intensive professional development on the new curriculum.

The curriculum chosen for the five target middle schools in the district was the Connected Mathematics Project 2 (CMP2). This project was developed by Michigan State University (2014) with funding from the National Science Foundation. The goal of CMP2 is to provide students with the skills and knowledge necessary to reason and communicate mathematically. To learn this program, middle school mathematics teachers in the five target middle schools in the district received professional development and support. In the first year of implementation, teachers were provided with 42 hours of training in both content and pedagogy. During the second year of implementation, teachers were provided with 2 full days and 1 half day of classroom-embedded support by a CMP2 consultant. The consultant modeled lessons, viewed lessons to provide feedback, cotaught lessons with teachers, and provided specific examples of what teachers should work on in order to teach the program with fidelity.

Deficiencies in the evidence. District administrators wanted to know if the CMP2 program is making a difference in students' mathematics achievement, and this had not yet been determined. Researchers have indicated that educators must make data-based decisions regarding the instructional needs of students (Fuchs, Fuchs, & Compton, 2012; Nelson, Slavit, & Deuel, 2012). Thus, the data comparing student academic progress before and after implementation of the program is essential to guide future educational decisions. Also, a committee of business and philanthropic leaders formed by the state governor stressed the importance of improving the skills of all students not achieving proficiency reading and mathematics, as well as reducing the achievement gap between students from low-income backgrounds and students who are not from low-income backgrounds (Connecticut Commission on Educational Achievement, 2010).

Therefore, it is important to know if the intervention of the CMP2 program is achieving this goal. As noted by Martin, Brasiel, and Turner (2012), the impact of implementation of CMP2 is undetermined because studies have shown mixed results. Consequently, additional research is needed. In addition, Eddy et al. (2008) suggested that more studies are needed to determine if the program can reduce the mathematics achievement gap between Caucasian students and ethnic minority students. Likewise, other researchers have supported the need for more research to determine the efficacy of CMP2 (Cai et al., 2013; King et al., 2011; Moyer, Cai, Wang, & Nie, 2011).

Audience. Teachers, building administrators, central office personnel, members on the board of education, and community members in the target district will be interested in the findings from this study in order to determine if the intervention should be continued or not. Educators and administrators in other districts in the United States and in other countries in which there is an achievement gap would also be interested in the findings so that the study could be replicated in their area. In addition, educators in colleges and universities who prepare teachers and administrators may be interested in the findings in order to improve the preparation of preservice teachers and administrators.

Setting. The target urban school district is located in the southwestern part of the state. According to the U.S. Census Bureau (2010), the estimated population for this city is 122,643. Within this urban district, there are 11 elementary schools, one school serving students in kindergarten through Grade 8, five middle schools, and three high schools. In the 2013-2014 school year, there were 16,100 students in the district, and the population was 22% African American, 30% Hispanic, 41% White, and 7% Asian American. Students who are not fluent in English make up 15% of the school's population, and 41% of students are eligible for free or reduced-price meals (U.S. Department of Agriculture, Food, and Nutrition Service, 2012). In addition, 9% of students receive special education services.

Role of researcher. The role of the researcher has changed since the initiation of the mathematics intervention in 2008. From August 2007 to October 2010, the researcher was a teacher on special assignment for secondary mathematics and, therefore, planned and monitored the intervention. The researcher also worked closely with the middle school mathematics teachers, the director for mathematics and science, and the middle school mathematics coaches. From November 2010 to July 2011, the researcher became an administrator with continuing responsibility for middle school mathematics. In August 2011, the researcher became the director for mathematics and science. Hence, she is responsible for all grade spans and all work associated with these two academic areas. Later in July 2013, the researcher became the director for school improvement and professional development for secondary schools (i.e., middle and high schools) in the district.

Definition of Terms

For the purpose of this applied dissertation, the following terms are defined.

Achievement gap. This term refers to the difference in academic performance between ethnic groups (Beecher & Sweeney, 2008; Boykin & Noguera, 2011; U.S. Department of Education, 2013).

Common core state standards. This term refers to standards that were developed under the guidance of members of National Governors Association Center for Best Practices and the Council of Chief State School Officers to “ensure that students make progress each year and graduate from high school prepared to succeed in college, career, and life” (Common Core State Standards Initiative, 2014, p. 1). The standards in English-language arts, literacy, and mathematics have been adopted by 43 states and Washington D.C.

Connecticut Mastery Test (CMT). This term refers to the state test completed annually by students in Grades 3 through 8 in mathematics and reading. The test in science is completed in Grades 5 and 8.

Connected Mathematics Project 2 (CMP2). This term refers to a middle school mathematics program created by researchers at Michigan State University and funded by the National Science Foundation. The program emphasizes conceptual understanding of mathematics.

Constructivist mathematics instruction and reform approach. This term refers to a way of instructing mathematics that is based on the belief that mathematical principles are better learned in the context of solving real-life problems through student-directed activities (Agodini, Deke, Atkins-Burnett, Harris, & Murphy, 2008).

National Science Foundation. This term refers to a federal agency whose mission includes "support for all fields of fundamental science and engineering, except for medical sciences" (National Science Foundation, 2013, para. 1). The foundation has funded research and development of mathematics curriculum as part of the national mathematics reform efforts.

Smarter Balanced assessments. This term refers to assessments aligned with the common core state standards that have been developed by the Smarter Balanced Assessment Consortium (2014a, 2014b) to assess the achievement of students in Grades 3 to 8 and Grade 11. Summative assessments and optional interim assessments were being used by participating states in the 2014-2015 school year.

Standards-based mathematics instruction. This term refers to mathematics instruction based on the principles and standards for school mathematics that were developed by the National Council of Teachers of Mathematics (2000).

Traditional mathematics instruction. This term refers to a way of instructing mathematics that is based on the belief that children will develop a strong understanding of mathematical principles by first being taught facts and procedures and then applying those skills to solve real-life problems (Agodini et al., 2008).

Purpose of the Study

The purpose of this study was to determine the efficacy of CMP2 at the sixth-, seventh-, and eighth-grade levels using an ex post facto approach with an interrupted time-series design. Retrospective data were used to ascertain if the new mathematics curriculum impacted the mathematics achievement of students on the state standardized assessments school years when compared to the school years before implementation of the program. The 2013-2014 assessment data have not been included in this research because for that school year, the state department of education allowed school districts to administer an alternative assessment rather than the CMT, which had been used in previous years.

The target school district administrators chose to administer a new assessment aligned to the common core state standards. Because this assessment was a field test of the Smarter Balanced assessment (Smarter Balanced Assessment Consortium, 2014a) to provide information regarding quality assurance, achievement standards, and test administration, no data for student performance in mathematics were provided to district schools. In the 2014-2015 school year, the Smarter Balanced assessment would be administered across the state, and data would be provided to the school district on student achievement.

Chapter 2: Literature Review

Introduction

The purpose of this study was to determine efficacy of CMP2 at the sixth-, seventh-, and eighth-grade levels using an ex post facto approach with an interrupted time-series design. The relevant topics discussed in this review of the literature include a brief history of mathematics education, the achievement gap in mathematics, professional development to support mathematics, research on CMP and CMP2 research, and the CMP2 theoretical framework. The research questions are also included.

A Brief History of Mathematics Education

Throughout the last few centuries, there has been a debate about who should learn mathematics and about the mathematical content that should be learned (Schoenfeld, 2004). In the 1800s, arithmetic skills beyond addition and subtraction were not needed for the majority of the population. In fact, arithmetic was sometimes called a “mere tradesman’s subject” (Cohen, 2003, p. 45), and the elite class barely studied mathematics at all. It was not until after the American Revolution that there was a new emphasis placed on an educated citizenry and mathematics was seen as the way to ensure this (Cohen, 2003).

In the early part of the 20th century, mass education referred to an elementary school education (Schoenfeld, 2004). However, the number of students in high school and taking higher level mathematics courses gradually increased (Garrett & Davis, 2003). This growth included students from a variety of backgrounds, interests, and abilities, many of whom would have not considered attending high school in previous generations (Garrett & Davis, 2003). Because of this diversity, mathematics educators were concerned that the college-preparatory mathematics curriculum was not meeting the needs of the students. There were discussions about how to adjust instruction and the school curriculum because both of these seemed to serve the few students of the highest abilities (Garrett & Davis, 2003).

It was determined during World War II that armies were not well prepared mathematically (Moch, 2011). Many army recruits lacked basic skills needed for bookkeeping and gunnery, and the U.S. Army had to provide basic skills in mathematics; this was the same situation for the U.S. Navy (Klein, 2007). Admiral Chester W. Nimitz stated that it was enormously difficult to find officer candidates for the Navy with the required mathematical abilities and that more than 60% of those who applied for entry into the Naval Reserves Training Corps failed the required mathematics test (Garrett & Davis, 2003). In addition, the lack of mathematics knowledge was the reason that 3,000 of the 8,000 college graduates who applied to other naval officer commissioning programs failed and was the reason for 75% of the failures in navigation courses (Garrett & Davis, 2003). This lack of mathematics skills for those in the armed forces helped raise the importance of mathematics education, even if it was just during wartime (Garrett & Davis, 2003).

After World War II, the mathematics curriculum and the way it was taught did not change and was based primarily on memorization of facts and building students' skills in computation (Moch, 2011). Moch (2011) reported that, during the 1950s, students were not interested in science and mathematics, the curriculum for these areas seemed obsolete, and teachers were unprepared to teach these courses. However, when the Soviet Union launched Sputnik, an unmanned satellite in 1957, U.S. educators began to rethink education priorities and what were essential for the survival of the country. According to Moch, the "launching of Sputnik provided the impetus for the funding to thrust mathematics reform to the forefront of education" (p. 166).

Because of the threat of the Soviet Union's space program and Sputnik, there was an examination of mathematics, science, and technology education in the United States (Fey & Graeber, 2003; Payne, 2003; Stotsky, 2007). The mid-1950s began a period in mathematics education when a new curriculum was promoted (Fey & Graeber, 2003; Stotsky, 2007). The reform for mathematics spread into the elementary and junior high school grades, and there was a call for the curriculum at these levels to have richer mathematical content that would emphasize students' understanding of the fundamental structures for mathematical concepts and procedures. The challenge was ensuring that teachers at these levels could teach this content (Fey & Graeber, 2003).

The late 1950s and 1960s were said to be the "golden decade for mathematics education" (Payne, 2003, p. 575). It was during this time that there was an unprecedented amount of money from the federal government dedicated to mathematics education. The reform effort brought the need for teacher training to the forefront. According to Payne (2003), the National Science Foundation provided more than $28.5 million for curriculum revisions and $15 million for teacher training, and the Office of Education also provided funding for mathematics and science education (Payne, 2003). It was also at this time that the National Council of Teachers of Mathematics became an important provider of professional development for teachers (Payne, 2003).

In September 1959, a 10-day meeting of 35 scientists, scholars, and educators was called by the National Academies of Sciences (Bruner, 1960). The goal of this committee was to understand how to teach science to students. Bruner (1960) stated that this marked the beginning of a view of mathematics that focused on problem solving, discovery, generalization, and the development of a complex understanding of mathematical processes. Bruner asserted that there needed to be a great understanding of mathematics so that one can apply it and use it. Bruner's writing supported the era of mathematics that was called the *new math* during the 1960s (Fey & Graeber, 2003).

During this time, the way of teaching mathematics was supported by research on the intellectual development of children and on learning theory. This period emphasized concepts and logical reasoning, developmental theories of learning, and the engagement of students in their own learning to discover mathematics. The pedagogical approach during this time was on students discovering mathematics through classroom activities that involved the use of manipulatives for younger students (Fey & Graeber, 2003). Bruner (1960) suggested that blocks, Cuisenaire rods, charts, and models could help students learn mathematics. This type of learning seemed be aligned with the psychological theories that concentrated on the importance of students being engaged in their own learning, but many mathematics educators found that it was difficult to foster this engagement every day (Fey & Graeber, 2003).

In the 1970s, there was growing concern and discontent over new math because evidence suggested that students in Grades 4 to 12 were not improving mathematically, and the pedagogy being used to deliver the mathematics curriculum had come into question (Fey & Graeber, 2003). In 1975, the Conference Board of Mathematical Science chose the National Advisory Committee for Mathematical Education to prepare the *Overview and Analysis of School Mathematics, Grades K-12.* The document indicated that not all teachers were implementing the mathematics reforms and recommended that teachers needed to have knowledge of both the content and effective instructional practices.

The report also recommended that references to new math be should refer only to “the multitude of mathematics education concerns and developments of the period 1955-1975” (National Advisory Committee for Mathematical Education, 1975, p. 137). Thus, the mathematics instructional trend during the second half of the century was back to the basics (Payne, 2003; Schoenfeld, 2004; Stotsky, 2007). Also, during this time, as part of the War on Poverty, the federal government gave almost complete attention to improving the achievement of poorly performing students, especially those students who were of low socioeconomic status (Heise, 1994; Stotsky, 2007).

As a result of the back-to-basics trend, the sequence of mathematics courses returned to the pre-Sputnik era of arithmetic in kindergarten to Grade 8, Algebra I in Grade 9, geometry in Grade 10, a second year of Algebra in Grade 11, and Precalculus in Grade 12. This era emphasized procedural skills, direct instruction, and widespread use of local and national testing. However, after a decade of direct instruction, the result was that not only were students not doing better mathematically, but they also were not able to solve problems efficiently (Fey & Graeber, 2003). This lead to the statement by the National Council of Teachers of Mathematics that focusing solely on the basics was wrong, and, as a result, the back-to-basics curriculum was replaced with a problem-solving curriculum (Schoenfeld, 2004). However, problem solving was done superficially because there was not a clear understanding of what problem solving actually meant (Schoenfeld, 2004).

Mathematics education reform was again at the forefront because of a series of critical national advisory reports and disappointing results from international comparisons of mathematics achievement (Coxford, Fey, Hirsch, & Schoen, 1999). The National Council of Teachers of Mathematics (1980) issued a reported entitled *An Agenda for Action*, which stated that mathematics education in the United States was not improving. This report recommended that the focus of school mathematics be on problem solving, that paper-and-pencil computation should not inhibit problem solving, that calculators be readily available to all students, and that there should be less emphasis on paper-and-pencil calculations with more than two digits (Klein, 2007).

Another report came from the National Commission on Excellence in Education (1983). The U.S. Secretary of Education T. H. Bell created the Commission to investigate and report on the state of education. The result was the production of a report entitled *A Nation at Risk: The Imperative for Educational Reform*, which detailed findings and recommendations for a change in U.S. education. This report examined many countries and their education systems. The report highlighted the increasing importance of technology and science for national prosperity and indicated that the United States had fallen behind countries in the education of scientists. These specific problems related to mathematics and science were listed in the Commission's report:

> 1. Critical shortages of physics, mathematics, and chemistry teachers exist at the secondary level.
>
> 2. The average salary of a beginning math teacher with a bachelor's degree is now only 60% of the beginning salary offered by private industry to bachelor degree candidates in mathematics.
>
> 3. Substantial numbers of unqualified persons are teaching science and mathematics in secondary school.
>
> 4. Even certified science and mathematics teachers at the secondary level are in need of in-service training.
>
> 5. New sequences of science and math courses and materials are needed which match stages of intellectual development of children.
>
> 6. Elementary and secondary schools need access to microcomputers, low-cost supplies, and other resources. (p. 3)

The report by the National Commission on Excellence in Education (1983) indicated that schools were too focused on the basics of reading and computation at the expense of comprehension, analysis, solving problems, and drawing conclusions. It stated that, although the American economy and society had changed over the past decades, the way in which the country educated its students had not (Heise, 1994). The report emphasized the low performance of minority students in mathematics (Stotsky, 2007) and the need for a more prepared teacher workforce (Heise, 1994). Overall, the report stated that education in the United States was second rate (McLeod, 2003; Schoenfeld, 2004; Stotsky, 2007).

In 1989, the National Council of Teachers of Mathematics developed the curriculum and evaluation standards for school mathematics. Overall, the 13 standards were in line with *An Agenda for Action* from 1980 but included more explanation and indicated that "the study of mathematics should emphasize reasoning so that students can believe that mathematics makes sense" (p. 29). The standards encouraged student-centered classrooms, discovery learning, and study of real-world problems and applications, and emphasized that all students should have access to calculators (Klein, 2007). Additionally, there was to be less attention on long division, paper-and-pencil fraction computation, rote practice, teaching by telling, memorizing rules and algorithms, and finding the exact form of answers (Klein, 2007).

Klein (2007) stated that those in favor of this approach to mathematics education provided supportive arguments for this way of teaching and learning. One argument was that teaching mathematics this way was said to be socially just. It provided all students with the chance to learn mathematics. The second argument was that this way of teaching and learning was based on the needs of business and industry. Both of these issues had been highlighted in the report entitled *A Nation at Risk* (National Commission on

Excellence in Education, 1983).

The 1990s represented the decade of the mathematics wars. The wars were centered on the contrast between the learning of basic skills versus the conceptual understanding of mathematics and also on instructional strategies. This debate has been characterized as the "disagreement between forward-thinking mathematics educators who wanted a 'conceptual approach'…and 'traditional' mathematicians and parents who… wanted only rote memorization and computational fluency (Stotsky, 2007, p. 493). Klein (2007) concurred that this debate was between progressive and conservative approaches to mathematics instruction and suggested that, although a traditional approach was criticized for being too focused on basic skills with little understanding by students, many universities expected students to have experienced a traditional mathematics curriculum.

In 1994, Congress reauthorized Title I of the Elementary and Secondary Education Act and passed the Goals 2000: Educate America Act. This act was intended to encourage "coherent, nationwide, systemic education reform, to improve the quality of learning and teaching in the classroom and workplace, and to define appropriate and coherent federal, state, and local roles and responsibilities for education reform" (Heise, 1994, p. 345). It also provided funds so that each state's department of education could develop standards and an assessment system within accountability measures that were considered essential to the reform of the American education system (Superfine, 2005).

In 1995 and 1999, U.S. students participated in the Third International Math and Science Study, which later became known as the Trends in International Math and Science Study. In both 1995 and 1999, eighth-grade students' average scores were lower than those of students in countries such as Japan, the Czech Republic, Australia, and the Netherlands (Roth et al., 2006). These were some of the same countries to which the report entitled *A Nation at Risk* report compared the U.S. students (National Commission on Excellence in Education, 1983). The *A Nation at Risk* report and the statistical analysis of the Third International Math and Science Study from 1999 both indicated that not all teachers in the United States were prepared to teach the subjects they were assigned to teach (Roth et al., 2006).

In 2000, the National Council of Teachers of Mathematics released the principles and standards for school mathematics, which described a future in which "all students have access to rigorous, high-quality mathematics instruction, including 4 years of high school mathematics. Knowledgeable teachers have adequate support and ongoing access to professional development" (para. 4). At the same time, the National Council of Teachers of Mathematics recognized that there were significant challenges in meeting this goal. The principles are the basic fundamentals for a superior education in mathematics, and they include statements about equity, curriculum, teaching, technology, learning, and assessment. The standards describe what mathematics students should be able to know and do. These content standards describe the essential content areas: number and operations algebra, geometry, measurement, and data analysis and probability. These process standards describe how the content knowledge can be accessed and used through problem solving, reasoning and proof, communication, connections, and representations.

In 2001, former President George W. Bush signed the No Child Left Behind Act, which demanded higher academic standards, high-quality teachers, and annual testing requirements for all schools in the United States (Klein, 2007). The legislation explained that, even though there had been over $200 billion in federal education spending since the passage of the Elementary and Secondary Education Act of 1965, students were still not being adequately educated (U.S. Department of Education, 2002). The No Child Left Behind Act called for more accountability in the form of rigorous state testing and goals that would insure that all students would make adequate yearly progress and reach proficiency levels in reading and mathematics by 2014.

However, based on international assessments, student achievement in the country did not improve (Gonzales et al., 2004). The scores of students from the United States on international assessments during the 2000s did not improve. For example, U.S. students participated again in the Trends in International Math and Science Study in 2003, and the results were not significantly different than in previous years. Although Grade 4 students scored higher than the international average, they still scored in the middle of the group of countries, outscoring their peers in 13 countries but being outscored by students in 11 countries (Gonzales et al., 2004). Grade 8 students also scored higher than the international average but were outperformed by 14 countries, including Japan, Russia, and the Netherlands.

Schmidt, McKnight, Cogan, Jakwerth, and Houang (1999) analyzed the mathematics curricula from various states and countries, and then analyzed U.S. performance on international assessments and made suggestions on how to improve mathematics and science in the United States. Schmidt et al. stated that the mathematics and science curricula were much too broad to study any topics in depth, coining the phrase “mile wide and an inch deep” (p. 4). Moreover, Schmidt, Wang, and McKnight (2008) stated that the analysis of the Trends in International Math and Science Study showed that the U.S. mathematics and science curricula were “unfocused, repetitive, and undemanding by international standards” (p. 532). The researchers indicated that mathematics and science instruction needed to be more coherent and uniform across schools and districts.

Schmidt et al. (2007) also commented that the knowledge of preservice teachers was not commensurate with that of teachers in other countries. In fact, U.S. preservice teachers studied only 43% of the advanced mathematics topics compared to preservice teachers in countries such as Korea and Taiwan, who studied 79% to 86% of the advanced mathematics topics, which resulted in not only a “curriculum gap” (Schmidt et al., 2007, p. 7) between the United States and other countries, but also a “preparation gap” (Schmidt et al., 2007, p. 7).

In 2006, the National Mathematics Advisory Panel was created to advise the President of the United States and the Secretary of Education on how to improve mathematics achievement for all students (Klein, 2007). The final report from the Panel, which was published in 2008, stated that students in the United States were not succeeding in mathematics at the levels that should be expected (U.S. Department of Education, 2008). According to the report, the security of the nation and general well-being of its citizens were dependent on superior mathematics education. The report continued to point out the mediocrity of U.S. students’ performance when compared to their international counterparts, something that many previous reports had pointed out. The suggestions from the report included that the U.S. curriculum needed to be streamlined and should “emphasize a well-defined set of skills” (U.S. Department of Education, 2008, p. 13) and that particular attention should be paid to the preparation of teachers.

Although the report from the National Mathematics Advisory Panel provided some ways to support the improvement of mathematics, it mainly focused on the content of public school mathematics curriculum but not on the pedagogy (U.S. Department of

Education, 2008). In comments about instructional practices for mathematics, the Panel stated generally that these practices should "be informed by high-quality research, when available, and by the best professional judgment and experience of accomplished classroom teachers" (U.S. Department of Education, 2008, p. xiv). The authors of the report for the National Mathematics Advisory Panel went on to state that there is an absence of research-based evidence to support either the implementation of a student-centered classroom or of a teacher-directed classroom (U.S. Department of Education, 2008).

Bottge, Grant, Stephens, and Rueda (2010) agreed with the National Mathematics Advisory Panel (U.S. Department of Education, 2008) that more research is needed regarding the essential mathematics content that students need and how the content should be taught. Bottge et al. argued that there needs to be a balance between a "conceptual understanding of the mathematics with procedural fluency" (p. 82). The authors indicated that there are two types of activities that should be incorporated into mathematics classrooms in order to do this. The first activity is called model exploration, which requires teachers to guide students through ways to solve a problem and then allow students apply the problem-solving strategies. The second type of activity is called model eliciting. For this model, teachers have students explore the mathematical concepts, test them out, and then revise their thinking.

Bottge et al. (2010) used an instructional method called enhanced anchored instruction. In this structure, (a) instructors use probing questions to guide student understanding of authentic-like problems; (b) students work together in small groups to discuss, test, and find solutions to the problems; and (c) instructors provide indepth instruction on skills and concepts as students need them. According to Bottge et al., enhanced anchored instruction provided students with multiple opportunities to do mathematics within a context. The researchers also emphasized that there is a need to help students understand the words within the problem.

Not only did enhanced anchored instruction help students understand the problem, but it also provided them with hands-on materials that could be scaffolded, generated multiple representations of the problems, and allowed for students to show their understanding in a variety of ways. Bottge et al. (2010) argued that their findings pointed to a new theoretical model for adolescents indicating that problem solving and computation should be in the context of practical problem solving. In order to achieve this, instructional methods and materials must show students the relevance of mathematics to their lives.

Achievement Gap in Mathematics

Saifer, Edwards, Ellis, Ko, and Stuczynski (2010) stated that the following factors contribute to the student academic-achievement gap: “poverty, mobility, language, homelessness, institutional racism, unequal distribution of resources, low expectations for students from culturally diverse backgrounds, teacher quality, and cultural incongruence between home and school” (p. 2). In an early comment on this gap, Coleman et al. (1966) stated that American education was still not equitable for all students and that students of color were less likely to have access to college preparatory and accelerated curricula. The report also stated that attending school did not help students overcome the deficiencies with which they entered and that the school facilities and the teacher impacted the achievement of students of color. However, Reardon (2011) suggested that this gap is not about skin color but about socioeconomics. The gap is not between White students and African American and Hispanic students but between students from high- and low-income backgrounds.

According to Balfanz and Byrnes (2006), the achievement gap is less prominent at the elementary level than it is at the middle school level. Middle school students who go to school in areas in which there is high poverty and a high ethnic minority population are falling behind in mathematics, and there are a plethora of reasons as to why the achievement gap has not closed, including the lack of a coherent curriculum, unprepared teachers, unequal opportunities for students, unmotivated students, and unsupportive climates for learning.

Akiba, LeTendre, and Scribner (2007) also argued that data suggest that the lack of teacher preparation and effectiveness contributes to the achievement gap, which could be called the “teaching gap” (p. 369). Andreasen, Swan, and Dixon (2007) reported that, when U.S. teachers were compared to their Chinese counterparts, the results indicated that U.S. teachers were lacking in their ability to diagnose children’s mathematical errors or misconceptions to a degree that intervention could take place on a conceptual level. Teachers in the United States could only elaborate student misconceptions on a procedural level, whereas the Chinese teachers could report student errors on both a procedural and conceptual level.

Andreasen et al. (2007) argued that U.S. teachers need opportunities to develop both their own pedagogical content knowledge and understanding of fundamental mathematics. Therefore, teacher training should include methods and strategies for teaching, as well as practice in identifying common student misconceptions and error patterns. Furthermore, in a position statement supporting the observations and recommendations of Andreasen et al., Akiba et al. (2007), and Balfanz and Byrnes (2006), the National Council of Teachers of Mathematics (2012) declared, “Differential access to high-quality teachers, instructional opportunities to learn high-quality mathematics, opportunities to learn grade-level mathematics content, and high expectations for mathematics achievement are the main contributors to differential learning outcomes among individuals and groups of students" (para 1).

When Shin, Davison, Long, Chan, and Heistad (2013) used growth-curve modeling to examine the achievement gaps in mathematics and reading for students over the years from Grade 4 to Grade 7, they found that the achievement gap widened in mathematics but was reduced in reading. Also, the provision for learning English as a second language improved academic achievement in both subject areas, but special education programs and free and reduced-price lunch programs did not affect achievement.

More recently, Strunk and McEachin (2014) studied the efficacy of district assistance and intervention teams who were charged with the task of working with the lowest performing school districts in California to improve their capacity to work with schools, particularly in the areas of professional development and support of research-based instruction and interventions The results showed that, over two implementation years and one postimplementation year, the intervention reduced the mathematics achievement gaps among African students, Hispanic students, and students from low-income backgrounds, as well as English-language learners when compared to White students, students who were not from low-income backgrounds, and non-English-language learners.

Professional Development to Support Mathematics

Research has shown that teachers' instructional skills and content knowledge have a positive effect on students' academic achievement (McMeeking, Orsi, & Cobb, 2012;

Podhajski, Mather, Nathan, & Sammons, 2009). According to Tallerico (2005), there are effective principles for providing effective professional development to adults: “(a) active engagement, (b) relevance to current challenges, (c) integration of experience, (d) learning styles variation, and (e) choice and self-direction” (p. 55). Recognizing the need for effective teacher professional development related to mathematics and science, the National Science Foundation funded local systemic change projects over a decade of implementation beginning in 1995. Heck, Banilower, Weiss, and Rosenberg (2008) reported that the principles of effective professional development, as described by Tallerico in 2005, were followed, and, additionally, the professional learning provided was focused on content and related to practice.

Although many teachers did not fully participate in the professional development as intended, Heck et al. (2008) indicated that the teachers reported that their attitudes towards standards-based teaching and the integration of it in their classes were positively affected. According to Weiss and Pasley (2009), who described the lessons learned about high-quality professional development from administrators in participating school districts, professional learning preparation includes “(a) the development of a vision of high-quality mathematics instruction within the district, (b) identification of needs, (c) setting of professional development goals, and (d) thoughtful attention and planning to working with teachers as professionals and key change agents” (p. 1).

To help implement changes in instruction at the classroom level, Weiss and Pasley (2009) advised the implementation of site-based, job-embedded professional development, which includes on-site professional-development sessions, local learning communities, and the development of mathematics coaches. The focus of job-embedded professional development should help teachers structure their discussions, share information, and develop questions in order to determine what students know and use student responses in the professional-development cycle.

Banilower, Boyd, Pasley, and Weiss (2006) reported that teachers were expected to participate in 130 hours of professional development over 3 years. Through the use of a teacher questionnaire, Heck et al. (2008) determined that the duration of teachers' participation in the professional development positively affected their self-efficacy regarding their knowledge of content and readiness to use standards-based instruction. The researchers suggested that additional research is required regarding integration of a variety of reform strategies to successfully meet the needs of teachers implementing standards-based instruction. Site-based, job-embedded professional development, according to Weiss and Pasley (2009), included preparing teacher leaders. The roles of teacher leaders needed to be defined, the leaders needed to learn how to work with adults, and there needed to be encouragement for these leaders. However, this development of teacher leaders could take years to achieve (Weiss & Pasley, 2009).

Heck et al. (2008) maintained that school principals must possess the leadership and vision to enact the required changes. Weiss and Pasley (2009) agreed that the improvement of mathematics should be supported by administrators at both the district and school levels and their roles and expectations should be defined. Weiss and Pasley also indicated that, at the district level, there needs to be an adoption of standards-based materials, funds made available for materials, teachers on special assignment, substitutes, assigned district days for professional development, and release time for classroom teachers. School-based administrators should provide release time for teachers to participate in professional development, have a budget to support the work, reduce classroom responsibilities of teacher leaders, give time and a location for teachers to collaborate, monitor the implementation, provide space for materials, work with teachers who are resistant, and inform parents about the importance of the program.

According to Weiss and Pasley (2009), the first phase for professional development is "setting the stage" (p. 9). At this initial stage, the professional-development leaders need to understand that there will be teachers who embrace the change but also those who do not want change (Weiss & Pasley, 2009). The leaders need to ensure that teachers know that the goal of the professional learning is to help students achieve. Student data may be used to justify and highlight the need for improvement and, therefore, for the professional development.

Weiss and Pasley (2009) also indicated that a trusting and respectful climate is essential, especially with secondary school teachers who may believe that they do not need any support because they know the mathematics content. The researchers also advised that the professional development should address diverse teachers' backgrounds, fit the school community's needs, and give teachers the opportunity to collaborate. These requirements were supported by Andreasen et al. (2007).

Wayne, Yoon, Zhu, Cronen, and Garet (2008) added that the professional development must allow for the active participation of teachers and meet their learning needs, but the authors emphasized that there must be an element of self-direction. Fogarty and Pete (2007) argued that sustained professional development should also be results oriented and have practical applications. According to Darling-Hammond and Richardson (2009), the professional development that is the most effective for teachers occurs over time and is part of a reform effort. Guskey and Yoon (2009) agreed and maintained that professional development must have a purpose and needs to focus on a combination of content and pedagogy.

Archibald, Coggshall, Croft, and Goe (2011), who stated similar components of effective professional development as those highlighted by the forgoing researchers, also indicated that professional development should be aligned with school goals, as well as state and district standards and assessments. Bonner (2006) stated that professional development must go beyond the one-shot, 1-day professional-development experience because teachers need access to ongoing professional development that models ways in which teachers can implement the changes in their classrooms. Similarly, Slavin (2013), who participated in reviews of studies of programs dedicated to assisting struggling readers, as well as studies related to primary and secondary reading and mathematics programs, concluded that greater levels of student achievement can be achieved by programs providing continuous professional development focused on instructional skills.

Learning Forward (2011), formerly the National Staff Development Council, developed the following standards for effective professional learning:

> Professional learning that increases educator effectiveness and results for all students (a) occurs within learning communities committed to continuous improvement, collective responsibility, and goal alignment; (b) requires skillful leaders who develop capacity, advocate, and create support systems for professional learning; (c) requires prioritizing, monitoring, and coordinating resources for educator learning; (d) uses a variety of sources and types of student, educator, and system data to plan, assess, and evaluate professional learning; (e) integrates theories, research, and models of human learning to achieve its intended outcomes; (f) applies research on change and sustains support for implementation of professional learning for long-term change; and (g) aligns its outcomes with educator performance and student curriculum standards. (p. 1)

Often, the efficacy of professional development for educators has been based on feedback from teachers rather than on improved student achievement (Desimone, 2011). Desimone (2011) suggested that more scientifically rigorous studies were needed to measure the effectiveness of professional-development initiatives. In many professional-development studies, there is an absence of data that directly links the effective professional-development models to student achievement; therefore, more research should be conducted in this area (Quint, 2011). In a literature review of more than 1,300 studies related to the effect of teacher professional development on student achievement, Yoon, Duncan, Lee, Scarloss, and Shapley (2007) found only nine studies that could be considered scientifically rigorous. Although studies have been conducted to try to link professional development of teachers to the increased achievement of their students, the numbers of teachers studied or the numbers of students taught by the teachers involved in the studies have been limited (Patel, Franco, Miura, & Boyd, 2012).

The Connected Mathematics Project

Between 1991 and 1996, the National Science Foundation provided funding to support the development of a mathematics curriculum for middle school students (Fey, Fitzgerald, Friel, Lappan, & Phillips, 2006). The program that was developed became known as the connected mathematics project, which focused on geometry, measurement, algebra, probability, and statistics (Fey et al., 2006). In 2000, the authors began a 5-year revision process of the program and developed the CMP2 (Fey et al., 2006; Lappan, Phillips, & Fey, 2007). The CMP2 is considered a standards-based curriculum because it adheres to the standards for mathematics instruction developed by the National Council of Teachers of Mathematics (2014). The following influences impacted the development of CMP2: “knowledge of theory and research; the authors’ imaginations and personal teaching and learning experiences; advice from teachers, mathematicians, teacher educators, curriculum developers, and mathematics education researchers; and advice from teachers and students who used pilot and field-test versions” (Michigan State University, 2014, p. 4).

The approach of the CMP2 program is based on the constructivist way of teaching

(Wilensky, 1995), including an emphasis on dialogue among students and on cognitive science in that it takes into account how students learn best during their middle school years. The CMP2 emphasizes the major themes in mathematics for students in Grades 6 to 8, provides opportunities for students to explore mathematics problems, and encourages teachers to use regular assessments to make data-based decisions regarding differentiation of instruction (Michigan State University, 2014).

There needs to be a balance between conceptual and procedural knowledge, and multiple representations are a vital part of learning (Michigan State University, 2014). The developers of CMP2 believed that the idea of conceptual understanding is the foundation for learning procedures and should occur before procedural practice. Schwartz (2008) argued that, after students understand the concept of division, they could practice problem solving using division procedures. Furthermore, students are expected be able to demonstrate their knowledge in a multitudes of ways, including symbolic expressions, written explanations, and graphs.

The CMP2 program is divided into four areas of mathematics: algebraic reasoning, geometric or measurement reasoning, rational numbers or proportional reasoning, and probability and statistical reasoning. These areas were included because of research literature recommending them and because of areas of deficiency for U.S. students on international assessments (Michigan State University, 2014). Within each of the 24 units of the curriculum, there are investigations composed of launch, explore, and summary sections (Eddy et al., 2008). During the launch phase of the lesson, the teacher introduces the problem to students with the intent to generate enthusiasm for the lesson.

In the exploration phase, students work on the problem either individually, in pairs, or in groups, while the teacher facilitates the conversations and helps answers any questions (Eddy et al., 2008). The lesson concludes with the summary phase, at which time students reflect upon their learning and share what they have learned during the lesson (Eddy et al., 2008). According to Choppin (2009), the expectation is that students gain a formal understanding of the concepts within the units, which cover approximately 4 to 6 weeks. Because the benefits that students may receive related to participating in the program are dependent on the content knowledge and instructional skills of the teachers, the project developers provided opportunities for professional learning (Michigan State University, 2014).

A study conducted by Patel et al. (2012) focused on professional-development workshops related to CMP2. The researchers believed that, as a result of the professional development, teachers would be better at recognizing and examining common student misunderstandings of the mathematical content and would also develop pedagogically sound practices. The results of this study did show that providing professional development to middle school mathematics teachers, which was focused on the curricular materials and pedagogy, improved their problem-solving and reasoning skills, as well as their content knowledge. However, a limitation of this study was that the number of participants in the study (i.e., 26 sixth-grade teachers, 18 seventh-grade teachers, and 13 eighth-grade teachers) was too small. The researchers stated that future studies should include more participants for these grades to determine if the gains are sustainable for these levels. In addition, the researchers stated that future studies should connect the gained mathematical content knowledge of the teachers to their students' achievement in mathematics, and the data collected should be analyzed longitudinally.

Garet et al. (2010) also stated that there are limited data on the connection between the professional development for middle school mathematics teachers and increased student achievement, despite the fact that there have been hundreds of studies since 2000 that tried to address this topic. Like Patel et al. (2012), Garet et al. indicated that their study of the effect of middle school mathematics professional development was limited by the study's sample size. Additionally, in a study conducted in 2011 to determine the effect of the professional development for middle school mathematics teacher on student achievement, Garet et al. recommended that there needs to be more professional development that places a direct emphasis on "common knowledge of mathematics" (p. xx). The CMP2 teacher guides provide more detailed information for each unit of the program, and the assessment resources booklet contains a variety of assessment materials for teachers. Other resources include the teaching transparencies booklet and additional practice and skills workbook, which provide transparencies and practice worksheets for teachers to use mathematics (Michigan State University, 2014).

Research on CMP2

Eddy et al. (2008) completed a randomized control trial study of CMP2 to determine if it would impact the mathematics achievement of 509 sixth-grade students in six schools in Oregon, Texas, and California. Only the Latino students in the treatment group performed better than Latino students in the control group. There were no other statistically significant differences between the students who participated in the CMP2 program and the 405 students who did not. Also, CMP2 students did not seem to be more willing to attempt new problems when compared to other students.

However, in classes in which teachers had high implementation fidelity of CMP2 and presented more problems to be completed than other teachers, students' mathematical reasoning skills improved. Eddy et al. (2008) stated that students may need more than 1 year of CMP2 in order to feel more confident attempting new problems. Teacher training, according to the authors, is an integral part of implementing the CMP2 program. Eddy et al. stated, "If done well, it has the potential to have meaningful impacts on student achievement; if done poorly, it has the potential to confuse and frustrate both students and teachers" (p. 46). Therefore, training to implement this program must go beyond a brief description of materials.

Eddy et al. (2008) did mention that their study had some limitations. One of the limitations was that schools were not randomly selected for the study. The schools in this study were the only schools that opted to participate in the study and follow all of the research protocols. Therefore, the authors noted that the results could be generalized only to schools with similar demographics and to teachers who were willing to implement a new curriculum. Another limitation was that teachers received the initial training just before the beginning of the school year. This meant that the teachers had little time to prepare the lessons or look at the materials of this new curriculum and program. The final limitation listed was that the training sessions were sometimes attended by as few as two teachers. This made it difficult to effectively model parts of the lesson, such as how to differentiate instruction and offer encouragement for students to accommodate their needs.

When Moyer, Cai, Laughlin, and Wang (2009) observed approximately 255 algebra lessons in sixth- to eighth-grade CMP2 classrooms and approximately the same number of traditional classrooms, the results showed that teachers who taught using the CMP2 program dedicated more time in the classroom for group learning. This meant that students were able to interact more with peers and to have more opportunities to understand the math concepts. Although students in traditional classes spent more time practicing procedural skills, students in the CMP2 class usually had more advanced conceptual skills.

In a later report, Moyer et al. (2011) offered more information about the study, which included the observation of 579 algebra-related lessons over 3 years in seven middle schools that had implemented CMP2 and seven middle schools that had not. The results indicated that students in the CMP2 classes participated in more cognitively demanding activities than students in the non-CMP2 classes. The authors pointed out that research (Hiebert & Grouws, 2007; Schoen, Cebulla, Finn, & Fi, 2003) has indicated that these activities enhance student achievement. Also, students in the non-CMP2 classes spent more time working individually on homework in class, but the students in the CMP2 classes spent more time discussing their solutions to homework problems in class. Use of calculators and manipulatives were the same in both types of classrooms, but the authors were surprised that the use of manipulatives was not higher than 10% of the time in the CMP2 classrooms. The use of physical manipulatives to solve problems is advocated in curricula adhering to the math standards (National Council of Teachers of Mathematics, 2014).

Unlike Moyer et al. (2009, 2011), Post et al. (2008) examined the academic achievement of 1,400 middle school students in five school districts in Minnesota that used either CMP2 or MathThematics (Billstein & Williamson, 1998) over a period of 3 years or more. The findings were not disaggregated by program. The results indicated that students performed above the national mean, as indicated by the normal curve equivalent, on the problem-solving and open-ended subtests of the ninth edition of the Stanford Achievement Test (Harcourt Brace & Company, 1997) but below the national norm on the procedures subtest. This test is a nationally normed, standardized, mathematics assessment.

The highest performing students in the Post et al. (2008) study were White students, students in advantaged socioeconomic groups, and students whose first language was English. In the only district using the new standards reference exam in mathematics (Wiley & Resnick, 1998), the students achieved above the national norms. Post et al. suggested that more research is needed to determine the following: “What kind of student mathematical outcomes do we value, and what are the dimensions of programs most likely to produce them?” (p. 210).

Tarr et al. (2008) also studied the impact of a standards-based curriculum on student achievement in a study of 2,533 students in 10 middle schools that used mathematics textbooks that were developed by publishers or with funding from the National Science Foundation, and the CMP2 was one of the programs used. The results indicated that, when teachers created a strong standards-based learning environment, students using the curriculum funded by the National Science Foundation performed better on the balanced assessment in mathematics (CTB/McGraw-Hill, 2003) than students using a publisher-developed curriculum. However, there was no difference between the two groups of students on the Terra Nova survey, which is a norm-referenced assessment. Tarr et al. suggested that continuous professional development is needed to ensure implementation fidelity.

In earlier research, Woodward and Brown (2006) had also found that the original version of CMP may not meet the needs of all students. The researchers compared the academic performance of 25 sixth-grade students participating in the program entitled Transitional Mathematics: Level 1 (West, 2004) and 28 sixth-grade students participating in the CMP for 1 academic year. All of the students were struggling learners who were considered “at risk for special education services” (Woodward & Brown, 2006, p. 151) in mathematics. The transitional mathematics program was developed with funding provided by grants from the U.S. Department of Education's Office of Special Education Program. The program, which was based on the standards created by the National Council of Teachers of Mathematics, was developed to meet the needs of struggling mathematics students. The students participating in the original version of CMP had additional practice in basic skills because educators were concerned about the lack of this practice in the program, but the practice work was unrelated to CMP. Pretests and posttests using the Terra Nova were completed to assess student academic performance.

Although there was no statistically significant difference between the two groups on the pretest, the posttest indicated that the students using the transitional mathematics program outperformed students using CMP. Moreover, on a survey of attitudes toward math completed by students, there was no statistically significant difference between the two groups on the pretest, but the posttest indicated that the students using the transitional mathematics program had more positive attitudes than students using the original version of CMP. Woodward and Brown (2006) suggested that the more favorable results for students in the transitional mathematics program resulted from the use of instructional methods designed for students with special needs.

Bouck, Kulkarni, and Johnson (2011) also studied the impact of the original version of CMP and a traditional mathematics program on the academic performance of struggling students. The researchers compared the achievement of 81 sixth-grade students, including 15 students with a disability, participating in CMP with 65 sixth-grade students, including 13 students with a disability, participating in a traditional mathematics program. Also included in the study were 70 seventh-grade students, including 12 students with a disability, participating in CMP and 79 sixth-grade students, including 10 students with a disability, participating in a traditional mathematics program. The disabilities identified in both grades were attention deficit hyperactivity disorder, autism, hearing impairment, and speech and language impairment. Students completed bimonthly assessments, which included both multiple-choice and open-ended problem-solving questions.

The results showed that there was no statistically significant difference between the students with and without disabilities in the traditional program and CMP. However, students without disabilities performed better than students with disabilities, and all students performed better on the multiple-choice questions than on the open-ended problem-solving questions. Bouck et al. (2011) suggested that more research is needed to determine the instructional needs of special education students but did note that, regardless of the curriculum used, students with disabilities need more practice with word problems.

Slavin, Lake, and Groff (2009) reviewed 100 studies of middle and high school mathematics programs to determine their impact on student achievement. The studies lasted for 12 weeks or more, included a control group that was chosen randomly or was matched to the intervention group, and the groups had similar pretest results. The mean effect size for the 40 studies of curricular programs, including the original version of CMP, was +0.03. Slavin et al. reported the six CMP studies had an effect size of -0.05. Moreover, the mean effect size for the 26 studies of the National Science Foundation textbooks was 0.00. This may have been because the programs have positive effects that were not assessed (Confrey, 2006; Schoenfeld, 2006; Slavin et al., 2009).

The effect size for the 38 computer-assisted instruction studies was only slightly larger (+0.10) than that of the studies of curricular programs. The largest mean effect size was +0.18 for 22 studies of instructional process programs, and, within this category, the nine cooperative learning studies had a mean effect size of +0.42. Slavin et al. (2009) argued that the three types of mathematics instruction are not mutually exclusive and may be most effective if implemented concurrently. The researchers also suggested that, based on the results of this review, “educators as well as researchers might do well to focus more on how the classroom is organized to maximize student engagement and motivation” (Slavin et al., 2009, p. 45).

Banilower (2010) found more positive results for CMP2, the second version of the program, in a 3-year longitudinal, quasi-experimental study of cohorts of sixth-grade students in 24 schools using CMP2 and 25 schools using a more traditional mathematics program. Over the 3 years, scores on the state assessments of students in the CMP2 group had positive improvement in their scores, but the control group did not. The difference between the groups was small but statistically significant. However, there was no difference in the 3-year scores on the balanced assessment of mathematics for students in the treatment and control groups. Students completed a survey at the start of Grade 6 and the end of Grades 7 and 8 regarding their attitudes toward mathematics. The students’ attitudes became less positive over the 3 years, but the decline was similar for both groups of students regarding their enjoyment of mathematics, intrinsic motivation to study mathematics, and confidence in studying mathematics. Regarding the students’ beliefs about the usefulness of mathematics, the CMP2 students’ positive beliefs declined more slowly than did those of students in the comparison group.

In a qualitative case-study format with an ethnographic perspective, Hansen-Thomas (2009) found that, when a teacher used discourse to encourage student dialogue in a CMP2 class, students whose first language was not English had greater academic success than when teachers predominantly favored the use of modeling. Also, Durkin (2005) found that the longer CMP2 was in use in a school district, the greater was the improvement of mean mathematics assessment scores for African American students.

Theoretical Framework for CMP2

The theoretical framework for CMP2 is the theory of constructivism or reform mathematics, which differs from traditional mathematics instruction. According to Ma and Singer-Glabella (2011), traditional mathematics instruction "is characterized by a routine of presenting a procedure, modeling an example problem, and then asking children to practice similar problems" (p. 8), but the constructivist approach, or reform mathematics instruction, "entails designing and posing tasks that call on children to reason about quantities, invent their own strategies, and discuss their thinking" (p. 8). The roots of this approach lie in the approaches of Dewey (1916) and Piaget (1954). Vygotsky's (1978) social-constructivist learning theory, which states that social interaction has a positive effect on the attainment of cognition, was also an important influence.

Ma and Singer-Glabella (2011) stated that there are significant differences between traditional mathematics instruction and constructivist, or reform, mathematics instruction. For example, in traditional mathematics instruction, students practice procedures that the teachers demonstrate to them. In contract, constructivist, or reform, mathematics instruction requires students to discuss problems with their classmates and determine the relationships between quantities and mathematical ideas. Brooks and Brooks (1999) presented five guiding principles of constructivism:

1. "Posing problems of emerging relevance to students" (p. 35). However, teachers can help students see the relevance.

2. “Structuring learning around primary concepts” (p. 46). The teacher should introduce students to the whole major concept and then to the parts.

3. “Seeking and valuing students’ points of view” (p. 60). The authors suggested, “Students’ points of view are windows into their reasoning” (p. 60).

4. Adapting to curriculum to address students’ suppositions. The teacher must first learn the students’ suppositions and then use them to engage the students in learning.

5. “Assessing student learning in the context of teaching” (p. 85). Informal assessment should be used as a formative tool to guide instruction rather than a summative tool.

According to Donovan and Bransford (2005), students in the mathematics classroom should be encouraged to express their ideas and talk about mathematics, take risks, and use their own ways to problem solve. Additionally, teachers should allow for the use of multiple strategies to solve a problem, take on the role of learner to learn what students know and do not know, and teach to allow for conceptual understanding rather than the sole understanding of processes and procedures. Freeman et al. (2013) indicated that, in the constructivist classroom, students are actively learning rather than passively listening to lectures, and this increases their performance on assessments.

Research Questions

The research questions generated were based on the review of the literature, the characteristics of the mathematics intervention at the target schools, and the information needs of the educators in the target school district. The following research questions were established to guide this applied dissertation:

1. Did the implementation of a professional-development intervention and a new mathematics curriculum impact the mathematics achievement of all students in Grades 6,

7, and 8 at the target middle schools on the state standardized assessments in the 2008-2009 to 2012-2013 school years when compared to the mathematics achievement of students prior to implementation?

2. Did the implementation of a professional-development intervention and a new mathematics curriculum impact the mathematics achievement of students in specific populations in Grades 6, 7, and 8 at the target middle schools on the state standardized assessments when compared to the mathematics achievement of students prior to implementation?

3. What are teachers' perceptions of the CMP2 program and the professional development provided?

Chapter 3: Methodology

Introduction

The problem to be addressed in this study was that it was necessary to assess the efficacy of a program implemented to improve the mathematics skills of middle school students in the target school district. The purpose of this study was to determine the efficacy of the CMP2 at the sixth-, seventh-, and eighth-grade levels using an ex post facto approach with an interrupted time-series design. Retrospective data were used to ascertain if the new mathematics curriculum impacted the mathematics achievement of students on the state standardized assessments when compared to the school years before implementation of the program. This chapter includes a description of the participants, data-collection instruments, research design, procedures, and data analysis. The limitations are also included.

Participants

For this study, the participants were 40 core mathematics teachers who taught middle school mathematics in the target school district and who participated in the professional-development training and then implementation for the intervention. Over the course of 3 years, all of the middle school mathematics teachers participated in the professional learning program. Grade 6 mathematics teachers participated in the 2008-2009 school year, Grade 7 mathematics teachers participated in the 2009-2010 school year, and Grade 8 mathematics teachers participated in the 2010-2011 school year. At the end of each initial year of training, these teachers completed a questionnaire regarding the program, the professional development received, and how they believed the program had begun to impact students in their classrooms.

Although middle school student data were gathered and analyzed, they were retrospective, deidentified data; therefore, the students were not direct participants in this study. There was a comparison of mathematics CMT scores for students in Grades 6, 7, and 8 prior to the mathematics intervention and then for the years with the intervention. Data were gathered for overall student achievement of middle school students in the district as well as for students who are listed in the following demographic categories: gender, African American, Hispanic, White, Asian American, free or reduced meals, special education, and English-language learners.

The demographics for middle school students completing the mathematics portion of the CMT for each year can be found in Item 1 of Appendix A. A chi-square test was performed to determine if there was a significant difference between the comparison group (i.e., students prior to the intervention) and the treatment group (i.e., students after the intervention). Initially developed by Karl Pearson in 1900, the chi-square test was used to "test the goodness of fit" (Franke, Ho, & Christie, 2012, p. 449) for frequency curves and later, in 1904, was extended to test for independence between rows and columns (Franke et al., 2012). According to Franke et al. (2012), the Pearson chi-square tests are "one of the most common sets of statistical analyses in evaluation and social science research" (p. 449). The information in Item 2 of Appendix A indicates that no statistically significant difference existed in the demographics between the comparison group and the treatment group.

Instruments

Academic performance. The CMT data regarding the mathematics achievement of all middle school students in the district were gathered to answer the first two research questions posed. According to the interpretive guide of the Connecticut State Department of Education (2013), the mathematics portion of the CMT was a criterion-reference test that assessed how well students were doing on skills or content strands important for student mastery. Content experts and practicing educators identified these skills or content. This mathematics assessment was administered in three sessions for students in Grades 5 through 8. These three sessions included multiple-choice and open-ended test items from 25 content strands aligned with the content and performance standards delineated in the state's mathematics curriculum standards for prekindergarten through 8.

Before the fourth-generation CMT was introduced in 2006, the state department of education employed assessment and evaluation concepts to examine the mathematics test items to ascertain if they were consistent with state content strands and standards (Hendrawan & Wibowo, 2011). The results, which confirmed a congruent match, helped to confirm the content validity of the assessment. Moreover, the reliability coefficients, using Cronbach's (1951) alpha measure of internal consistency, are set at 0.90 for the significant cut points of the test (Hendrawan & Wibowo, 2011), and this is considered to be a high rating (George & Mallery, 2003; Tavakol & Dennick, 201l).

Students who complete the mathematics portion of the CMT received a total scale score for mathematics. The scale scores were based on the raw scores (i.e., number of points earned), and then the raw scores were converted to scale scores. This was to ensure an accurate comparison of student performance between the different forms of the test. According to the interpretive guide of the state department of education, psychometric procedures were used to make sure that the scale score represents the same level of performance regardless of the test form.

Scores from the mathematics portion of the CMT for middle school students in the target school district were used for two purposes. First, the middle school mathematics scores were analyzed for the overall performance of the city's middle school students in Grades 6, 7, and 8 for the years prior to the intervention and for the years after the intervention. Next, middle school mathematics scores by demographic category were analyzed prior to the invention and for the years following the intervention. Additionally, using the information gleaned from the demographic categories both prior to the intervention and after, there was an analysis of the achievement gap in the school district. As stated previously, the achievement gap is the difference in achievement between the highest performing students and the lowest performing students.

Teacher perceptions. Data from a second instrument, a questionnaire completed anonymously by the middle school mathematics teachers (see Appendix B), was used to help answer the third research question regarding teachers' perceptions of the new mathematics program, how it impacted their students during the first year of implementation, and their perceptions of the professional development they received for this intervention. As previously stated, this survey was completed by the mathematics teachers at the conclusion of the first year of training and implementation of the intervention. The teachers who participated in the survey were core mathematics teachers who participated in the training and teaching of the CMP2.

The questionnaire included 10 statements and a place for teachers to provide additional comments. Eight of the 10 statements used a 4-point Likert-type rating scale that ranged from *strongly agree* to *strongly disagree*. This scale is named after the inventor and psychologist, Rensis Likert (1932), and is one of the most used scales to measure attitudes and perceptions (Balasubramanian, 2012). The scale that was used in the teacher questionnaire was a forced-choice scale that had no neutral choice (Trochim, 2006a, 2006b). The use of this type of a symmetric agree-disagree scale means that each respondent must specify a level of agreement or disagreement (Gall, Gall, & Borg, 2014).

Regarding the other two statements on the questionnaire, one asked teachers to respond affirmatively or negatively, and one asked teachers to choose from *too much, just right,* or *too little.* The questionnaire was developed by the researcher to provide teachers with a voice about the professional development they were receiving, to gain insight on how best to support teachers the following year to ensure implementation with fidelity, and to gauge teachers' perceptions of the intervention.

Lodico, Spaulding, and Voegtle (2010) stated that a questionnaire developed by the researcher is valuable because it can be written for the specific purpose of the research, the unique setting, and program being investigated. De Vaus (2002) and Korb (2012a, 2012b) suggested that there should be the establishment of content validity for the questionnaire; therefore, after this survey was developed, it was reviewed by the six district mathematics coaches for question clarity and content. Revisions were made to the survey based on the feedback from the mathematics coaches. According to Gall et al. (2014), because researchers are more interested in group than in individual means, the validity and reliability standards for surveys are most often less rigorous than those for summative assessments.

Procedures

Data collection began after approval was given by the school district's research department and the university's Institutional Review Board provide. The retrospective, composite school achievement data were gathered for the state test (i.e., CMT) for middle school students in Grades 6, 7, and 8 from the state department of education's public website. Additional composite school data regarding cohort groups and the anonymous retrospective survey data were gathered from the target school district's administrators. Additionally, the anonymous retrospective survey data were gathered from the target school district and analyzed.

Design. As indicated in Chapter 1, an ex post facto, quasi-experimental approach with an interrupted time-series design was used to answer Research Questions 1 and 2. Gay, Mills, and Airasian (2009) stated that an ex post facto approach may be used to determine the reason for the change in the group of individuals. Cohen, Manion, Morrison, and Morrison (2000) defined ex post facto data as data gathered "after the fact or retrospectively" (p. 205). This design identifies the relationship between the independent variable and dependent variable and represents the area in which the researcher has no control over the independent variable; therefore, the research is nonexperimental (Gall et al., 2014). For this research study, the independent variable was the mathematics intervention (i.e., CMP2) and the dependent variable was mathematics academic achievement of middle school students.

According to Creswell (2012), an interrupted time-series design is used when studying one group over time, obtaining numerous pretest measures, administering an intervention, and then measuring the outcomes (i.e., posttests) over a period of time. McDowall (2004) and Lewis-Beck, Bryman, and Liao (2004) added that an interrupted time-series design may estimate the causal effect of an isolated intervention, which separates the time period into two parts: preintervention and postintervention. A data analysis is completed to compare the means of the dependent variable for the two periods.

For this research design, there was a treatment group and a comparison group, but the participants were not randomly assigned, and there was one intervention studied. Both groups in this study consisted of all the middle school students in the district who participated in the CMT: The first group (i.e., the comparison group) attended target district schools prior to the intervention, and the second group (i.e., the treatment group) attended target district schools after implementation of the intervention. Data from all the public middle school students in the school district who took the state tests for the years prior to the intervention (i.e., the comparison group) and after the intervention (i.e., the treatment group) were used. Data included the percentage of all students and students by subgroup achieving at each of the levels of below basic, basic, proficient, goal, and advanced on the state test.

To answer Research Question 3, a survey design, which is a nonexperimental, quantitative research approach (Creswell, 2012), was used to determine teachers' perceptions of the implementation of the intervention and their perceived effectiveness of the intervention. According to Wolf (1978), the purpose of conducting the survey is to establish the social validity of the intervention. Wolf claimed that social validity includes "the social significance of the goals, the social appropriateness of the procedures, and the social importance of the effects" (p. 207). Additionally, Carter (2009) stated, "The most frequent method for determining the degree of acceptance for a procedure or program has been to ask those receiving, implementing, or consenting to a treatment about their opinions of the treatment" (p. 2).

Data analysis. To determine the mathematics academic achievement of middle school students before and after implementation of the intervention, pretest archival data and posttest data from the CMT were analyzed. For Grade 6, the pretest archival data were analyzed for 2005 through 2008, and the posttest data were analyzed for 2009 through 2013. For Grade 7, the pretest archival data were analyzed for 2005 through 2009, and the posttest data were analyzed for 2010 through 2013. For Grade 8, the pretest archival data were analyzed for 2005 through 2010, and the posttest data were analyzed for 2011 through 2013.

Data were compared for overall achievement for the years prior to and after the intervention and also for achievement by category (i.e., specific groups) prior to and after the intervention. Fisher's exact test of independence was performed to determine any statistically significant differences in the means, and the outcome of this analysis indicated whether there was a possible relationship between the independent variable (i.e., the CMP2 intervention) and dependent variable (i.e., mathematics academic achievement of middle school students). As indicated in the limitations, this relationship was only suggested. Fisher's exact test of independence was utilized because researchers have indicated that it results in a precise probability value when used for 2 x 2 contingency tables (Cramer & Howitt, 2004; McDonald, 2009; Wong, 2011).

Also, Fisher's exact test of independence was performed to determine the statistical significance of preimplmentation and postimplementation differences in the achievement gap between White students and both African American and Hispanic students, as well as between economically disadvantaged students and all students. Economically disadvantaged students were compared to all students because the state department of education does disaggregate achievement information for students who are not economically disadvantaged.

In addition, the CMT vertical scales were used to analyze the CMT math data to determine growth of students across grade levels. The state department of education that developed the vertical scales indicated that individual vertical scale scores describe the same theoretical level of achievement for each grade (Connecticut State Department of Education, 2015). Therefore, these scores were used to compare students' scores in consecutive grades. An independent-samples *t* test was conducted to compare the treatment and comparison groups for improvement in CMT math-score growth across grades. The responses to the 10 questions concerning teachers' perceptions of the effectiveness of the intervention were analyzed to answer Research Question 3 using descriptive statistics. The responses were analyzed to determine frequencies and percentages of teachers choosing each response.

Summary

The problem to be addressed in this study was that the scores on the state assessment indicate that not all middle school students in an urban school district have the knowledge and skills needed to be mathematically proficient. The purpose of this study was to determine if the implementation of a professional-development intervention for a new mathematics curriculum impacted the mathematics achievement of students in Grades 6, 7, and 8 at the target middle schools according to the state standardized assessments in the 2008-2009 to 2012-2013 school years.

An ex post facto, quasi-experimental approach with an interrupted time-series design was used to answer the first two research questions about achievement in mathematics. Retrospective data were used to look at the overall mathematics achievement for the city's middle school students prior to the mathematics intervention and after the mathematics intervention. Additionally, data were analyzed for special populations prior to and after the mathematics intervention. To answer Research Question 3, teachers' perceptions of the intervention were solicited through a survey design, which was a nonexperimental, quantitative research approach. The retrospective, anonymous data were gathered and analyzed to determine teacher perceptions of the intervention.

Chapter 4: Results

Introduction

The purpose of this study was to determine if the implementation of a professional-development intervention and a new mathematics curriculum impacted the mathematics achievement of students in Grades 6, 7, and 8 on the state standardized assessments in the 2008-2009 to 2012-2013 school years at the target middle schools. An ex post facto, quasi-experimental approach with an interrupted time-series design was used to answer the first two research questions about achievement in mathematics. Retrospective state testing data from the state department of education's public website was used to look at the overall mathematics achievement for the city's middle school students prior to the mathematics intervention and after the mathematics intervention. Data were also analyzed for the various categories (i.e., subgroups) of students prior to and after the mathematics intervention. To answer the third question, teachers' perceptions of the intervention were solicited through a survey design, which involved a nonexperimental, quantitative research approach. The retrospective, anonymous data were gathered and analyzed to determine teacher perceptions of the intervention.

Results for Research Question 1

Did the implementation of a professional-development intervention and a new mathematics curriculum impact the mathematics achievement of all students in Grades 6, 7, and 8 at the target middle schools on the state standardized assessments in the 2008-2009 to 2012-2013 school years when compared to the mathematics achievement of students prior to implementation? Tables 2, 3, and 4 show the percentages of students in the comparison and treatment groups performing at each CMT level in mathematics for each middle school grade.

The years of implementation of the intervention were staggered, with the implementation occurring one grade level at a time. Grade 6 teachers received just-in-time professional development for the intervention as they were implementing it for the first time during the 2008-2009 school year. Therefore, the spring of 2009 was the first time that Grade 6 students took the CMT after receiving this intervention. The average percentage of Grade 6 students performing at the proficient level and above increased after the intervention from 74.2% to 84.9% (see Table 2).

Table 2

Percentage of Sixth Graders Performing at Each Level on Math Assessment

	Below basic		Basic		Proficient		Goal		Advanced	
Group	No.	%	No.	%	No.	%	No.	%	No.	%
Comparison										
2006	158	14.7	162	15.1	240	22.3	306	28.5	208	19.4
2007	125	12.0	115	11.1	239	23.0	328	31.5	233	22.4
2008	119	11.3	117	11.1	240	22.8	343	32.5	235	22.3
Treatment										
2009	59	6.2	110	11.6	192	20.3	325	34.4	259	27.4
2010	57	5.8	99	10.1	207	21.2	344	35.2	271	27.7
2011	43	4.5	83	8.6	150	15.6	338	35.1	384	36.2
2012	41	4.2	67	6.9	214	22.1	301	31.1	344	35.6
2013	38	3.8	76	7.6	206	20.5	313	31.2	371	37.0

Grade 7 teachers received just-in-time professional development for the intervention as they were implementing it for the first time during the 2009-2010 school year. Therefore, the spring of 2010 was the first time that Grade 7 students took the CMT after receiving this intervention. The average percentage of Grade 7 students performing at the proficient level and above increased after the intervention from 75.2% to 82.9% (see Table 3).

Grade 8 teachers received just-in-time professional development for the intervention as they were implementing it for the first time during the 2010-2011 school year. Therefore, the spring of 2011 was the first time that Grade 8 students took the CMT after receiving this intervention. The average percentage of Grade 8 students performing at the proficient level and above increased after the intervention from 75.2% to 83.2% (see Table 4).

Table 3

Percentage of Seventh Graders Performing at Each Level on Math Assessment

	Below basic		Basic		Proficient		Goal		Advanced	
Group	No.	%	No.	%	No.	%	No.	%	No.	%
Comparison										
2006	154	14.2	162	14.9	260	24.0	318	29.3	190	17.5
2007	142	13.2	161	15.0	225	21.0	327	30.5	217	20.2
2008	104	9.9	131	12.5	251	23.9	322	30.7	241	23.0
2009	72	7.1	122	12.0	247	24.3	328	32.2	248	24.4
Treatment										
2010	66	6.9	121	12.7	239	25.0	296	31.0	233	24.4
2011	47	4.8	122	12.5	211	21.7	352	36.2	241	24.8
2012	50	5.1	85	8.6	207	20.9	363	36.7	284	28.7
2013	62	6.2	114	11.3	235	23.4	341	33.9	253	25.2

Fisher's exact test of independence was performed to determine statistical significance of the differences between the treatment and comparison groups in the percentage of students achieving proficiency. As shown in Table 5, Fisher's exact test indicated that the differences were statistically significant for students in all three middle school grades, and the treatment group outperformed the comparison group.

Vertical-scale scores were used to analyze the CMT data for growth across grades of student cohort groups. According to the Connecticut State Department of Education (2015), vertical-scale score comparisons cannot replace but can enhance "the usual year-to-year comparisons based on the percentage of students scoring at each achievement level" (p. 27).

Table 4

Percentage of Eighth Graders Performing at Each Level on Math Assessment

	Below basic		Basic		Proficient		Goal		Advanced	
Group	No.	%	No.	%	No.	%	No.	%	No.	%
Comparison										
2006	165	15.1	157	14.3	237	21.6	324	29.6	213	19.4
2007	136	12.6	156	14.5	264	24.5	319	29.6	204	18.9
2008	128	12.1	160	15.1	245	23.2	320	30.3	204	19.3
2009	76	7.4	130	12.7	259	25.2	348	33.9	213	20.8
2010	69	6.6	133	12.9	216	21.1	374	36.5	224	21.9
Treatment										
2011	57	6.0	125	13.1	245	25.7	317	33.2	210	22.0
2012	49	5.1	113	11.6	261	26.9	327	33.7	220	22.7
2013	50	5.0	96	9.5	248	24.7	339	33.7	273	27.1

Table 5

Results of Test for Statistical Significance of Differences in Scores at Proficient Level

	Comparison group		Treatment group		
Grade	No.	%	No.	%	*p*
Sixth	2,352	74.2	4,123	84.9	< .0001
Seventh	3,174	75.2	3,255	82.9	< .0001
Eighth	3,969	75.2	2,440	83.2	< .0001

Tables 6 through 11 show the average vertical-scale scores of all students who took the test during that year. The Matched N Average represents the average vertical-scale score for only those students who had a score in the first and last years being analyzed (Connecticut State Department of Education, 2015). To determine the growth over the course of the 3 years, the average from the first year was subtracted from the average of the most recent year. This is the Matched N Growth (Connecticut State Department of Education, 2015).

In 2006, the cohort group was in Grade 6. In 2007, the students were in Grade 7. In 2008, the students were in Grade 8. These were years prior to the intervention. This cohort group had an average score of 521 in Grade 6, an average score of 544 in Grade 7, and an average score of 561 in Grade 8. Table 6 shows the average scale scores for each grade level and the Matched N Average, as determined by the Connecticut State Department of Education (2015). By subtracting the Grade 6 Matched N Average of 524 from the Grade 8 Matched N Average of 561, the result is a positive Matched N Growth of 37. Therefore, there was some growth during this time prior to the intervention.

Table 6

Average Vertical-Scale Scores, 2006-2008

Grade	Year	Average scale score	Matched N average	Matched N growth
Sixth	2006	521	524	
Seventh	2007	544	---	
Eighth	2008	558	561	37

In 2007, the cohort group was in Grade 6. In 2008, the students were in Grade 7. In 2009, the students were in Grade 8. These were also the years prior to the intervention. This cohort group had an average score of 529 in Grade 6, an average score of 550 in Grade 7, and an average score of 564 in Grade 8. Table 7 shows the average scale scores for each grade level and the Matched N Average, as determined by the Connecticut State Department of Education (2015). By subtracting the Grade 6 Matched N Average of 535 from the Grade 8 Matched N Average of 566, the result is a positive Matched N Growth of 31. Therefore, there was some growth during this time prior to the intervention.

Table 7

Average Vertical-Scale Scores, 2007-2009

Grade	Year	Average scale score	Matched N average	Matched N growth
Sixth	2007	529	535	
Seventh	2008	550	---	
Eighth	2009	564	566	31

In 2008, the cohort group was in Grade 6. In 2009, the students were in Grade 7. In 2010, the students were in Grade 8. These were also the years prior to the intervention. This cohort group had an average score of 530 in Grade 6, an average score of 554 in Grade 7, and an average score of 567 in Grade 8. Table 8 shows the average scale scores for each grade level and the Matched N Average, as determined by the Connecticut State Department of Education (2015). By subtracting the Grade 6 Matched N Average of 536 from the Grade 8 Matched N Average of 570, the result is a positive Matched N Growth of 34. Therefore, there was growth during these years prior to the intervention.

Table 8

Average Vertical-Scale Scores, 2008-2010

Grade	Year	Average scale score	Matched N average	Matched N growth
Sixth	2008	530	536	
Seventh	2009	554	---	
Eighth	2010	567	570	34

In 2009, the cohort group was in Grade 6. In 2010, the students were in Grade 7. In 2011, the students were in Grade 8. In Grade 6, the students participated in the intervention for the first time. At each grade level, the teachers were teaching the intervention for the first time. This cohort group had an average score of 539 in Grade 6, an average score of 554 in Grade 7, and an average score of 568 in Grade 8. Table 9 shows the average scale scores for each grade level and the Matched N Average, as determined by the Connecticut State Department of Education (2015). By subtracting the Grade 6 Matched N Average of 541 from the Grade 8 Matched N Average of 571, the result is a positive Matched N Growth of 30. Therefore, there was growth during this time period, which was the first year of the intervention for each grade level.

Table 9

Average Vertical-Scale Scores, 2009-2011

Grade	Year	Average scale score	Matched N average	Matched N growth
Sixth	2009	539	541	
Seventh	2010	554	---	
Eighth	2011	568	571	30

In 2010, the cohort group was in Grade 6. In 2011, the students were in Grade 7. In 2012, the students were in Grade 8. Students participated in the intervention all 3 years, and teachers were all in their second year of teaching the intervention. This cohort group had an average score 541 in Grade 6, an average score of 558 in Grade 7, and an average score of 569 in Grade 8. Table 10 shows the average scale scores for each grade level and the Matched N Average, as determined by the Connecticut State Department of Education (2015). By subtracting the Grade 6 Matched N Average of 544 from the Grade 8 Matched N Average of 572, the result is a positive Matched N Growth of 28. Therefore, growth continued during this time period.

In 2011, the cohort group was in Grade 6. In 2012, the students were in Grade 7. In 2013, the students were in Grade 8. Students participated in the intervention all 3 years, and teachers were all in their third year of teaching the intervention. This cohort group had an average score of 550 in Grade 6, an average score of 563 in Grade 7, and an average score of 573 in Grade 8. Table 11 shows the average scale scores for each grade level and the Matched N Average, as determined by Connecticut State Department of Education (2015). By subtracting the Grade 6 Matched N Average of 552 from the Grade 8 Matched N Average of 577, the result is a positive Matched N Growth of 25. Therefore, there was continued growth during this time period.

Table 10

Average Vertical-Scale Scores, 2010-2012

Grade	Year	Average scale score	Matched N average	Matched N growth
Sixth	2010	541	544	
Seventh	2011	558	---	
Eighth	2012	569	572	28

Table 11

Average Vertical-Scale Scores, 2011-2013

Grade	Year	Average scale score	Matched N average	Matched N growth
Sixth	2011	550	552	
Seventh	2012	563	---	
Eighth	2013	573	577	25

Table 12 shows the years before and after intervention, the average scale score for each grade level and year, and the Matched N Growth for each year. Although the Matched N Growth declined over the years, the average scale score for each grade level increased. The average scale score for Grade 6 from 2006 to 2013 increased by 19 points, and the average scale score for Grade 7 increased from 2006 to 2013 by 19 points. The average scale score for Grade 8 from 2006 to 2013 increased by 49 points. A paired *t* test for statistical significance was performed to determine whether the differences in the Matched N Growth of students between the comparison and treatment groups were statistically significant. The results of the paired-samples *t* test indicated that the Matched N Growth of students was significantly greater at. 05 for the comparison group than for the treatment group $t = 2.8014$, $p = 0.0487$.

Table 12

Average Scale Scores and Matched N Growth by Grade Level, 2006-2013

	Average scale scores			
Years	Grade 6	Grade 7	Grade 8	Matched N growth
2006 to 2008	521	544	524	37
2007 to 2009	529	550	564	31
2008 to 2010	530	554	567	34
2009 to 2011	539	554	568	30
2010 to 2012	541	558	569	28
2011 to 2013	550	563	573	25

The answer to Research Question 1 is that the implementation of a professional-development intervention and a new mathematics curriculum improved the mathematics achievement of all students in Grades 6, 7, and 8 on the state standardized assessments. However, the year-to-year growth of student performance on the assessment did not improve significantly after the mathematics intervention.

Results for Research Question 2

Did the implementation of a professional-development intervention and a new mathematics curriculum impact the mathematics achievement of students in specific populations in Grades 6, 7, and 8 at the target middle schools on the state standardized assessments when compared to the mathematics achievement of students prior to implementation? According to the Connecticut State Department of Education (2008), specific populations are students who are American Indian, Asian American, Hispanic, African American, and White, as well as students with disabilities, English-language learners, and students who are economically disadvantaged. Each specific population is counted in a school's or district's scores if there are 40 or more students of the specific population in the grades tested.

For the urban district in this study, the following specific populations included 40 or more students in Grades 6, 7, and 8: African American, Hispanic, White, and Asian American students, as well as special education students, English-language learners, and students who were economically disadvantaged. Table 13 shows the percentage of sixth graders in each subgroup who scored at or above proficient on the CMT in math.

Table 13

Percentage of Sixth Graders by Subgroup Scoring Proficient on Math Assessment, 2006-2013

	Comparison group				Treatment group					
Subgroup	2006	2007	2008	Mean	2009	2010	2011	2012	2013	Mean
African American	40.0	62.2	64.2	55.4	62.8	70.9	67.6	77.8	76.7	71.2
Hispanic	62.8	65.9	69.6	66.1	77.1	75.6	82.9	86.2	83.6	81.1
White	87.9	89.8	86.6	88.1	92.7	95.4	96.4	95.9	97.0	95.5
Asian American	87.3	84.3	96.2	89.3	96.9	97.0	97.0	95.5	97.1	96.7
ED	50.5	62.5	65.3	59.4	70.6	74.0	78.0	82.7	80.7	77.2
SPED	24.0	27.0	26.5	25.8	62.1	54.2	63.9	70.0	67.4	63.5
ELL	43.3	38.6	44.7	42.2	48.5	51.2	61.8	63.0	62.9	57.5
Female	70.6	78.4	77.0	75.3	84.5	85.5	88.0	86.9	89.0	86.8
Male	69.8	75.6	78.2	74.5	79.8	82.7	85.8	90.8	88.3	85.5

Note. ED = Economically disadvantaged. SPED = Special education. ELL = English-language learner.

Table 14 shows the percentage of seventh graders in each subgroup who scored at or above proficient on the CMT in math. Table 15 shows the percentage of eighth graders in each subgroup who scored at or above proficient on the CMT in math.

Table 14

Percentage of Seventh Graders by Subgroup Scoring Proficient on Math Assessment, 2006-2013

	Comparison group					Treatment group				
Subgroup	2006	2007	2008	2009	Mean	2010	2011	2012	2013	Mean
African American	47.3	46.9	60.1	68.8	55.8	62.6	70.7	70.6	65.9	67.5
Hispanic	59.6	60.9	68.0	71.5	65.0	73.0	73.5	81.6	78.2	76.6
White	87.2	88.5	90.5	91.7	89.5	92.0	94.0	95.0	94.3	93.8
Asian American	83.1	85.9	88.6	94.4	88.0	95.4	95.7	96.8	95.5	95.9
ED	51.5	52.6	64.3	66.8	58.8	67.5	70.3	78.0	72.4	72.1
SPED	31.0	24.5	32.7	50.9	34.8	58.5	51.1	50.0	47.5	51.8
ELL	40.0	34.2	50.5	37.8	40.6	42.6	36.1	53.7	43.7	44.0
Female	71.4	73.8	80.0	79.1	76.1	82.7	81.8	86.8	82.0	83.3
Male	70.3	69.7	75.3	82.7	74.5	78.2	83.4	85.9	82.9	82.6

Note. ED = Economically disadvantaged. SPED = Special education. ELL = English-language learner.

Fisher's exact test of independence was performed to determine the statistical significance of the differences in achievement for the students in the specific populations for both the comparison and treatment groups in each grade (see Appendix C). The Fisher's exact test indicated that the differences were statistically significant for Grade 6 students in all of the specific populations studied, and the treatment groups outperformed the comparison groups. The Fisher's exact test indicated that the differences were statistically significant for Grade 7 students in all of the specific populations studied, and the treatment groups outperformed the comparison groups, except for special education students and English-language learners. The Fisher's exact test indicated that the differences were statistically significant for Grade 8 students in all of the specific populations studied, and the treatment groups outperformed the comparison groups, except for English-language learners.

Table 15

Percentage of Eighth Graders by Subgroup Scoring Proficient on Math Assessment, 2006-2013

	Comparison group						Treatment group			
Subgroup	2006	2007	2008	2009	2010	Mean	2011	2012	2013	Mean
African American	43.0	49.0	49.6	60.7	67.1	53.9	61.9	72.5	72.7	69.0
Hispanic	59.6	60.9	68.0	71.5	65.0	73.0	73.5	81.6	78.2	76.6
White	61.4	64.6	62.4	72.0	73.1	66.7	74.3	75.5	95.5	94.3
Asian American	91.7	82.3	90.6	93.9	95.7	90.8	92.9	92.8	92.4	92.7
ED	54.2	56.1	55.2	67.5	67.8	57.7	67.6	73.8	76.2	72.5
SPED	33.0	34.5	23.5	50.0	44.6	37.1	74.5	52.4	60.0	62.3
ELL	41.0	46.3	35.3	42.4	34.2	39.8	35.2	46.2	48.5	42.1
Female	69.8	72.6	72.7	82.3	78.2	75.1	83.0	83.6	85.6	84.1
Male	71.4	73.2	72.8	77.7	82.8	75.6	78.8	83.0	85.3	82.4

Note. ED = Economically disadvantaged. SPED = Special education. ELL = English-language learner.

As shown in Tables 16 and 17, the Fisher's exact test of independence indicated that a statistically significant achievement gap existed between White students and both African American and Hispanic students before implementation of the CMP2 intervention and persisted after implementation of the curriculum. White students outperformed both groups.

Table 16

Results of Test for Significant Differences in Proficient Scores for African American and White Students

	African American		White		
Grade	No.	%	No.	%	*p*
Preimplementation					
Sixth	373	55	1,208	88	< .0001
Seventh	500	56	1,657	89	< .0001
Eighth	612	54	2,319	89	< .0001
Postimplementation					
Sixth	681	71	1,890	96	< .0001
Seventh	525	67	1,468	94	< .0001
Eighth	390	76	1,115	95	< .0001

Table 17

Results of Test for Significant Differences in Proficient Scores for Hispanic and White Students

	Hispanic		White		
Grade	No.	%	No.	%	*p*
Preimplementation					
Sixth	601	66	1,208	88	< .0001
Seventh	786	65	1,657	89	< .0001
Eighth	1,000	67	2,319	89	< .0001
Postimplementation					
Sixth	1,275	81	1,890	96	< .0001
Seventh	996	77	1,468	94	< .0001
Eighth	749	76	1,115	95	< .0001

As indicated by the data in Appendix D, there was a small reduction in the achievement gap for African American and Hispanic students. Table 18 shows that the Fisher's exact test of independence indicated that a statistically significant achievement gap existed between economically disadvantaged students and all students before implementation of CMP2 and persisted after implementation of the curriculum. All students outperformed economically disadvantaged students. However, as indicated by the data in Appendix E, there was a small reduction in the achievement gap for economically disadvantaged students.

Table 18

Results of Test for Significant Differences in Proficient Scores for Economically Disadvantaged and All Students

	Economically disadvantaged students		All students		
Grade	No.	%	No.	%	*p*
Preimplementation					
Sixth	783	59	2,352	74	< .0001
Seventh	1,026	59	3,174	75	< .0001
Eighth	1,290	60	3,969	75	< .0001
Postimplementation					
Sixth	1,789	76	4,123	85	< .0001
Seventh	1,381	72	3,255	83	< .0001
Eighth	1,001	73	2,440	83	< .0001

The answer to Research Question 2 is that the implementation of a professional-development intervention and a new mathematics curriculum improved the mathematics achievement of most students in specific populations in Grades 6, 7, and 8 on the state standardized assessments. However, special education students in Grade 7 and English-language learners in Grades 7 and 8 did not experience improved achievement.

Results for Research Question 3

What are teachers' perceptions of the CMP2 program and the professional development provided? An anonymous questionnaire asking teachers their opinions about the professional development was given to each middle school mathematics teacher during the last professional development session of the first year of implementation. Ten sixth-grade teachers responded to the questionnaire in the spring of 2009. The questionnaire data showed that the majority (80%) of the Grade 6 teachers were members of the Middle School Mathematics Curriculum Committee. This committee was composed of a group of teachers from the school district who work to develop district-wide assessments and curricular pacing guides for the district. Eighty percent of the Grade 6 teachers strongly agreed or agreed that the amount of professional development they received was just right. Also, the results of the aggregated answers recorded in Table 19 indicate that 90% of respondents believed that the professional development was helpful to them and helped them grow as educators.

Table 19

Responses of Sixth-Grade Teachers Regarding the Professional Development and Math Program

	SA or A		D or SD		NR	
Statement	No.	%	No.	%	No.	%
1. The professional development I received so far this year has been helpful to me in implementing the standards-based math program.	9	90	1	10	0	0
2. I have changed some of my instructional strategies and approach based on the professional development I have received.	8	80	1	10	1	10
3. The professional development provided to me this year has allowed me to grow as an educator.	9	90	1	10	0	0
4. I have seen an increase in students' use of math vocabulary in my class.	9	90	1	10	0	0
5. I have seen an increase in the amount of mathematical communication and explanation students exhibit, whether verbal or written, in my class this year.	8	80	2	20	0	0
6. I have seen an increase in my students' willingness and ability to work together in my class this year.	9	90	1	10	0	0
7. The curriculum provides a consistent, coherent, and rigorous curriculum compared to curriculum in previous years.	6	60	1	10	3	30
8. I believe that the implementation of a standards-based program will become easier each year I implement it.	9	90	1	10	0	0

Note. SA = Strongly agree. A = Agree. D = Disagree. SD = Strongly disagree. NR = No response.

Grade 6 teachers also responded positively to the impact that the professional-development program had on their students. Grade 6 teachers (90%) strongly agreed or agreed that they had seen an increase in the amount of mathematics vocabulary that their students were using and in the students' willingness and ability to work together. Furthermore, the Grade 6 teachers (80%) strongly agreed or agreed they saw an increase in students' mathematical communication, both verbal and in writing. Regarding the Grade 6 curriculum, 60% of Grade 6 teachers responded that they strongly agreed or agreed that the grade-level curriculum was consistent, coherent, and rigorous compared to curriculum in previous years.

The questionnaire was completed by 13 seventh-grade teachers in the spring of 2010. The questionnaire data show that more than three quarters of the Grade 7 teachers (77%) were members of the Middle School Mathematics Curriculum Committee. Ninety-two percent of the Grade 7 teachers strongly agreed or agreed that the amount of professional development they received was just right and, as shown in Table 20, 100% of the Grade 7 teachers strongly agreed or agreed that the professional development was helpful to them and helped them grow as educators.

Grade 7 teachers also responded positively to the impact that the professional-development program had on their students. All Grade 7 teachers strongly agreed or agreed that they had seen an increase in the amount of mathematics vocabulary that their students were using and an increase in students' mathematical communication, both verbal and in writing. Moreover, Grade 7 teachers (92%) strongly agreed or agreed that they saw an increase in their students' willingness and ability to work together. Regarding the Grade 7 curriculum, 85% of Grade 7 teachers strongly agreed or agreed that the grade level curriculum was consistent, coherent, and rigorous compared to curriculum in previous years.

Table 20

Responses of Seventh-Grade Teachers Regarding the Professional Development and Math Program

	SA or A		D or SD		NR	
Statement	No.	%	No.	%	No.	%
1. The professional development I received so far this year has been helpful to me in implementing the standards-based math program.	13	100	0	0	0	0
2. I have changed some of my instructional strategies and approach based on the professional development I have received.	13	100	0	0	0	0
3. The professional development provided to me this year has allowed me to grow as an educator.	13	100	0	0	0	0
4. I have seen an increase in students' use of math vocabulary in my class.	13	100	0	0	0	0
5. I have seen an increase in the amount of mathematical communication and explanation students exhibit, whether verbal or written, in my class this year.	13	100	0	0	0	0
6. I have seen an increase in my students' willingness and ability to work together in my class this year.	12	92	1	8	0	0
7. The curriculum provides a consistent, coherent, and rigorous curriculum compared to curriculum in previous years.	11	85	2	15	0	0
8. I believe that the implementation of a standards-based program will become easier each year I implement it.	13	100	0	0	0	0

Note. SA = Strongly agree. A = Agree. D = Disagree. SD = Strongly disagree. NR = No response.

The questionnaire was completed by 17 eighth-grade teachers in the spring of 2011. The data indicated that only 59% of the Grade 8 teachers were members of the Middle School Mathematics Curriculum Committee. Only 12% of the Grade 8 teachers stated that the amount of professional development that year, 42 hours, was just right and 76% of the Grade 8 teachers stated that the amount of professional development was not enough. However, as indicated in Table 21, 100% of the Grade 8 teachers strongly agreed or agreed that the professional development helped them implement the program, 94% strongly agreed or agreed they had changed some of their instructional strategies and approaches to teaching mathematics, and 88% strongly agreed or agreed that the professional development helped them grow as educators.

Table 21

Responses of Eighth-Grade Teachers Regarding the Professional Development and Math Program

	SA or A		D or SD		NR	
Statement	No.	%	No.	%	No.	%
1. The professional development I received so far this year has been helpful to me in implementing the standards-based math program.	17	100	0	0	0	0
2. I have changed some of my instructional strategies and approach based on the professional development I have received.	16	94	1	6	0	0
3. The professional development provided to me this year has allowed me to grow as an educator.	15	88	2	12	0	0
4. I have seen an increase in students' use of math vocabulary in my class.	16	94	0	0	1	6
5. I have seen an increase in the amount of mathematical communication and explanation students exhibit, whether verbal or written, in my class this year.	14	82	2	12	1	6
6. I have seen an increase in my students' willingness and ability to work together in my class this year.	14	82	2	12	1	6
7. The curriculum provides a consistent, coherent, and rigorous curriculum compared to curriculum in previous years.	15	88	2	12	0	0
8. I believe that the implementation of a standards-based program will become easier each year I implement it.	17	100	0	0	0	0

Note. SA = Strongly agree. A = Agree. D = Disagree. SD = Strongly disagree. NR = No response.

Grade 8 teachers also responded positively to the impact this program had on their students. Grade 8 teachers strongly agreed or agreed that they had seen an increase in the amount of mathematics vocabulary their students were using (94%). Moreover, Grade 8 teachers (82%) indicated that they saw an increase in their students' willingness and ability to work together and an increase in students' mathematical communication, both verbal and in writing. Regarding the Grade 8 curriculum, 88% of Grade 8 teachers strongly agreed or agreed that the grade level curriculum was consistent, coherent, and rigorous when compared to curriculum in previous years.

The answer to Research Question 3 is that, although there were some differences in the teachers' perceptions regarding the amount of professional development they were offered, they indicated that the professional development they did receive improved their practice. The teachers also believed that their students benefited from the implementation of the CMP2 program.

Chapter 5: Discussion

Overview of the Study

The problem addressed in this study was that it was necessary to assess the efficacy of a program implemented to improve the mathematics skills of middle school students in the target school district. The program, first implemented in the 2008-2009 school year for Grade 6, 2009-2010 in Grade 7, and 2010-2011 in Grade 8, was implemented because the scores on the state assessment indicated that not all middle school students in an urban school district had the knowledge and skills needed to be mathematically proficient. Three years of data (i.e., Spring 2006, Spring 2007, and Spring 2008) from the fourth-generation CMT in mathematics for the five target middle schools in the district indicated that there were only two subgroups (i.e., Asian American and White) for which over 80% of students achieved at the proficient level of Level 3 or above (Connecticut State Department of Education, 2013).

According to Hayes (2010), there are five levels at which students are able to achieve for the state mastery test: advanced (i.e., exceptional content knowledge), goal (i.e., extensive content knowledge), proficient (i.e., adequate content knowledge), basic (i.e., partially developed content knowledge), and below basic (i.e., limited content knowledge). In an effort to address the levels of mathematics achievement on the state tests, an intervention (i.e., CMP2, a problem-centered curriculum), and a professional development program for teachers were implemented.

The purpose of this study was to determine the efficacy of the CMP2 at the sixth-, seventh-, and eighth-grade levels. It was important to improve students' mathematics skills because research indicates that mathematical knowledge impacts success in college, early career earnings, and growth for later earnings (Siegler et al., 2012). The National

Council of Teachers of Mathematics (2004) stated that mathematical skills are needed not only for employment, but also for activities in everyday life, such as making decisions about purchases and health insurance, as well as planning for retirement.

The participants in this study were 10 sixth-grade math teachers, 13 seventh-grade math teachers, and 17 eighth-grade math teachers who implemented the intervention and participated in the professional development. Although middle school student data were gathered and analyzed, they were retrospective, deidentified data; therefore, the students were not active participants in this study. An ex post facto, quasi-experimental approach with an interrupted time-series design was used to answer Research Questions 1 and 2. Regarding the impact of the intervention on the mathematics achievement of students, the treatment group was composed of those students who took the state standardized mathematics assessments after the implementation of the intervention.

For Grade 6 students, the assessment data after the intervention were collected beginning in the spring of 2009. For Grade 7 students, the assessment data after the intervention were collected beginning in the spring of 2010. For Grade 8 students, the assessment data after the intervention were collected beginning in the spring of 2011. Data were collected through the spring of 2013. The assessment data for the treatment group of students was compared to the assessment data for the comparison group of students who completed the state standardized mathematics assessments before the implementation of the intervention.

All middle school mathematics teachers from the target urban district were involved in the training and implementation of the CMP2 program. To learn to teach the new mathematics program, middle school mathematics teachers in the five target middle schools in the district participated in the professional-development program and received support. In the first year of implementation, teachers were provided with 42 hours of training in both content and pedagogy. After the completion of the first year of the professional-development program, the participating teachers completed a questionnaire to determine their perceptions of the implementation of the intervention and their perceived effectiveness of the intervention. During the second year of implementation, teachers were provided with 2 full days and 1 half day of classroom-embedded support from a CMP2 consultant. The consultant modeled lessons, viewed lessons to provide feedback, cotaught lessons with teachers, and provided specific examples of what teachers should work on in order to teach the program with fidelity.

In order to ensure that the program was implemented with fidelity, the program was phased in beginning with the professional development and implementation of the program for Grade 6 teachers. The Grade 6 teachers implemented the program beginning in the 2008-2009 school year. Grade 7 teachers implemented the program beginning in the 2009-2010 school year. Grade 8 implemented the program beginning in the 2010-2011 school year. An ex post facto, quasi-experimental approach with an interrupted time-series design was used to gather data. In addition, the middle school teachers who participated in the professional development for the intervention completed a questionnaire to determine teachers’ perceptions of the implementation of the intervention and their perceived effectiveness of the intervention.

Discussion of Results

Research Question 1. Did the implementation of a professional-development intervention and a new mathematics curriculum impact the mathematics achievement of all students in Grades 6, 7, and 8 at the target middle schools on the state standardized assessments in the 2008-2009 to 2012-2013 school years when compared to the mathematics achievement of students prior to implementation? The results presented in Chapter 4 showed that, overall, for all students in Grades 6, 7, and 8, there was an increase in the mean percentage of students scoring at the proficient and above levels on the state mathematics assessment when comparing the treatment and comparison groups of students.

For Grade 6 students, this mean percentage grew from 74.2% prior to the intervention to 84.9% after the implementation of the intervention. For Grade 7 students, the mean percentage grew from 75.2% prior to the intervention to 82.95% after the implementation of the intervention. For Grade 8 students, the mean percentage grew from 75.2% prior to the intervention to 83.2% after the implementation of the intervention. When Fisher’s exact test of independence was performed to determine statistical significance of differences between the treatment and comparison groups in the percentage of students achieving proficiency, the results indicated that the differences were statistically significant for students in all three grades.

Additionally, the vertical-scale scores for the mathematics assessment for the CMT showed that there was an increase in mathematics achievement for students in all grades as cohorts of students progressed from grade to grade (Connecticut State Department of Education, 2015). For each of the 3-year cohorts beginning in the 2006-2008 school year and ending in the 2011-2013 school year, there was a Matched N Growth ranging from 25 to 34 points. However, a paired *t* test comparing the differences between the matched N Growth of students in the comparison and treatment groups indicated that the Matched N Growth of students was significantly greater for the comparison group than for the treatment group.

The answer to Research Question 1 is that the implementation of a professional-development intervention and a new mathematics curriculum improved the mathematics achievement of all students in Grades 6, 7, and 8 on the state standardized assessments. However, the year-to-year growth of students' performance on the assessment did not improve significantly after the mathematics intervention.

The positive effects of CMP2 found in the current study were consistent with the findings from other studies. Monaghan (2013), in a study that included 3,346 middle school students in 66 schools, found that students using CMP2 performed significantly better on the Wisconsin Knowledge and Concepts Examination (Wisconsin Department of Public Instruction, 2014) than students using other programs. Additionally, Post et al. (2008) studied the academic achievement of 1,400 middle school students in five school districts in Minnesota over 3 years. Although their research included students using CMP2 and another mathematics program, the results from the study found that students performed above the national mean for the problem-solving and open-ended subtest of the Grade 9 Stanford Achievement Tests (Harcourt Brace & Company, 1997).

Ellis, Kupczynski, Mundy, and Jones (2012) also compared the mathematics achievement of Grade 6 and 7 students in two Texas middle schools using CMP with that of students in five schools using other programs. The researchers found that the students in the CMP program in both grades outperformed students in the other programs on the math portion of the Texas Assessment of Knowledge and Skills (Texas Education Agency, 2011). Ellis et al. maintained that the success of using the CMP program could be due to the fact that it is a strong inquiry-based instructional program in which students are provided with time to investigate, discuss, and think through problems and also because there is a robust teacher professional-development program.

However, the favorable impact of the CMP2 intervention is not supported by the results from some studies. The results from Martin et al. (2012) in a study of 35 schools implementing CMP2 in the mid-Atlantic region indicated that the effect of the use CMP2 on student achievement on the Terra Nova CAT-2 Basic Multiple Assessments Form (CTB/McGraw-Hill, 2003) was not statistically significant, effect size = 0.02, p = .777. Tarr et al. (2008) had similar findings when they studied 2,533 students in 10 middle schools. They found that there was not difference between the results for students who used CMP2 and those who did not on the norm-referenced test (i.e., the Terra Nova survey). Additionally, Woodward and Brown (2006) found that students using a transitional mathematics program outperformed those who were using the first version of CMP. In a review that assessed mathematics programs, Slavin et al. (2009) suggested that the negative effect size for the original version of CMP may have been because the positive effects of the program were not assessed.

The lack of significant improvement in the vertical growth trends of students in the treatment group in the current study is not consistent with the finding of Banilower (2010) that 24 schools using CMP2 had a more positive growth trajectory than 25 matched schools using a traditional mathematics program. Similarly, Cai, Nie, and Moyer (2010) found that, overall, the rate of growth from Grades 6 to 8 on open-ended tasks and translation tasks for students who using CMP was statistically significantly larger than that of students who were not using CMP. The 695 CMP students in 25 classes experienced higher mean gains in performance than 589 students not using CMP on questions related to problem conceptual understanding, as well as representing problem situations (Cai, Wang, Moyer, Wang, & Nie, 2011).

Although the non-CMP curricula placed a strong emphasis on computation and equation-solving problems, there was no significant difference between the two groups in these areas (Cai et al., 2011). The CMP curriculum includes problems that are cognitively more demanding (Moyer et al., 2011) and, as stated in Chapter 2, the implementation of these more demanding tasks is positively associated with student achievement in mathematics (Hiebert & Grouws, 2007). In a follow-up to the Cai et al. (2010, 2011) studies, Cai et al. (2013) found that 243 Grade 11 students who had used CMP in middle school outperformed the non-CMP students on a graphing task. The researchers suggested that CMP students might be more likely to attend to the mathematics of the problem due to its real-life context.

Research Question 2. Did the implementation of a professional-development intervention and a new mathematics curriculum impact the mathematics achievement of students in specific populations in Grades 6, 7, and 8 at the target middle schools on the state standardized assessments when compared to the mathematics achievement of students prior to implementation? The data showed that most of the specific populations at each grade level were positively impacted by the implementation of the CMP2 intervention. Fisher's exact test of independence showed that the only groups for which there was not a statistically significant difference in achievement between the treatment and comparison groups were Grade 7 special education students and Grade 7 and Grade 8 English-language learners.

For all other groups at all three grade levels, there was a statistically significant difference between the treatment and comparison groups for the percent of students who scored at or above proficient on the mathematics CMT. Furthermore, although the achievement gap between White students and both African American and Hispanic students was still statistically significant after implementation the CMP2 program in the target school district, there was a small reduction in the achievement gap for each of the ethnic minorities.

The answer to Research Question 2 is that the implementation of a professional-development intervention and a new mathematics curriculum did improve the mathematics achievement on the state standardized assessment for most of the students in specific populations in Grades 6, 7, and 8. However, special education students in Grade 7 and English-language learners in Grades 7 and 8 did not experience improved achievement. Furthermore, the achievement gap between White students and both African American and Hispanic students, as well as the economic achievement gap between economically disadvantaged students and all students, although still significant, were reduced.

The results from the current study do not support the research from Durkin (2005), who studied Grade 8 students in Delaware using CMP in the years from 1998 to 2004. Although Durkin's results indicated that the longer CMP was in use in a school district, the greater the improvement of mean mathematics assessment scores for African American and special education students, there were no statistically significant increases in the percentage of students meeting the state standard on the Delaware State Testing Program assessment.

On the other hand, similar results regarding the improved mathematics achievement of most of the students in specific populations were reported by Vega and Travis (2011), who found that a reform mathematics curriculum can have a positive impact on certain student groups. Similar to the results in this study, these researchers' results showed that students who used a reform mathematics program and were economically disadvantaged or African American outperformed those students who did not use a reform mathematics program. However, unlike the results in this study, Vega and Travis found that students with limited English-language skills who used a reform mathematics program also outperformed students who did not use a reform mathematics program. The results were inconclusive for the other specific student groups. This is similar to what Hansen-Thomas (2009) determined. Hansen-Thomas found that, when a teacher encouraged student dialogue in three sixth-grade CMP2 classes, English-language learners had greater academic success than in classes in which teachers predominantly used modeling.

Moreover, Post et al. (2008) found that the highest performing student groups in their study using the mathematics program were Caucasian students, economically disadvantaged students, and students whose first language was not English. Bouck et al. (2011) found that, in their research on the original version of CMP, the impact on achievement for students with disabilities was inconclusive. Their recommendation was that more research needs to be done on the instructional needs of special education students.

Cai et al. (2011) analyzed data from specific student groups using CMP2 and also found that there was an improvement in mathematics achievement for specific student groups. The findings were similar to what was found in the current study. The researchers determined that the use of CMP2 in the classroom improved the mathematics achievement for all ethnic groups for open-ended tasks and translation tasks. For these two tasks, African American and Hispanic students had at least as large a growth rate as White students and, for computation and equation-solving tasks, Hispanic students' growth was positive.

Additionally, research from Telese (2007), in a study of Grade 6 students in six Texas middle schools using CMP, showed similar results. Of the 1,250 students in the schools, 77% were Mexican American students. The results indicated that all students in all schools experienced improved achievement, and students in the school with the highest percentage of students of low socioeconomic status showed significant improvement in achievement on mathematics assessments. Telese suggested that the results indicated that CMP may have a positive effect on the mathematics skills of students in ethnic and economically disadvantaged groups.

In a randomized control trial study of the implementation of CMP2 with 509 sixth-grade students in six schools, Eddy et al. (2008) found that the achievement gap on the state assessment between Latino students and Caucasian students in the group using CMP2 was less than for the non-CMP group. Eddy et al. suggested that the CMP2 program may be able to reduce achievement gap between ethnic minority students and Caucasian students.

Research Question 3. What are teachers' perceptions of the CMP2 program and the professional development provided? An anonymous questionnaire asking teachers their opinions about the professional development was completed by each middle school mathematics teacher during the last professional-development session of the first year of implementation. Grade 6 teachers completed the questionnaire in the spring of 2009. Grade 7 teachers completed the questionnaire in the spring of 2010. Grade 8 teachers completed the questionnaire in the spring of 2011.

A smaller percentage of Grade 8 teachers (59%) than Grade 7 (77%) and Grade 6 teachers (80%) were members of the Middle School Mathematics Curriculum Committee. Although it is unclear as to why Grade 8 has less teacher representation on the curriculum committee, one reason could be that, at the time of the implementation, many of the Grade 8 mathematics teachers coached sports after school and were unable to commit time to the committee. Another reason could be that some of the teachers were veteran teachers who were at the end of their teaching careers and may have been less engaged in committee work.

In a classic work, Huberman (1993) suggested that late-career teachers may disengage from professional activities. Also, Hargreaves (2005), who interviewed 14 teachers with more than 20 years of experience, found that some of them indicated they had diminishing energy and were disinclined to support change initiatives. Similarly, when Masuda, Ebersole, and Barrett (2013) interviewed 16 teachers regarding their receptiveness of professional learning initiatives, although late-career teachers supported continuous learning, they were dissatisfied with compulsory professional-development sessions that they considered not pertinent to their work.

Most teachers agreed that the training was helpful in implementing the program, helped them grow as educators, and also helped them change their instruction. Also, most teachers in Grade 6 (80%) and Grade 7 (92%) agreed or strongly agreed that the amount of professional development was appropriate; however, 76% of the Grade 8 teachers, who had the same number of professional-development hours as teachers in Grades 6 and 7, stated that it was not enough. Most of the Grade 8 teachers at the time of the training and implementation of the intervention were certified to teach kindergarten through Grade 8 or Grades 7 through 12. Although it is unclear as to why only Grade 8 teachers felt that more professional development was needed, it is possible that one reason could be that the use of the lesson stages in CMP2 (i.e., launch, explore, summarize) was very different from the way that most Grade 8 teachers usually taught Therefore, they felt that more practice was needed.

Teachers' positive perceptions of the CMP2 professional development are supported by a study conducted by Siew, Amir, and Chong (2015) to determine the perceptions of 21 inservice and 25 preservice teachers regarding professional development for project-based science, technology, engineering, and mathematics strategies. The results showed that teachers believed that they gained many ideas about how to motivate students and encourage creative development. Additionally, Heck et al. (2008) used a questionnaire to determine that the extent of teachers' participation in professional development positively impacted their self-efficacy concerning their content knowledge and their readiness to implement the standard-based program. Similarly, Patel et al. (2012) found that teachers participating in a CMP2 professional-development program increased their content knowledge, reasoning skills, and problem-solving skills.

The favorable perceptions of the CMP2 professional development found in this study were supported by some of the findings of Smith (2015), who found that all teachers reported that their practices changed as a result of the professional development, and the changes included the physical classroom environment. The teachers believed that students worked together better, which improved their communication skills. On the other hand, Smith found that the Grade 9 teachers did not believe that the professional-development program related to interactive learning was effective, and the data showed that there was no improvement in student achievement after teachers participated in the program. The achievement data from the Smith research is contrary to the data analyzed in this study; students in this study did show an improvement in academic achievement overall and for some specific student groups.

There is strong research support for the positive benefits of professional development (Archibald et al., 2011; Learning Forward, 2011; Marsicano, Morrison, Moomaw, Fite, & Kluesener, 2015; Podhajski et al., 2009). According to Harris and Sass

(2011), professional development for middle school mathematics teachers that is content oriented has a positive effect on student achievement. Harris and Sass stated that these positive effects are because of an increase exposure to content and not because of pedagogical training.

McMeeking et al. (2012) were also able to show that there was a connection between professional development of middle school teachers and positive student achievement. Moreover, in a study of 259 teachers of Grades 4 and 5 and 184 teachers of Grades 6 to 8 in their first 6 years of teaching of mathematics, Campbell et al. (2014) found that teachers' mathematical content and pedagogical content knowledge was statistically significantly positively related to student achievement in state mathematical assessments. This research is also supported by Guskey and Yoon (2009), who stated that professional development must have a purpose and must include both content and pedagogy.

According to Martin et al. (2012), the professional development recommended by the CMP2 publishers and generally available to teachers to implementing the program consists of 5 days of professional development: 2 days during the summer and 3 days during the school year. These researchers also stated that, if there are teachers who have used CMP2 previously, these teachers mentor the new ones. Otherwise, an additional day of professional development is given during the school year for those new to the CMP2 program.

As noted in Chapter 1, the professional development and support for teachers in the target school district exceeded these recommendations. The professional development for teachers implementing CMP2 consisted of a 2-hour introduction to CMP2 during the spring prior to the year the program was implemented and then 6 hours of just-in-time training for each CMP2 book used during that first year of implementation. For the first year of implementation, the total amount of professional development for each mathematics teacher implementing the program was 42 hours. This level of training may have contributed to teachers' instructional skills and, as a consequence, helped increase student achievement. Providing several days of professional development is supported by Bonner (2006), who said that professional development cannot just be a 1-day experience if the expectation is that teachers will change the practices within their classrooms. Slavin (2013) also stated that professional development of teachers needs to be continuous.

Weiss and Pasley (2009) stated that there should be teacher leaders to assist with the professional development of teachers. Also, according to Reinke, Stormont, Herman, and Newcomer (2013), using coaches to support the acquisition of new instructional skills of teachers is associated with increased fidelity of implementation and also positive results for students. Without ongoing support, teachers will more likely to stop using the intervention. The teachers in the target school district have in-class support from a school-based mathematics coach and a consultant who had expertise in CMP2. The coaches began assisting teachers in the 2007-2008 school year and continued through the 2012-2013 school year. Their full-time job was to support teachers' instruction in the classroom.

Beginning in the 2013-2014 school year, the coaches became middle school mathematics support specialists who spend half of their time supporting teachers' instruction in the classroom and the other half working with struggling students. All the mathematics coaches attended the professional development with the teachers but also had additional sessions designed for their specific role, which was to help teachers. The mathematics coaches met for 6 hours in August, prior to the school year, to learn how to support teachers with the program. They also met weekly for 2 hours during the school year with the curriculum associate for secondary mathematics to discuss challenges, successes, and needs, as well as to provide support to one another and learn about best practices in mathematics. The use of mathematics coaches to support teachers with the implementation of CMP2 may also have contributed to the teachers' positive perceptions of CMP2 because they received individualized, classroom-embedded support.

Teachers in the target school district also responded positively regarding the impact of the CMP2 program on student skills. More than 80% of teachers in each grade level strongly agreed or agreed that they had observed an increase in the use of mathematics vocabulary by their students, an increase in the amount of mathematical communication and explanation (i.e., verbal or written), and an increase in students' willingness and ability to work together. Communication (i.e., verbal or written) and collaboration (i.e., the ability to work together) are two important skills that are said to be needed for the 21st century (Kyllonen, 2012; Larson & Miller, 2011).

According to the questionnaire responses, teachers in Grades 7 and 8 (85% and 88%, respectively) believed that the curriculum for CMP2 for their grade level was consistent, coherent, and rigorous when compared to the curriculum in previous years. Only 60% of Grade 6 teachers agreed with this, 30% of the Grade 6 teachers did not provide an answer, and one sixth-grade teacher disagreed. Grade 6 was the only level in which some teachers did not respond to this statement. The lack of responses and disagreement may be related to the initial belief of many Grade 6 teachers that the CMP2 program was too difficult for students. Because the questionnaire was completed in the first year of implementation, the teachers may have been unsure about the intervention. Therefore, they may not have had a definitive opinion for this statement at that time.

The findings in the study of CMP2 by Eddy et al. (2008) are primarily consistent with the positive perceptions of the program by the teachers in this study. The researchers' results indicated that the teachers believed that these student skills were best developed in the CMP2 program rather than the traditional program: (a) conceptual understanding, (b) mathematical problem solving, (c) application to real life, (d) communicating mathematical concepts, and (c) mathematical reasoning. Only for computational skills did the teachers believe that the traditional program was superior.

Martin et al. (2012) stated that the publisher of CMP2 recommended that students should have 50 minutes of mathematics instruction each school day in order to complete all the units in the school year. The target school district altered the middle school schedule to allow for 60 minutes of mathematics instruction per day to ensure that teachers were able to cover all the materials necessary to implement CMP2 with fidelity. This was 50 minutes per week more than the time recommended by the publisher. The additional time the district allotted for the mathematics classes could have contributed teachers' positive perceptions regarding CMP2 because teachers they had sufficient time to teach the program.

Implications of Findings

The data gathered to answer the research questions indicated that the implementation of the CMP2 curriculum significantly and positively impacted the mathematics skills of middle school students, as indicated by the number of students in the treatment group who scored at or above proficient on the state mathematics assessments. In addition, the teachers believed that CMP2 was having a positive effect on students' mathematics skills. Because of the gains in mathematics achievement and teachers' perceptions, the target school district should continue to use the curriculum.

The continued use of CMP2 and eventually the next version, CMP3, should help students acquire the skills needed to meet common core state standards for mathematics (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010) and the skills needed for the 21st century. The Partnership for 21st-Century Learning (2011) stated that 21st-century skills are “a broad set of knowledge, skills, work habits, and character traits that are believed by educators, school reformers, college professors, employers, and others to be critically important to success in today’s world” (p. 1).

Larson and Miller (2011) maintained that 21st-century skills are not something new, should not be overlooked, and should be incorporated into what is already being taught. Additionally, Kyllonen (2012) argued that there is an overlap between the common core state standards and 21st-century skills. The Partnership for 21st-Century Learning (2011) recommended that the adoption of the common core state standards should include not only the mastery of content, but also “critical thinking and problem solving, collaboration, communication and creativity and innovation” (p. 3).

The data gathered from the questionnaires showed that, overall, teachers were satisfied with the professional-development training they received to implement the CMP2 curriculum. Therefore, the classroom coaching support provided to the teachers should continue. Reinke et al. (2013) asserted that a benefit of coaching support is that it is differentiated to meet the specific needs of each teacher. Moreover, new teachers should participate in the same professional development as the teachers who originally implemented CMP2. Learning Forward (2011) indicated that support for learning must be sustained in order to establish deep-rooted changes in professional practice. The findings of a research report compiled by Darling-Hammond and Richardson (2009) revealed that effective professional development "is intensive, ongoing, and connected to practice; focuses on the teaching and learning of specific academic content; is connected to other school initiatives; and builds strong working relationships among teachers" (p. 46).

The schedule for professional development used in the CMP2 intervention should be repeated for the introduction of other programs in other academic areas and for CMP3, which is the next version of the mathematics program. The implementation should be staggered by grade level, just-in-time training for teachers should be provided during the first year of implementation, and coaches should provide classroom support for teachers. In addition, educators at the target school district should interview Grade 8 teachers to determine why they believed the level of CMP2 professional development was insufficient and if the teachers still believe that they need additional professional development sessions. Additional training could then be provided if needed, and the information gained should be used to inform future professional learning for Grade 8 teachers. Campbell et al. (2014) argued, "If the intent is to improve student mathematics achievement prior to high school in order to build a necessary base for students' future learning, then a key approach is to enhance the knowledge of their teachers" (p. 421).

Although the intervention of the CMP2 curriculum improved the overall mathematics achievement of students in all three middle school grades, it will be important for the school district educators to develop strategies to enhance the mathematics achievement of special education students in Grade 7 and English-language learners in Grades 7 and 8. Because both of these groups had improved achievement after CMP2 implementation in Grade 6 and special education students experienced improvement in Grade 8, it may be helpful to investigate whether there were varying levels of program implementation at each grade level. The U.S. Department of Education, Office of Planning, Evaluation and Policy Development, Policy and Program Studies Service (2011) stated that it is not possible to determine if negative results are related to program efficacy or inadequate implementation of the program unless implementation fidelity is rigorously measured. Other researchers have also expressed this view (Bailey, 2010; Lewis, Barrett, Sugai, & Horner, 2010; Obiakor, Harris, Mutua, Rotatori, & Algozzine, 2012; Rajan & Basch, 2012).

School district educators will also need to address the existing mathematics achievement gap between the identified ethnic minority groups and Caucasian groups, as well as that between all students and economically disadvantaged students, using research-based interventions. Because researchers have found that these gaps are also a persistent challenge at the state and national levels (Connecticut Commission on Educational Achievement, 2010; National Center for Education Statistics, 2014b; Van den Bergh et al., 2010), researchers have found some positive effects for initiatives addressing the issue (Strunk & McEachin, 2014).

Strunk and McEachin (2014) found that, when economically disadvantaged high school students spent time participating in organized activities in schools and communities, their mathematics achievement improved. The achievement gap could be diminished because this participation may act as resource compensation for the economically disadvantaged students. This is important because, as suggested by the Educational Opportunity Monitoring Project (2014), achievement gaps between ethnic groups may be partially attributed to socioeconomic inequalities between the groups. Strunk and McEachin found that California’s district assistance and intervention teams of experts, approved and financed by the state but contracted by school districts, were able to initiate reforms that contributed to the reduction of ethnic, socioeconomic, and language achievement gaps. These reforms were achieved in an environment of high-stakes accountability.

Limitations

Generally, there are limitations to all research that is ex post facto. According to Gay et al. (2009), some of these limitations are serious. The first limitation is that the apparent cause-and-effect relationship may not be what it seems; therefore, caution needs to be exercised when interpreting the results of this research. There could be other reasons for the causal connection among the multiple variables. The change in the one variable could actually be caused by another variable or by something that was unaccounted for (Gay et al., 2009). For example, as stated earlier, the middle school schedule was changed so that each academic class was 60 minutes and there were mathematics coaches in each middle school building whose task was to support teachers with the implementation of CMP2.

Additionally, during the early years of implementation, four of the five middle schools were involved in the Middle School Transformation initiative. In these four middle schools, students were placed in two academic groups (i.e., college preparatory and honors) compared to previous years when students were disaggregated in five different levels by achievement and the lower level classes were taught only elementary mathematics concepts. The intent of this initiative was based on the belief that all students can learn and, therefore, all students should be learning grade level content with any needed additional supports.

A second limitation for ex post facto research includes lack of manipulation of the independent variable by the researcher. Gall et al. (2014), Gay et al. (2009), and Leedy and Ormrod (2005) warned that, because the researcher does not manipulate the independent variable, the research is considered suggestive because the causal links are not as strong as determined with experimental research. Gay et al. stated that this lack of randomization, manipulation, and control factors make it difficult to establish cause-and-effect relationships with any degree of confidence. For this type of research, the participants in the group are already determined and the research is retrospective.

On the other hand, an ex post facto design can be vital to research. Johnson and Christensen (2010) and Gerber, Marek, and Martin (2011) stated that this design is important and can make a contribution to the educational research literature. Cohen et al. (2000) agreed that this approach does suggest probable causes or effects but does not confirm causality. Additionally, Lodico et al. (2010) stated that maturation is an internal validity threat when using an interrupted time-series research approach because changes in the participants may be due to “growth or maturation that can occur in physical, mental, or emotional functioning” (p. 244). Shaughnessy, Zechmeister, and Zechmeister (2014) maintained that any changes in the measuring instruments used and historical events are also possible threats to the internal validity of the interrupted time series.

There are also limitations regarding the use of questionnaires. Suter (2006) noted that, because the participants are self-reporting, the survey results are subject to respondent bias. Creswell (2012) proposed that a low response rate on the surveys could be a serious limitation. Measurement and representation errors could, according to Coughlan, Cronin, and Ryan (2009), be another limitation.

Recommendations for Future Research

As a governing state in the Smarter Balanced Assessment Consortium (2014b), Connecticut is involved in the development of the Smarter Balanced assessments (Smarter Balanced Assessment Consortium, 2014a), in English-language arts or literacy and mathematics, which are aligned to the common core state standards. Although these new assessments were first completed by students in Grades 3 to 8 and Grade 11 in the spring of 2014, no data regarding student performance on the assessment were provided to school districts. In the spring of 2015, however, students would again take the new assessments and data would be provided to the school districts in the summer. Therefore, research will need to be conducted to see how the implementation of CMP2, and the next version, CMP3, will impact student achievement on the new assessments and how the new assessments will impact the implementation of the mathematics curriculum.

Also, this study could be replicated in other school districts in the target state as well as in other states and the results compared to those in this study in order to determine the generalizability of the findings in a variety of settings. As suggested by other researchers (Eddy et al., 2008; Shin et al., 2013; Strunk & McEachin, 2014), it will be important that these studies examine the achievement gap between ethnic minority and White students to gain information that may be used to reduce the achievement gap.

Future research could also replicate the professional-development model used in this study for the training of middle school mathematics teachers in both the CMP2 and CMP3 curricula. The amount and duration of professional development in this study was beyond what was recommended by the publishers. Future research could be carried out to determine if extended professional learning improves student achievement. Moreover, as suggested by Reinke et al. (2013), additional research is needed to investigate whether sustained coaching, such as that available to teachers in this study, has a long-term effect on teachers' instructional skills. Lastly, future research should be conducted to determine if the model for professional development used in this study can transfer to other academic areas and other grade levels.

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Appendix A

Demographics and Fisher's Exact Test of Independence for

Treatment and Comparison Groups

Demographics and Fisher's Exact Test of Independence for

Treatment and Comparison Groups

Item 1: Demographics

	Comparison Group					
	2005-2006 *N*=1074		2006-2007 *N*=1040		2007-2008 *N*=1054	
	n	%	*n*	%	*n*	%
Female	537	50	500	48	518	49
Male	537	50	540	52	536	51
Black/African American	257	24	205	20	216	20
Hispanic/Latino	274	26	314	30	319	30
White/Caucasian	480	45	450	43	441	42
Asian	63	6	70	7	78	7
English Language Learners	127	12	127	12	85	8
Free/Reduced Lunch Eligible	483	45	411	40	432	41
Full Price Lunch	591	55	629	60	622	59
Special Education	96	9	100	10	102	10

	Treatment Group									
	2008-2009 *N*=945		2009-2010 *N*=978		2010-2011 *N*= 962-		2011-2012 *N*=967		2012-2013 *N*=1004	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Gender										
Female	459	49	470	48	483	50	480	50	492	49
Male	486	51	507	52	479	50	487	50	512	51
Black/African American	191	20	199	20	182	19	194	20	189	19
Hispanic/Latino	293	31	320	33	293	30	333	34	335	33

White/ Caucasian	396	42	392	40	419	44	369	38	403	40
Asian	65	7	67	7	66	7	67	7	68	7
English Language Learners	103	11	82	8	68	7	100	10	89	9
Free/Reduced Lunch Eligible	445	47	454	46	454	47	485	50	512	51
Full Price Lunch	500	53	524	54	508	53	482	50	492	49
Special Education	58	6	48	5	36	4	40	4	46	5

Item 2: Fisher's Exact Test of Independence

Fisher's Exact Test of Independence for Grade 6 Students for Specific Populations

	Comparison Group (2006, 07, 08)			Treatment Group (2009, 10, 11, 12,13)			Fisher's Exact Test	
	N	n	%	N	n	%	p	Significant
African American	678	373	55	955	681	71	< 0.0001	Yes
Hispanic	907	601	66	1574	1275	81	<0.0001	Yes
White	1371	1208	88	1979	1890	96	<0.0001	Yes
Asian American	211	189	90	333	322	97	0.0013	Yes
SPED	298	77	26	228	144	63	<0.0001	Yes
ELL	339	142	42	442	253	57	<0.0001	Yes
ED	1326	783	59	2350	1789	76	<0.0001	Yes
Female	1555	1166	75	2384	2070	87	<0.0001	Yes
Male	1613	1209	75	2472	2113	85	< 0.0001	Yes

Note. ED = economically disadvantaged; SPED = special education; ELL = English language learners

Fisher's Exact Test of Independence for Grade 7 Students for Specific Populations

	Comparison Group (2006, 07, 08, 09)			Treatment Group (2010, 11, 12,13)			Fisher's Exact Test	
	N	n	%	N	n	%	p	Significant
African American	893	500	56	779	525	67	< 0.0001	Yes
Hispanic	1204	786	65	1299	996	77	< 0.0001	Yes
White	1854	1657	89	1566	1468	94	< 0.001	Yes
Asian American	271	239	88	265	254	96	0.0013	Yes
SPED	292	102.2	35	201	104	52	0.0541	No
ELL	431	175	41	343	150	44	0.4201	No
ED	1750	1026	59	1918	1381	72	< 0.0001	Yes
Female	2088	1587	76	1933	1611	83	< 0.0001	Yes
Male	2135	1601	75	1989	1644	83	< 0.0001	Yes

Note. ED = economically disadvantaged; SPED = special education; ELL = English language learners

Fisher's Exact Test of Independence for Grade 8 Students for Specific Populations

	Comparison Group (2006, 07, 08, 09)			Treatment Group (2010, 11, 12,13)			Fisher's Exact Test	
	N	n	%	N	n	%	p	Significant
African American	1134	612	54	566	390	69	< 0.0001	Yes
Hispanic	1497	1000	67	749	76	77	< 0.0001	Yes
White	2319	2071	89	1165	1115	95	< 0.001	Yes
Asian American	322	293	91	205	190	93	0.0123	Yes
SPED	440	163	37	129	81	63	<0.0001	Yes
ELL	455	182	40	225	93	42	0.7406	No
ED	2141	1290	60	1380	1001	73	< 0.0001	Yes
Female	2573	1930	75	1461	1229	86	< 0.0001	Yes
Male	2702	2054	76	1460	1210	85	< 0.0001	Yes

Note. ED = economically disadvantaged; SPED = special education; ELL = English language learners

Appendix B

Teacher Questionnaire

Teacher Questionnaire

My Professional Development

1. The professional development I received so far this year has been helpful to me in implementing the standards-based math program.

   Strongly Agree Agree Disagree Strongly Disagree

2. I have changed some of my instructional strategies and approaches based on the professional development received.

   Strongly Agree Agree Disagree Strongly Disagree

3. The professional development provided to me this year, has allowed me to grow as an educator.

   Strongly Agree Agree Disagree Strongly Disagree

4. I have seen an increase in students' use of math vocabulary in my class this year.

   Strongly Agree Agree Disagree Strongly Disagree

5. I have seen an increase in the amount of mathematical communication and explanation students exhibit, whether verbal or written, in my class this year.

   Strongly Agree Agree Disagree Strongly Disagree

6. I have seen an increase in my students' willingness and ability to work together in my class this year

   Strongly Agree Agree Disagree Strongly Disagree

7. The sixth grade curriculum provides a consistent, coherent and rigorous curriculum compared to the curriculum used in previous years.

   Strongly Agree Agree Disagree Strongly Disagree

8. I believe that the implementation of a standards-based program will become easier each year I implement it.

Strongly Agree Agree Disagree Strongly Disagree

9. I was a member of the MS Math Committee or I have provided feedback to members of the committee regarding the math curriculum, lessons, assessments, etc.

Yes No

10. The amount of professional development so far this year has been:
Too Little Just Right Too Much

Additional comments:

Appendix C

Results of Fisher's Exact Tests for Students in Specific Populations

Results of Fisher's Exact Tests for Students in Specific Populations

Grade 6

	Comparison Group (2006, 07, 08)			Treatment Group (2009, 10, 11, 12,13)			Fisher's Exact Test	
	N	n	%	N	n	%	p	Significant
African American	678	373	55	955	681	71	< 0.0001	Yes
Hispanic	907	601	66	1574	1275	81	<0.0001	Yes
White	1371	1208	88	1979	1890	96	<0.0001	Yes
Asian American	211	189	90	333	322	97	0.0013	Yes
SPED	298	77	26	228	144	63	<0.0001	Yes
ELL	339	142	42	442	253	57	<0.0001	Yes
ED	1326	783	59	2350	1789	76	<0.0001	Yes
Female	1555	1166	75	2384	2070	87	<0.0001	Yes
Male	1613	1209	75	2472	2113	85	< 0.0001	Yes

Note. ED = economically disadvantaged; SPED = special education; ELL = English language learners

Grade 7

	Comparison Group (2006, 07, 08, 09)			Treatment Group (2010, 11, 12,13)			Fisher's Exact Test	
	N	n	%	N	n	%	p	Significant
African American	893	500	56	779	525	67	< 0.0001	Yes
Hispanic	1204	786	65	1299	996	77	< 0.0001	Yes
White	1854	1657	89	1566	1468	94	< 0.001	Yes
Asian American	271	239	88	265	254	96	0.0013	Yes
SPED	292	102.2	35	201	104	52	0.0541	No
ELL	431	175	41	343	150	44	0.4201	No
ED	1750	1026	59	1918	1381	72	< 0.0001	Yes
Female	2088	1587	76	1933	1611	83	< 0.0001	Yes
Male	2135	1601	75	1989	1644	83	< 0.0001	Yes

Note. ED = economically disadvantaged; SPED = special education; ELL = English language learners

Grade 8

	Comparison Group (2006, 07, 08, 09)			Treatment Group (2010, 11, 12,13)			Fisher's Exact Test	
	N	n	%	N	n	%	p	Significant
African American	1134	612	54	566	390	69	< 0.0001	Yes
Hispanic	1497	1000	67	749	76	77	< 0.0001	Yes
White	2319	2071	89	1165	1115	95	< 0.001	Yes
Asian American	322	293	91	205	190	93	0.0123	Yes
SPED	440	163	37	129	81	63	<0.0001	Yes
ELL	455	182	40	225	93	42	0.7406	No
ED	2141	1290	60	1380	1001	73	< 0.0001	Yes
Female	2573	1930	75	1461	1229	86	< 0.0001	Yes
Male	2702	2054	76	1460	1210	85	< 0.0001	Yes

Note. ED = economically disadvantaged; SPED = special education; ELL = English language learners

Appendix D

Changes in Ethnic Achievement Gap

Changes in Ethnic Achievement Gap

	Preimplementation			Postimplementation			Difference Between Preimplementation and Postimplementation
	Specific Groups %	White %	Difference in Percentage Points	Specific Groups %	White %	Difference In Percentage Points	Percentage Points
Grade 6							
African American	55	88	33	71	96	25	8
Hispanic	66	88	22	81	96	15	7
Grade 7							
African American	56	89	33	67	94	27	6
Hispanic	65	89	24	77	94	17	7
Grade 8							
African American	54	89	35	69	95	26	9
Hispanic	67	89	22	76	95	19	3

Appendix E

Changes in Economic Achievement Gap

Changes in Economic Achievement Gap

	Preimplementation			Postimplementation			Difference Between Preimplementation and Postimplementation
	ED Students %	All Students %	Difference in Percentage Points	ED Students %	All Students %	Difference In Percentage Points	Percentage Points
Grade 6	59	74	15	76	85	9	6
Grade 7	59	75	16	72	83	11	5
Grade 8	60	75	15	73	83	10	5