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PRELIMINARY EVALUATION OF THE MATHUP CURRICULUM

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BY

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ABSTRACT

The purpose of this study was to evaluate the effects of the novel math curriculum, mathUP, on math development for pupils receiving this instruction. Two Rhode Island schools participated: a charter school that had implemented mathUP and a suburban control school located in a higher socioeconomic (SES) community. Kindergarten students (*n*=41) were assessed on the following measures: two for early numeracy skills, one for visuospatial working memory (WM), and one for math achievement. Fifth-grade students (*n*=73) were administered a standardized measure of math achievement and an experimenter-generated math test. In addition, kindergarten and fifth-grade teachers in each school completed a brief questionnaire about their math instruction practices. Teacher reports revealed that the mathUP curriculum incorporated many research-based characteristics associated with improved math achievement. Findings also showed that early numeracy skills and visuospatial WM are important for kindergarten math achievement. In contrast to known academic achievement gaps between students from low and high SES circumstances, there were no significant differences between the kindergarten students on early numeracy skills, visuospatial WM, and math achievement. Additionally, fifth-grade students demonstrated comparable math achievement and performance on the math test. Overall, these results provide preliminary evidence that mathUP is an effective math curriculum with many evidence-based characteristics that may offset disadvantages usually associated with lower SES circumstances.

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CHAPTER 1: INTRODUCTION

Statement of the Problem

There are two widely known problems regarding the math achievement of students in the United States (U.S.). From a global perspective, the math achievement of American students is much lower than students from other industrialized nations. For example, the 2009 Program for International Student Assessment (PISA) reported that 17 OECD[1] countries demonstrated higher scores than the U.S. (Fleischman, Hopstock, Pelczar, & Shelley, 2010). Further, within the U.S., math achievement gaps are apparent between students from higher and lower socioeconomic (SES) backgrounds (National Center for Education Statistics, 2011). These problems are worrisome because much research has documented the negative long-term consequences of poorly developed mathematical skills (for a review see Geary, 2011b). These issues highlight the importance of mathematics education and the need for an effective math curriculum.

To address these concerns, an educator at a Providence charter school has created, and the school has implemented, a novel math curriculum named mathUP. This program involves explicit instruction, strategic revisiting of concepts, and teaching to mastery, resulting in a math curriculum that has systematic scope and sequence throughout the elementary grades. For math instruction, students are homogeneously grouped, combining students across grades and classrooms to place them appropriately. A database also is kept to monitor the progress of students and student groups. This helps a teacher to recognize which concepts are not known

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[1] The Organization for Economic Co-operation and Development (OECD) is an intergovernmental organization that helps governments foster economic growth and development. As of 2013, most of its member countries are highly industrialized.

adequately by individual pupils and to be able to address those knowledge gaps. These characteristics conform with many of the standards advocated by research for an effective math curriculum, such as the use of explicit instruction (Baker, Gersten, & Lee, 2002; National Mathematics Advisory Panel, 2008). Although mathUP has been well received by staff at the charter school, no research has evaluated the effects of this curriculum. Therefore, the purpose of this study was to determine if the mathUP curriculum has enhanced math development for students receiving this instruction.

Critical Review of the Literature

This critical review explores early predictors of math achievement and the math expectations for upper elementary pupils. Additionally, the characteristics of effective math curricula that foster math achievement are reviewed. This discussion leads to the conclusion that the unique characteristics of the mathUP curriculum warrants an evaluation of its effect on math achievement.

Early Predictors of Math Achievement

Early numeracy skills. Prior to kindergarten, most children already have a set of basic quantitative competencies generally referred to as number sense (Kaufmann & Nuerk, 2005). There is no consensus on what these abilities encompass but it is thought that early numerical competencies provide the foundation for the development of more complex mathematical skills and develop with formal education (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Thus, early numeracy skills are viewed as critical for the successful acquisition of later math skills and for math achievement (e.g., Geary, 2011a; Jordan et al., 2007). Drawing from the available research, common elements of number sense include the abilities to count and discriminate quantities (Berch, 2005; Geary, 2000; Jordan, Kaplan, Oláh, & Locuniak, 2006). Numerous studies have specifically assessed these two indices of number sense and found them to be strong predictors of later math achievement (e.g., Jordan et al., 2007; Stock, Desoete, & Roeyers, 2009). Many studies also have included performance on arithmetic tasks, such as story problems, as a measure of number sense (e.g., Jordan et al., 2007; Jordan et al., 2006). However, research is beginning to suggest that the use of these tasks may be problematic, especially for younger children, in light of the fact that the same measure may be used both as a predictor and as an outcome (Östergren & Träff, 2013).

In terms of early counting ability, before school entry this refers to a preverbal counting system used for the enumeration of up to 4 items (Geary, 2000). Typically, this skill develops from a combination of fundamental principles and counting experiences (Geary, 2004). Coupled with counting principles, children's observations of counting help them to make inductions about the basic features of counting. These inductions further develop children's understanding of counting, but also instill beliefs about features of counting (e.g., belief that counting must start at an endpoint in a set of items). As such, young children may learn both essential and unessential principles of counting (Geary, 2004). However, over time and with formal education experiences, counting knowledge matures as children learn which principles are unessential. Children's use of counting strategies also changes as they gradually acquire, and more frequently use, sophisticated, more efficient strategies (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007). Generally, research suggests that older children use more memory-based processes, such as retrieval, instead of finger or verbal counting (Gersten, Jordan, & Flojo, 2005).

Another aspect of number sense is the ability to discriminate quantities (i.e., ordinality), reflecting a basic understanding of more than, less than, and ordinal relations. This is important for forming magnitude representations (e.g., 5 is bigger than 2) that support one's knowledge of number progression and ability to identify where numbers would occur on a number line (i.e., 5 would be beyond 2). In particular, research suggests that an inherent magnitude representational system underlies ordinality and number line knowledge (Geary, Hoard, Nugent, & Byrd-Craven, 2008). This is a natural logarithmic system that compresses distances between consecutively larger numbers. This means that when one is making number line placements, the perceived difference between consecutive large numbers is less than for consecutive smaller numbers. With formal education though, number line estimates become more accurate because the natural number-magnitude system is gradually modified to a linear system in which the distance between two consecutive numbers is the same regardless of their size. Consistent with this theory, the pattern of children's number estimates from kindergarten to Grade 2 change from logarithmic to mostly linear (Geary et al., 2008; Siegler & Booth, 2004).

Much research has found that difficulties with counting and poor accuracy in making placements on a number line are linked to poor math achievement in the early elementary grades (e.g., Geary, 2011a; Geary, Hoard, Nugent, & Bailey, 2012; Geary et al., 2008; Stock et al., 2009). For instance, children at risk for mathematical learning disability (MLD) make more counting errors in kindergarten and first-grade than their typically-achieving peers (e.g., Geary et al., 2007). Research also has compared children who have very low, low, or typical math achieving scores. Results suggest a continuum of difficulties with counting and number line estimates (e.g., Geary et al., 2007; Geary et al., 2012; Geary et al., 2008). Thus, when evaluating the effects of a curriculum, early number line estimation and counting skills also should be considered because these skills have been documented to be predictors of later math achievement.

Visuospatial working memory. Much research has supported the importance of working memory (WM) for math achievement (e.g., Geary, 2011a; Geary et al., 2009; Geary et al., 2012; Holmes & Adams, 2006). Research findings are discussed within the multi-component model of WM posited by Baddeley (Baddeley, 2003). Specifically, WM is a limited capacity system composed of independent components that may interact with each other but are distinct constructs (De Smedt et al., 2009). These components include a higher-order domain-general central executive that is responsible for coordinating complex cognitive processes and the other three subsystems.

Of particular focus is the visuospatial sketchpad subsystem that temporarily holds and manipulates visual and spatial information. Research suggests that visuospatial WM may be more strongly related to math achievement in younger than older children (e.g., Holmes & Adams, 2006; Murphy, Mazzocco, Hanich, & Early, 2007). For instance, De Smedt and colleagues (2009) found that the visuospatial sketchpad was a unique predictor of Grade 1, but not Grade 2, math achievement. This decreasing reliance on the visuospatial system may reflect age-related changes in counting strategy development as children rely less on visuospatial strategies (e.g., finger counting), and use more verbal strategies (e.g., direct retrieval using verbal cues; Geary, 2004; Gersten et al., 2005). Because early math achievement is linked to strong visuospatial WM for young children, this type of WM should be considered when assessing the students entering school.

Math Expectations for Upper Elementary Pupils

Not only do early math skills (e.g., number sense) at school entry predict subsequent math achievement, but the procedural skills and mathematical reasoning (i.e., understanding of math) taught in the early elementary grades are also important (Claessens & Engel, 2013). Because mathematics is hierarchical and structured, a solid foundation of skills and knowledge is crucial for the development of higher mathematics. The core concepts of elementary math include proficiency with numbers, the place value system, whole number operations (e.g., addition of whole numbers), fractions and decimals, and problem solving (Wilson, 2009). To acquire these skills, basic constructs are taught in the earlier grades and are further developed, generalized, and modified in later grades. For instance, a Common Core State Standard (CCSS; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) for kindergarten students is to understand addition and subtraction (an element of whole number operations). Classroom instruction in the following grades would further solidify this understanding and enhance proficiency with whole number operations. By fifth grade, students should have acquired enough understanding and skill with whole numbers so that they are able to interpret simple numerical expressions by analyzing the basic operations involved in the equation. By the time students are in eighth-grade, they should be able to solve more complex expressions such as those involving integer exponents. This progressive nature of math highlights the importance for analysis of math achievement in upper elementary grades to assess whether or not students have developed strong foundational skills, as well as whether they have acquired more advanced skills specific to their grade-level expectations.

Important Features of Math Curricula

For students to acquire and master the skills necessary for more advanced mathematics, the nature of the math curriculum they receive is very important. Much research has delineated the characteristics of a good math curriculum. Recent programs that have been found to be effective often make use of computer-assisted instruction and cooperative learning (where students work in small groups or pairs; National Mathematics Advisory Panel, 2008). Research also has supported the monitoring of student learning using formative assessment, and a curriculum that follows a logical sequence and is focused on teaching the core concepts of elementary math (Baker et al., 2002; National Mathematics Advisory Panel, 2008). A focus on procedural skills and conceptual understanding also is important (National Mathematics Advisory Panel, 2008; Wilson, 2009). Additionally, the use of explicit instruction is an effective approach to teaching math, especially for students with severe math difficulties (Baker et al, 2002; Kroesbergen & Van Luit, 2003; National Mathematics Advisory Panel, 2008; Slavin & Lake, 2008). This type of instruction has several features: it is structured, systematic, provides clear explanations and feedback, and uses scaffolds to help students learn (see Archer & Hughes (2011) for a detailed discussion of the elements of explicit instruction). Although there is no consensus on the best textbook series to use, most research has found that many of the programs with large textbooks that attempt to address a broad array of topics (perhaps because they have little emphasis on deep understanding) are detrimental to math achievement (Loveless, 2001).

mathUP Curriculum: Evaluating a New Curriculum

The present study focused on the novel mathUP curriculum that has been implemented in a Rhode Island charter school with students in kindergarten to grade 5. Many characteristics of this program reflect the aforementioned research-based practices for effective math instruction and for improving math achievement. In particular, explicit instruction of concepts, rules, and strategies is involved (e.g., Baker et al., 2002; National Mathematics Advisory Panel, 2008). The curriculum follows a logical sequence with an emphasis on student mastery of math skills and understanding (National Mathematics Advisory Panel, 2008). Additionally, a database is used to monitor student learning (Baker et al., 2002). Further, there are some unique attributes of the mathUP program that may augment math learning and achievement. First, concepts are strategically revisited so if individual students did not adequately learn a concept, it would be taught again thereby avoiding gaps in knowledge. This is expected to improve math achievement by helping students to master the basic skills necessary for later, more complex math. Second, students are regrouped homogeneously across grades and classrooms for math instruction. This grouping is flexible as students can move from one group to another based on their needs and mastery of math concepts. To understand the potential effects of this grouping practice on math achievement, a brief discussion of ability grouping is presented.

Various conceptualizations of ability grouping practices have been proposed (e.g., Slavin, 1987b; Tieso, 2005) but, in general, they reflect ability-grouped classes (i.e., tracking), regrouping for specific subjects such as mathematics (i.e., between-class grouping), and the creation of subgroups within a class (i.e., within-class grouping). The current research on ability grouping practices vary depending on the type of ability grouping and how it is conceptualized. Many studies have focused on tracking and found that it is not be beneficial and can have differential effects on academic achievement (e.g., Lleras & Rangel, 2009; Slavin, 1987a). That is, students placed in lower level classes tend to demonstrate lower achievement than if they were not placed in those classes whereas students in higher level classes tend to demonstrate higher achievement. Thus, the academic gap between low- and high-achieving students may become even greater (Chang, Singh, & Filer, 2009). On the other hand, less research has been conducted on the effects of between-class grouping at the elementary school level. Some studies tentatively suggest that it may increase student math achievement, especially if the curriculum is adapted to fit the needs of students (e.g., Slavin, 1987a; Tieso, 2005). The lack of clear findings is partially attributed to inconsistencies in defining between-class grouping, the groups of students studied, neglect of influences such as teacher expectations and instructional time, and less research at the elementary school level on regrouping for academic subjects. The grouping practice in the mathUP curriculum most closely aligns with this type of ability grouping and can further understanding of the effects of between-class grouping on elementary math achievement. As well, the mathUP curriculum uses flexible grouping where students can move from one group to another depending on the students' needs. These unique features of the mathUP curriculum, coupled with evidence-based characteristics, warrant a preliminary evaluation of the mathUP program to assess its effects on student math achievement.

Purpose of the Present Study

Much research has found that entry-level number sense and visuospatial WM are important early predictors of math achievement (e.g., Geary, 2011a; Jordan et al., 2007). Studies also have found that these difficulties persist for older elementary students (e.g., Geary, 2011a). In order to evaluate the effects of the mathUP curriculum on math achievement, it is important to assess the comparability of students entering school (i.e., their number sense and visuospatial WM). Likewise, it is important to consider the math knowledge and achievement of students who have received math instruction for several years. Therefore, in this study the math performance by kindergarten and fifth-grade students at the charter school that has implemented the mathUP curriculum and a control school was compared. A qualitative comparison of curricula in each school also was conducted.

In summary, the purposes of the present study were to:

1. Explore the comparability of students entering the charter school providing the mathUP curriculum and the control school in terms of math performance and early predictors of math achievement. It was hypothesized that the math performance and number sense skills for kindergarten students from the control school, located in a higher SES suburban community, would be better than the math performance

and number sense skills for kindergarten students from the charter school that primary has students from lower SES urban communities. Because of delays beginning the study[2], it was not possible to assess the kindergarten students until November. Hence, it is important to note that the pupils already had received three months of instruction.

2. Investigate the effects of the mathUP curriculum on math achievement. It was hypothesized that fifth-grade math achievement from the charter school will be comparable or superior to the control school. That is, it was hypothesized that the mathUP program provides a curriculum that offsets disadvantages usually associated with lower SES circumstances.

[2] Originally, this study aimed to recruit a second control school whose SES and ethnic population is comparable to the students attending the charter school. However, logistical issues (e.g., district did not want testing during school hours) and difficulties with obtaining permission postponed the study.

CHAPTER 2: METHODOLOGY

Participants

As noted previously, two schools from Rhode Island were involved in this study: an urban charter school that has implemented the mathUP program (mathUP school) and a suburban public school (control school) that has been classified by the Rhode Island Department of Education as making adequate progress in math. The study sample consisted of 41 kindergarten students (mathUP school = 20, control school = 21) and 76 fifth-grade students (mathUP school = 17, control school = 59). However, three fifth-grade students from the control school did not give their assent, so the sample was reduced to 73 students (see Table 1 for the demographic characteristics of the students who participated). In addition, four teachers from kindergarten class (mathUP = 2, control = 2) and five fifth-grade teachers (mathUP = 2, control = 3) completed a brief questionnaire about the math instruction provided in each of their classrooms.

Table 1
Demographic Characteristics for Kindergarten and Fifth-Grade Students

Demographic Characteristic	mathUP School	Control School
Kindergarten		
n	20	21
Mean age (years), *SD*	5.52 (.29)	5.69 (.31)
Females (%)	45	67
Males (%)	55	33
Fifth Grade		
n	17	56
Mean age (years), *SD*	10.66 (.28)	10.72 (.34)
Females (%)	59	45
Males (%)	41	55
Students eligible for subsidized lunch (%)*	78	34

Note. The percent of students eligible for subsidized lunch was obtained from the Rhode Island Education Department of Education for 2012-2013 and pertains to the whole school population.

Materials

Kindergarten measures.

Early numeracy skills: Number Knowledge Test (NKT). Children's knowledge of number concepts was assessed with the NKT. This evaluated knowledge of the number sequence and of the abilities to count, compare numbers, and solve arithmetic problems. The test is suitable for children from four to ten years old and is composed of four levels. Knowledge tested at the lower levels generally is acquired before knowledge evaluated at higher levels. This measure has been reported to have good internal consistency and validity (item response theory reliability = .93; Clarke & Shinn, 2004; Gersten et al., 2005). The NKT is administered individually and requires spoken responses from the child. For each participant, the NKT score was calculated by adding the number of correct responses. This score was used in subsequent analyses.

Early numeracy skills: Number line task (NLT). This ten-item measure, adapted from Geary (2011a), assesses children's knowledge of the linear, mathematical number line. Previous research has found a one-year test-retest reliability of .47 (Östergren & Träff, 2013). In this task, each student received ten sheets of paper (i.e., one for each trial) that had a 25-centimeter line printed across the middle with two numerical endpoints (0 and 100). The target number to be estimated was printed above the line. Each sheet was presented one at a time to the participants and pupils were asked to mark where the target number should be placed on the line. Prior to beginning this task, a teaching trial was given in which each student was given the target number "50" and appropriate corrective feedback was provided.

The qualitative responses from this task were analyzed in terms of the average error (e.g., Geary, 2011a). A scale in which 2.5 mm corresponds to 1 unit on the number line was used. For each trial, the pupil's mark was converted to a number using this scale. Next, the absolute difference between the number and target was calculated. In order for smaller differences on the task to reflect greater accuracy on the task, corresponding with magnitude difference on the other measures, the absolute difference was multiplied by -1. Therefore, a number closer to zero reflected a smaller distance between the target and the student's mark. The average error was the mean of these differences across the 10 trials and served as an index of accuracy on the number line task for analyses.

Visuospatial working memory. Two subtests (i.e., Picture Memory and Zoo Locations) from the Wechsler Preschool and Primary Scale of Intelligence–Fourth Edition (WPPSI–IV) were used to assess visuospatial working memory. These tests, administered individually, are appropriate for children from ages 2 years, 6 months to 7 years, 7 months. The Picture Memory measure involves viewing target pictures and then choosing the target items from a set of options. The Zoo Locations task presents animal cards on a zoo layout for a set duration and then requires the participant to replicate the placement. For five-year-old children (divided into 5,0-5,5 and 5,6-5,11 year old age groups), the split-half reliability coefficient for Picture Memory is .89 and .90, and for Zoo Locations it is .82 and .84 (Wechsler, 2012). These reliability coefficients suggest that both subtests have strong reliability.

For each student, a visual Working Memory Index (WMI) score was derived from the Picture Memory and Zoo Location subtests and was used in all analyses. First, the total number of correct responses on the Picture Memory and Zoo Locations subtests was calculated to produce a PM and ZL score, respectively. The PM and ZL scores were changed to scaled scores based on the student's age. Then, the two scaled scores were summed to produce the WMI score.

Math achievement. The Applied Problems subtest from the Woodcock-Johnson III Tests of Achievement battery (Woodcock, McGrew, & Mather, 2001) was used as a measure of math achievement. This is an untimed, individually-administered test that assesses the ability to analyze and solve math problems. For this task, students are given math problems orally and have to respond verbally with their answer. The Applied Problems subtest is appropriate for individuals aged 2 to 90 years and was normed on a large sample representative of the U.S. population according to the 2000 census. This test also has strong reliability and validity (r_{11} = .92 for five year olds; McGrew & Woodcock, 2001). For each student, a standardized score based on the pupil's age and total number of correct responses was used as their math achievement score and used in subsequent analyses.

Fifth-grade measures.

Math achievement. The Applied Problems also was used as a measure of math achievement for the fifth-grade participants. This subtest has been reported to have good reliability and validity for 10 year olds (r_{11} = .91; McGrew & Woodcock, 2001). Again, for each student a math achievement standardized score was derived from the student's age and total number of correct answers, and used for analyses.

Experimenter designed fifth-grade math test (MTest). Permission was acquired from administers at the two schools for access to their math curricular materials. However, there was a lack of materials available[3] and both schools purported that their curriculum reflected the Common Core State Standards for Mathematics (CCSSM). Thus, the researcher reviewed the CCSSM to understand the scope of math skills taught from kindergarten to sixth-grade. This information aided in the design of an appropriate fifth-grade math test (presented in Appendix A) that assessed the range of math skills and concepts taught in the two curricula. To avoid ceiling effects, some questions reflecting sixth-grade Standards also were incorporated into the test. However, as a result of logistical issues (e.g., available time for test

[3] The mathUP school did not use a textbook but instead, used math packets for topics. There was no opportunity to review these as each packet differed based on student needs and topics. The control school also used several programs in recent years and depended on the teachers creating assignments based on grade level expectations. Again, the researcher did not obtain access to these programs due to the frequent change in materials.

administration), only a subset of the Common Core State Standards (CCSS) for the fifth and sixth grades were included. A draft of the test was reviewed by a fifth-grade math teacher and by an elementary school math coach who had extensive experience with CCSSM. The draft was modified based on the feedback from these individuals.

The result was a 43-item test that encompassed eleven math concept and skill domains (see Table 2). Of note, the volume and coordinate plane subscales only had one item in order to shorten the test administration time. These subscales were chosen to have only one item because the types of questions needed to assess the underlying math skills and concepts were relatively homogeneous compared to other subscales. The place value subscale has the most items because more questions were needed to assess the range of skills and concepts encompassed by this subscale. In addition, the word problems subscale does not reflect a specific CCSS because the questions require that the student use mathematical reasoning and various math skills to solve problems with novel semantic concepts (e.g., see problem #22 and 23 in Appendix A). Cronbach's alpha for the 11-subscale test was .75, which suggests that there is good reliability. The subscales also have good reliability (Cronbach's alpha ranged from .71 to .76; see the Results section for a further discussion of the validity and reliability of the math test and its subscales).

Table 2
Math Test Subscales and Associations with Common Core State Standards for Mathematics (CCSSM)

Concepts Assessed	Number of Items (n = 43)	Associated CCSSM
1. Numerical expressions	3	Write and interpret numerical expressions
2. Patterns and relationships	4	Analyze patterns and relationships
3. Place value	13	Understand the place value system
4. Computation	4	Perform operations with multi-digit whole numbers and with decimals to hundredths
5. Addition and subtraction of fractions	4	Use equivalent fractions as a strategy to add and subtract fractions
6. Multiplication and division	4	Apply and extend previous understandings of multiplication and division
7. Volume	1	Geometric measurement: Understand concepts of volume
8. Coordinate plane	1	Graph points on the coordinate plane to solve real-world and mathematical problems
9. Shape properties	3	Classify two-dimensional figures into categories based on their properties
10. Central tendency (mean, median, mode, and range)[a]	4	Summarize and describe distributions
11. Word problems	2	Does not reflect a specific CCSS as this is incorporated across multiple grades

Note. All Common Core State Standards (CCSS) are for fifth-grade mathematics unless otherwise noted.
[a]This subscale assesses a sixth grade CCSS.

The test required students to select an answer out of a set of options (i.e., multiple-choice format) or to provide a written response (i.e., fill-in-the-blank, computation, problem solution, and short answer questions). It was administered in a group setting and all students recorded their answers on their copy of the test. Each answer was given a value that ranged from zero to two: zero for incorrect responses, one for correct multiple-choice items, and one to two points for correct written responses. The number of points possible for correct or partially correct written responses depended on the number of answers possible and whether the response was general vs. explicit or included all vs. just a few possible answers. That is, responses were scored using either a two-point scale (0 = wrong, 1 = correct) or a three-point scale (0 = wrong, 1 = correct but only a general idea or a few possible answers were mentioned, and 2 = correct and a deeper understanding or all answers were mentioned). For each student, the total math score based on the overall number of points attained was used for analyses.

Teacher measure.

Math instruction questionnaire. To gain a better understanding of the nature of the math instruction that students receive, the kindergarten and fifth-grade teachers from the two schools each were asked to complete a brief survey about their math instruction. For instance, there were questions about the amount time allotted for math instruction per day, if instruction is provided to groups or to the whole class, and if students are assigned math homework (see Appendix B and C for a complete list of questions for the kindergarten and fifth-grade teachers). The responses were coded according to the school and grade; teacher names or classrooms were not entered.

Procedure

The study met all university and Federal standards for working with human participants, as defined by the University of Rhode Island’s Institutional Review

Policy. Permission was obtained from administrators in each school to conduct the study and to have access to curricular material and additional achievement information that may impact performance on test measures (e.g., screening results for math achievement at the beginning of the school year). Prior to testing, parental consent was acquired via permission letters (in both Spanish and English) that explained the study. Likewise, student assent was obtained at the child's school before taking part. All students were assessed during regular school hours at their own school. The kindergarten pupils were tested in November and December, 2013, whereas fifth-grade pupils were evaluated in December 2013 and January 2014. Kindergarten and fifth-grade teachers from the two schools also completed the math instruction questionnaire in either December 2013 or January 2014.

The kindergarten participants were given measures of early numeracy (NKT and the number line task), visuospatial WM (Picture Memory and Zoo Locations), and math achievement (Applied Problems). Test administration for the kindergarten students occurred over two sessions, each lasting approximately 20 minutes. The Applied Problems, NKT, and number line tasks were given in the first session and the visuospatial WM tests were given in the second session. The fifth-grade students completed the experimenter-generated fifth-grade math test and the Applied Problems task during two sessions. The individual administration of the Applied Problems measure lasted about 20 minutes; group administration of the math test was approximately 40 minutes in duration.

CHAPTER 3: RESULTS

Preliminary Analyses

Prior to conducting comparison analyses, performance on all variables were evaluated for normality by examining box plots, skewness, and kurtosis. Outliers for each group were identified and not included in further analyses. This resulted in the exclusion of two kindergarten students and one fifth-grade student who were outliers on the Applied Problems measure. As a result, 39 kindergarten and 72 fifth-grade students were included in the data analyses. The descriptive statistics for the kindergarten and fifth-grade students are shown in Tables 3 and 4, respectively.

Table 3
A. Means and Standard Deviations for All Kindergarten Variables

	mathUP School (n = 19)		Control School (n = 20)	
Variable	*M*	*SD*	*M*	*SD*
Early numeracy				
NKT (raw score) (max. possible = 30)	9.74	2.56	11.00	3.26
NLT (raw score) (max. possible = 0)	-22.92	7.24	-21.00	10.13
WMI (standard score)	19.58	4.54	19.90	3.18
Applied Problems (standard score)	104.95	9.02	110.35	8.54

B. Ranges for All Kindergarten Variables

Variable	Min.	Max.	Min.	Max.
Early numeracy				
NKT (raw score)	6.00	14.00	7.00	16.00
NLT (raw score)	-36.30	-8.80	-39.10	-2.85
WMI (standard score)	12.00	29.00	14.00	25.00
Applied Problems (standard score)	89.00	126.00	94.00	126.00

Table 4
A. Means and Standard Deviations for All Fifth-Grade Variables

	mathUP School (n = 17)		Control School (n = 55)	
Variable	*M*	*SD*	*M*	*SD*
Applied Problems (standard score)	100.00	10.55	102.78	11.17
MTest (raw score) (max. possible = 49)	23.41	11.12	26.29	6.58

B. Ranges for All Fifth-Grade Variables

Variable	Min.	Max.	Min.	Max.
Applied Problems (standard score)	84.00	124.00	77.00	128.00
MTest (raw score)	8.00	47.00	13.00	42.00

Correlational Analyses

Table 5 presents the correlations among the visual working memory, early numeracy, and math achievement variables for kindergarten students. The results indicate there was a significant positive relationship between the NKT and NLT results, showing that higher performance on the NKT corresponded with a greater accuracy on the number line task, $r(39) = .59$, $p < .05$. Moreover, performance on the NKT and NLT was significantly and positively correlated with that on the Applied Problems, $r(39) = .45$, $p < .05$ and $r(39) = .43$, $p < .05$. This suggests that stronger early numeracy skills covary with better math achievement in kindergarten. There was also a significant positive correlation between Applied Problems and WMI indicating that higher math achievement in kindergarten was related to stronger visuospatial working memory, $r(39) = .43$, $p < .05$. For the fifth-grade students, their math performance on the Applied Problems and math test measures were significantly correlated, $r(72) = 0.70$, $p < .0001$. Thus, higher math achievement on the Applied Problems subtest was related to higher scores on the math test.

Table 5
Correlations of Kindergarten Variables

Measure	*1*	*2*	*3*
1. WMI	–		
2. NKT	0.08	–	
3. NLT	0.03	0.59*	–
4. Applied Problems	0.43*	0.45*	0.43*

Note. WMI = visuospatial WM; NKT = Number Knowledge Test; NLT = number line task.
* $p < .05$.

Group Comparison on Math Achievement: Kindergarten

MANOVA was used to test the first hypothesis regarding the comparability of students entering the two schools in kindergarten (i.e., that there would be significant differences in terms of math achievement and number sense). For this analysis, the categorical independent variable was school and the continuous dependent variables were number sense (i.e., NKT and NLT), visuospatial working memory (i.e., WMI), and kindergarten math achievement (i.e., Applied Problems). Findings revealed no significant difference between kindergarten students from the mathUp and control schools on measures of number sense, visuospatial working memory, or math achievement, $F(4, 34) = 1.10$, $p > .05$, Wilks' $\Lambda = 0.89$. Thus, the first hypothesis was not confirmed as the kindergarten students from the mathUP and control schools demonstrated comparable math achievement and number sense.

Group Comparison on Math Achievement: Fifth-Grade

This analysis tested the second hypothesis that fifth-grade students from the mathUP school would demonstrate comparable or better math achievement than the fifth-grade students from the control school. To evaluate this, a MANOVA was conducted in which the categorical independent variable was school and the continuous dependent variables were math achievement and performance on the math test. Results of the MANOVA indicated that there was no significant difference between fifth-grade students from the mathUP and control schools on either of the two measures, $F(2, 69) = 0.86$, $p > .05$, Wilks' $\Lambda = 0.98$.

Effect Size Calculations for Fifth-Grade Math Achievement

To further assess the effects of the mathUP curriculum on math achievement, the differences in fifth-grade math performance between the two schools were compared to the predicted difference using Cohen's *d*. All effect sizes were calculated using the control school as the reference group. Based on demographic factors, it was expected that the fifth-grade students from the control school would perform better than the pupils from the mathUP school. In support of this, a medium effect size of -0.49 was expected based on the math performance of fifth-grade students from the two schools on the 2012-2013 New England Common Assessment Program (NECAP). Note, the 2013-2014 data is not available at this time. In contrast, comparison of math performance on the standardized measure of math achievement revealed a small to medium effect size ($d = -0.25$). Similarly, there was a smaller effect size for the math performance on the fifth-grade math test ($d = -0.44$). This suggests that the fifth-grade students from the mathUP school demonstrated higher math performance than expected.

Reliability and Validity of the Fifth-Grade Math Test

The significant correlation between the math test and Applied Problems suggest that the experimenter-generated math test is a valid measure of math achievement ($r(72) = 0.70$, $p < .0001$). Cronbach's alpha was used to determine the internal consistency of the math test, and was calculated for the entire test and its 11 subscales. Research suggests that an alpha of at least .70 or higher is acceptable for new instruments (DeVon et al., 2007). Based on this, results indicate that the test and its subscales are reliable and have good internal consistency (see Table 6).

Table 6
Reliability Estimates for the Math Test and Its Subscales

Scale (Number of Items)	Cronbach's alpha
Math test (n = 43)	0.75
Numerical expressions (n = 3)	0.73
Patterns and relationships (n = 4)	0.72
Place value (n = 13)	0.71
Multiplication and division (n = 4)	0.72
Addition and subtraction of fractions (n = 4)	0.76
Multiplication and division (n = 4)	0.72
Volume (n = 1)	0.75
Coordinate plane (n = 1)	0.75
Shape properties (n = 3)	0.72
Central tendency (mean, median, mode, and range) (n = 4)	0.73
Word problems (n = 2)	0.73

Analyses of Math Concepts on the Fifth-Grade Math Test

For exploratory purposes, fifth-grade group differences on certain math concepts were analyzed. The items on the fifth-grade math test were grouped into concepts (i.e., subscales; see Table 2) and analyzed using two-sample t-tests. A summary of the results is presented in Table 7. The findings indicate that fifth-grade students from the control mid-SES school were better at interpreting numerical expressions than were fifth-grade students from the mathUP school, $t(19.99) = 2.38$, $p < .05$. They also were better at analyzing patterns and relationships than pupils from the mathUP School, $t(70) = 2.76$, $p < .05$. Stronger understanding of the place value system was demonstrated by students from the control school, $t(70) = 2.12$, $p < .05$, and they also were better able to apply multiplication and division strategies to different situations, $t(19.129) = 2.62$, $p < .05$. As well, fifth-grade students from the control school demonstrated greater achievement than students from the mathUP school when presented with novel concepts in word problems, $t(70) = 2.68$, $p < .05$.

In contrast, students from the mathUP school performed better adding and subtracting fractions using equivalent fractions than did students from the control school, $t(18.18) = -4.98$, $p < .0001$. These pupils also demonstrated higher performance on central tendency concepts (i.e., mean, median, mode, range), $t(19.09) = -2.18$, $p < .05$.

There were no significant differences between students from both schools on calculations with multi-digit whole numbers and decimals, $t(70) = 1.22$, $p > .05$. The two groups also were comparable on the volume question, $t(19.48) = -1.22$, $p > .05$, and on the item requiring graphing points on a coordinate plane to solve a problem, $t(70) = 1.39$, $p > .05$. Lastly, there was no significant difference between the students from the mathUP and control schools on using shape properties to classify two dimensional figures into categories, $t(70) = 0.34$, $p > .05$.

Table 7
Math Concept Differences Between Fifth-Grade Students

	mathUP School		Control School			
Math Concept	*M*	*SD*	*M*	*SD*	Max	*t*
	Higher Performance by Control School Students					
Numerical expressions	1.65	1.11	2.33	0.70	3.00	2.38*
Patterns and relationships	2.18	1.13	2.98	1.03	4.00	2.76*
Place value	9.24	4.97	11.84	4.24	13.00	2.12*
Multiplication and division	0.76	1.09	1.49	0.60	4.00	2.62*
Word problems	0.65	0.79	1.24	0.79	2.00	2.68*
	Higher Performance by mathUP Students					
Addition and subtraction of fractions	2.24	1.60	0.24	0.74	4.00	-4.98**
Central tendency (mean, median, mode, and range)	1.94	1.64	1.04	0.90	4.00	-2.18*
	Similar Performance by mathUP and Control School Students					
Computation	2.59	0.87	2.82	0.61	4.00	1.22
Volume	0.18	0.39	0.05	0.23	1.00	-1.22
Coordinate plane	0.35	0.49	0.55	0.50	1.00	1.39
Shape properties	1.65	1.00	1.73	0.80	3.00	0.34

***** $p < .05$. ** $p < .0001$.

Qualitative Comparison of Teaching Practices: Kindergarten

The responses from the teacher questionnaire were reviewed to delineate potential differences and similarities in teaching practices. A subset of the findings pertaining to math teaching practices for the kindergarten teachers is shown in Table 8 (see Appendix D for the whole set of responses). In general, the mathUP school had slightly smaller kindergarten class sizes and allotted more time for math instruction.

Although all the kindergarten teachers at both schools provided homework, there was more assigned per week at the mathUP school. Small groups were also more frequently used at the mathUP school. Specifically, only one of the three classes at the control school used groups of varying sizes and they were only formed when students needed additional support. On the other hand, the mathUP curriculum consistently required the implementation of small groups. To generate these groups, the kindergarten students are initially divided into two groups based on math level. Within each group, the students are further divided into groups of four mixed ability groups and rotate through math centers. These groupings are flexible and can change throughout the school year based on the students' math performance and math assessments.

The kindergarten teachers at the control school used a textbook for instruction whereas teachers at the mathUP school did not. This textbook series was recently implemented and used for about a year. The focus of instruction for students at the control school was on learning a few core topics, concepts, and skills. In contrast, the focus of instruction at the mathUP school was on a broad variety of topics and concepts. The instructional format between both schools also was examined. Reports from the mathUP kindergarten teachers revealed frequent revision of topics previously taught. There was also greater progression from simple to more complex topics. On the other hand, at the control school, concepts and skills were more often taught on a chapter-by-chapter basis. All the teachers at both schools engaged in the following practices to the same degree: applied previously taught material and skills to current topics, and taught concepts and skills individually and then applied them.

All kindergarten teachers at both schools reported using whole, group, and supplemental (e.g., response-to-intervention) math instruction. Their students also used computers during math lessons, although how often the computers were used depended on the teacher. In general, it was reported that students' math learning was tracked at both schools. However, the degree to which this informed math instruction depended on the teacher and school. Specifically, one kindergarten teacher at the mathUP school did not track student progress and the other who did reported that this sometimes affected math instruction. On the other hand, both kindergarten teachers at the control school tracked their students' math performance and reported that this affected their math instruction to varying degrees (i.e., never and often). All kindergarten teachers reported that there was direct teaching of concepts, rules and strategies.

Table 8
Kindergarten Teaching Practices

Teaching Practice	mathUP School	Control School
Average class size	16	18
Structure of instruction		
Whole or group instruction	Both	Both
Math instruction time (min.)	50-60	30-40
Math activities	"5 min. word problem at quiet time; 45 min. math instruction and review through centers" "It's flexible time that allow for whole group instruction to introduce new topics and small group instruction when appropriate"	"Whole group learning, hands on manipulatives, written practice" "Sometimes/as needed; whole group instruction; small groups, computers"
Use of computers	Often	Rarely, Often
Use of groups	Yes	No, Yes
Number of students per group	4	Depends
How groups are formed	Kindergarten students are split into 2 groups by math level. These may change based on math assessments and how students progress. Within each group, the students rotate through centers in groups of 4 mixed ability groups (so mostly based on math level & areas of need)	Small groups are formed to help students who need additional assistance
Format of instruction[a]		
Previously taught ideas are reviewed	Often-Frequently	Often
Application of previously taught material and skills to current topics	Sometimes-Often	Sometimes-Often
Concepts and skills taught solely on a chapter-by-chapter organization	Rarely	Rarely-Sometimes

Table 8 (Cont.)

Teaching Practice	mathUP School	Control School
Concepts and skills taught individually and then applied	Sometimes	Sometimes
Progression from less to more complex topics	Rarely-Often	Sometimes
Direct teaching of concepts, rules, and strategies	Yes	Yes
Focus to learn a few core concepts and skills or on a broad variety of skills	Broad variety	Core concepts
Use of textbook for instruction	No	Yes
How long textbook series has been used (in years)		1
Comments about the math program		"Not familiar enough to comment" "I love it! User friendly website, predictable routine, language from Common Core"
Supplemental math instruction (e.g., RTI)	Yes	Yes
Tracking of student learning	No, Yes	Yes
How much does this affect math instruction	Sometimes	Often-Never
Homework assigned	Yes	Yes
How often homework is assigned per week	3-4 times per week	Less than once a week; 3-4 times a week
Time to complete for each day of math homework (min.)	5-10	10

Note. If there were multiple responses from different teachers then each response was included in the table.
[a]Responses were rated on 5 item scale (Never, Rarely, Sometimes, Often, and Frequently).

Qualitative Comparison of Teaching Practices: Fifth-Grade

Responses from the fifth-grade teacher questionnaires were reviewed and a subset of their reported teaching practices are presented in Table 9 (see Appendix E for the whole set of responses). In general, the mathUP school has smaller fifth-grade class sizes and less instruction time than the control school. According to the responses, fifth-grade students from the mathUP school also used computers more often. In contrast to the control curriculum, mathUP did not involve a textbook for instruction and more frequently reviewed previously taught ideas. The teachers of the mathUP curriculum also reported more frequently teaching students to apply previous math knowledge and skills to current topics, taught concepts and skills individually before its application, and had greater progression from simple to more complex topics.

In terms of similar teaching practices, both schools engaged in both whole and group instruction and used small flexible groups of 2 to 6 students. All the teachers also assigned homework three to four times per week, and the time to complete each day of homework was comparable. Other common characteristics of the mathUP and control curricula were the tracking of student learning and provision of supplemental math instruction (e.g., RTI). Teachers from both schools reported engaging in explicit instruction and focusing on teaching core, as well as a variety of math concepts and skills.

Table 9

Fifth-Grade Teaching Practices

Teaching Practice	mathUP School	Control School
Average class size	18	24
Structure of instruction		
Whole or group instruction	Both	Both
Math instruction time (min.)	60-72	75-90
Math activities	"60 min. math concept/wk; 30 min. 2x/wk for review of computational skills & previous units (toolbox)" "Overall we have two days/wk with 90 min. for math: 60 min. for main unit concepts, currently fractions and 30 min. for toolbox practice (foundations)"	"60 min. whole class instruction and 30 min. RTI" "class instruction and RTI groups" "Introduction to concepts; practice – together and in small groups; computer use, reteach using RTI, review homework"
Use of computers	Sometimes-Often	Rarely-Sometimes
Use of groups	Yes	Yes
Number of students per group	2-6	2-6
How groups are formed	They vary based on need. We form the groups to work on different skills when help is needed because of different learning styles. These groups change quite regularly based on performance or need.	Math level and mixed ability grouping. Different groups for different areas of content based on math screening results, chapter tests results, and daily participation mixed abilities - changes based on need flexible grouping depending on who needs help or excels

Table 9 (Cont.)

Teaching Practice	mathUP School	Control School
Format of instruction[a]		
Previously taught ideas are reviewed	Frequently	Often
Application of previously taught material and skills to current topics	Frequently	Often
Concepts and skills taught solely on a chapter-by-chapter organization	Rarely-Frequently	Sometimes
Concepts and skills taught individually and then applied	Often-Frequently	Sometimes-Often
Progression from less to more complex topics	Often-Frequently	Sometimes-Often
Direct teaching of concepts, rules, and strategies	Yes	Yes
Focus to learn a few core concepts and skills or on a broad variety of skills	Core concepts, both	Both
Use of textbook for instruction	No	Yes
How long textbook series has been used (in years)		1
Comments about the math program		Most like it. Dislike some of the lessons that don't seem age appropriate Really uses practice that applies Common Core
Supplemental math instruction (e.g., RTI)	Yes	Yes
Tracking of student learning	Yes	Yes
How much does this affect math instruction	Sometimes-Often	Sometimes-Often
Homework assigned	Yes	Yes
How often homework is assigned per week	3-4 times per week	3-4 times a week
Time to complete for each day of math homework (min.)	20-23	15-25

Note. If there were multiple responses from different teachers then each response was included in the table.

[a]Responses were rated on 5 item scale (Never, Rarely, Sometimes, Often, and Frequently).

CHAPTER 4: DISCUSSION

There is much evidence of noteworthy gaps in math achievement between students from higher and lower SES backgrounds (e.g., National Center for Education Statistics, 2011; Sirin, 2005). Further, early difficulties with math tend to persist and affect later academic achievement (e.g., Geary et al., 2009; Murphy et al., 2007). To address these concerns, a novel math curriculum (mathUP) was created and implemented in a public urban charter school. The present study explored the effects of this curriculum on math achievement by comparing the math performance of fifth-grade students from the charter school and a suburban public school located in a higher SES community. In consideration of school entry differences in skills that could affect later math achievement, the comparability of kindergarten students from both schools also was assessed. Specifically, it was hypothesized that there would be differences in early numeracy skills and math achievement with the students who were entering the charter school not being as advanced in early math concepts. In terms of the fifth-grade students, it was predicted that having received several years of the mathUP curriculum would result in at least comparable performance for the lower SES pupils.

Effects of the mathUP Curriculum

Comparability of entering students. As noted above, there commonly are achievement gaps between students from higher and lower SES circumstances that are evident as early as at school entry (e.g., Jordan et al., 2006; Jordan, Kaplan, Ramineni, & Locuniak, 2009; National Center for Education Statistics, 2011). However, the current study found that the kindergarten students from the control and mathUP schools demonstrated similar early numeracy skills, visuospatial working memory, and math achievement. One possible explanation for this may be because it was not possible to administer the assessments for the kindergarten students until three months after the school year had started. The rate at which children's early numeracy skills develop during their first year in school affects their math achievement (e.g., Jordan et al., 2007; Jordan et al., 2009). Thus, even though students from lower SES circumstances may enter school with various disadvantages, the curriculum is an important factor in fostering students' early numeracy skills and math achievement. It may be possible that a few months of receiving mathUP, a curriculum characterized by many research-based practices, helped diminish any initial differences between kindergarten students entering the two schools.

Another factor contributing to the comparability of kindergarten students from the two schools may be the amount of time allotted for math instruction. At the control school, students received 30 to 40 minutes of math instruction per day whereas students from the mathUP school received about 50 to 60 minutes. Further, the fact that the mathUP program is characterized by explicit instruction, logical sequencing, and emphasis on skill mastery and understanding may have helped the lower SES students progress quickly (c.f., Gersten et al., 2009; National Mathematics Advisory Panel, 2008). The use of small groups, computer-assisted instruction, and progress monitoring also have been found to be effective for elementary school students (e.g., Kroesbergen &Van Luit, 2003). According to teacher reports, the mathUP curriculum is characterized by many of these practices. Thus, the increased amount of math instruction time, coupled with evidence-based teaching practices, may have helped foster students' math learning and achievement at the charter school. This may have attenuated differences potentially present at the outset. In any case, the present findings did not support the predicted result that the kindergarten students attending the charter school would demonstrate lower performance on math and math related tasks.

Effects on fifth-grade math achievement. In support of the second hypothesis, there were no significant differences in performance between the fifth-grade students from the two schools on the two measures of math achievement that were administered (i.e., on the Applied Problems measure and on the experimenter-designed math test). Although the control school performed somewhat better than the mathUP school, the differences in math performance on the two measures of math achievement were smaller than expected based on the NECAP fifth-grade math performance. In particular, the difference between the two schools on the standardized measure of math achievement was smaller than on the experimenter-designed math test. This may reflect the specific focus on problem solving skills in the former measure whereas the math test assesses more math domains and skills.

Exploratory analyses revealed group differences on particular math concepts in the math test. On the one hand, fifth-grade students from the mathUP school demonstrated higher performance on central tendency concepts and on adding and subtracting fractions using equivalent fractions. On the other hand, students from the control school were better at interpreting numerical expressions, analyzing patterns and relationships, and using multiplication and division strategies. They also demonstrated a stronger understanding of the place value system and were able to solve more novel word problems than were students from the mathUP school. Across both schools, the fifth-grade students performed similarly on calculations with multi-digit whole numbers and decimals. They had comparable performance on questions regarding volume, the coordinate plane, and figure classification based on shape properties. Overall, these findings suggest that each curriculum has differing strengths in particular aspects of math. At the same time, the lack of significant differences between the two groups of pupils on the Applied Problems and the math test, in contrast to commonly found SES differences, suggests that mathUP may well have had positive effects on math achievement.

An alternative explanation for these findings is that, regardless of curriculum effects, the cohort of fifth-grade students recruited for the study were comparable on early numeracy skills and math achievement in earlier grades (e.g., kindergarten). If the fifth-grade students from both schools had, in fact, been comparable on these factors in kindergarten, then they would be more likely to exhibit similar math achievement in later grades. This assumption would align with previous research suggesting that strong early numeracy skills and visuospatial working memory positively affect later math outcomes (e.g., Jordan et al., 2009). Additionally, early numeracy skills in kindergarten mediate differences in math achievement and rate of growth between students from low and middle SES backgrounds (Jordan et al., 2009). Thus, results are ambiguous: comparable performance for the fifth-grade students may stem from attributes of the mathUP curriculum during the elementary grades or may, counter to typical patterns, have occurred because the math abilities of the students were similar from the start of their education. However, testing on the NECAP

(Rhode Island Department of Elementary and Secondary Education & The Providence Plan, 2014) indicates that during the 3rd, 4th, and 5th grades, the cohort of fifth-grade students from the control school demonstrated higher performance in math. This tentatively suggests that comparable math abilities at the start of education cannot account for the similar fifth-grade math performance. More longitudinal data would be beneficial to permit clearer evaluation of whether the mathUP curriculum has positive effects on math achievement.

Characteristics of the mathUP Curriculum

Descriptions of each curriculum were obtained from teacher self-reports on the teaching practices in their classroom. The limitations of self-reportings warrant cautious interpretation of the results. In general, the mathUP school has smaller class sizes than the control school and does not use a textbook for instruction. Instead, sets of packets have been utilized that target a sequence of math concepts. Both curricula use small groups for student learning and also provide whole class, group, and supplemental math instruction in both grades. However, the use of small groups based on math level and mixed ability was implemented earlier (beginning in kindergarten) and more frequently in the mathUP curriculum. Direct teaching and tracking of student progress are other reported characteristics of the mathUP and comparison curricula, although how often the monitoring of student progress informed math instruction depended on the school, grade, and teacher. For example, one kindergarten teacher at the mathUP school did not track student progress, whereas another reported that monitoring sometimes affected her math instruction. On the other hand, both kindergarten teachers at the control school monitored students' math performance and reported that this affected their math instruction to varying degrees. According to teacher reports in both kindergarten and fifth-grade, the mathUP curriculum is characterized by more frequent review of previously taught topics and by progression from simple to more complex topics, whereas the control curriculum more often taught concepts and skills on a chapter-by-chapter basis.

Review of the teacher questionnaires revealed specific curriculum characteristics and practices pertaining to each of the two grades. For kindergarten, the mathUP curriculum provided more math instruction time and homework. The focus also was on teaching a broad variety of topics and skills whereas the control curriculum was more focused on teaching a few core topics, concepts, and skills. For both curricula, the kindergarten teachers reported engaging in the following practices to the same degree: applying previously taught knowledge and skills to current topics, and teaching concepts and skills individually before applying them. In addition, computers were employed during math instruction, although how often the computers were used depended on the teacher and available resources.

In contrast, fifth-grade students from the mathUP school received less math instruction time but comparable amounts of math homework than their peers from the comparison school. The mathUP curriculum for fifth-grade also was characterized by more frequent use of computers, teaching students to apply previously taught material and skills to current topics, and teaching concepts and skills individually before its application. According to fifth-grade teacher reports, both curricula emphasized teaching both core and a variety of math concepts and skills.

In sum, although review of the actual materials and observation of teaching practices would be more reliable, teachers' input indicates that the mathUP curriculum contains many research-based practices for effective math instruction, such as explicit instruction and the use of math- and mixed ability-level groups. There were more similarities in the reported teaching practices for the fifth-grade students between both schools than for the kindergarten students. In particular, the use of small groups based on math level and mixed ability was implemented beginning in kindergarten for the mathUP curriculum. This earlier differentiation of instruction can be effective in fostering math achievement and skills and diminish the gaps in math achievement between pupils from high and low SES circumstances. In support of this, the present findings from this study indicated that the kindergarten students from both schools (located in different SES communities) demonstrated similar early numeracy skills, visuospatial working memory, and math achievement when assessed three months after the start of the school year. Further, there were no significant differences between the fifth-grade students from both schools on broad measures of math achievement.

Early Influences on Math Achievement

The measures administered to the kindergarten cohort also permit an evaluation of early influences on math achievement. As noted in the introduction, a large body of research suggests that early numeracy skills and working memory are related to later math achievement (e.g., Aunio & Niemivirta, 2010). In particular, counting skills (e.g., knowledge of counting and use of appropriate counting strategies) and numerical representations (i.e., understanding of numbers) are two aspects of early numeracy skills that have been documented to be strongly associated with math achievement (e.g., Geary et al., 2007). The findings from this study support the evidence that better early numeracy skills are related to higher math achievement for kindergarten students.

Research also suggest that visuospatial working memory may have an influence on math achievement in the earlier grades (e.g., Preßler, Krajewski, & Hasselhorn, 2013). For example, Geary et al. (2007) compared visuospatial working memory to the number line task performance and number set knowledge (i.e., ability to select all of the groups of numbers that add up to a certain sum) of students with math difficulties and controls. They found that visuospatial working memory was related to more accurate estimation on the number line task, better number set knowledge, and higher math achievement. In contrast, the present study did not reveal a significant relationship between visuospatial working memory and early numeracy skills. There are several possible reasons why the result was not statistically significant. First, although the measure of visuospatial working memory has strong reliability and validity (Wechsler, 2012), the instructions were delivered verbally and this may have placed demands on verbal working memory as well. Increased demands on the working memory system may confound which cognitive systems are associated with early numeracy skills.

A second potential reason may be that the central executive component of working memory has a stronger contribution to math achievement and early numeracy skills that confounds the influence of visuospatial working memory. Compared to research on the other subsystems of working memory, more studies have found that the central executive plays a key role in math achievement and early numeracy skills (e.g., Andersson & Lyxell, 2007; Kroesbergen, Van Luit, Van Lieshout, Loosbroek, & Van de Rijt, 2009; McLean & Hitch, 1999). Theoretical support also comes from Baddeley's model in which the central executive is conceptualized as a higher-order system. This component regulates the other working memory subsystems and includes executive functions that have been linked with early numeracy skills and math achievement (e.g., Bull & Scerif, 2001). Therefore, future studies evaluating the cognitive deficits associated with math difficulties, especially at school entry, could avoid this confound either by including measures of the central executive and phonological working memory and/or by using other visuospatial working memory assessments that do not have a verbal component.

Limitations

The current study has several limitations that should be considered. The first limitation is the small and unequal sample sizes for kindergarten and fifth-grade students. This could have biased the findings because the group of students who participated might differ from those who did not participate. A future study with larger sample sizes could overcome this limitation.

A second possible limitation is that at the control school, a variety of programs had been used for the fifth-grade students during their elementary grades. It was difficult to evaluate the different methods and to detail the nature of instruction utilized over prior years. The curriculum in previous years consisted of materials that the teachers created based on student learning objectives. The variability and effectiveness of materials within and across grades no doubt affected the math instruction and achievement of fifth-grade students from the control school. In short, the lack of information about the math programs used in the control school prevents real comparison of the curricula.

Because of the unavailability of the math materials, teacher reports were used to gain information about the pedagogical philosophy underlying each curriculum, but this has questionable reliability and sensitivity. For instance, all teachers reported that they applied previously taught skills to current topics but it is not possible to ascertain the extent to which this was done. It also is probable that the fifth-grade math test created for the study is not a valid measure of math achievement. However, the math test had a strong and positive relation with the Applied Problems subtest, known to be a standardized and rigorous measure of math achievement (McGrew & Woodcock, 2001).

Another limitation is that SES information was based on the number of students who were eligible for subsidized lunch for the whole school (Rhode Island Department of Elementary and Secondary Education & The Providence Plan, 2014). This is a global assumption and may not be representative of the specific SES profiles for the kindergarten and fifth-grade students. A more rigorous approach would have been to obtain SES information for each student and to then assess the association of SES with math performance, early numeracy skills, and visuospatial working memory.

Finally, it would have been preferred if data collection began earlier in kindergarten. Further, the data is not longitudinal so it may have been possible that the fifth-grade students from both schools demonstrated similar math achievement in earlier grades, as noted earlier. Assessment of early numeracy skills and math achievement prior to school entry and subsequent longitudinal data collection would allow for a better understanding of how the mathUP curriculum affects math achievement over time.

Implications and Future Directions

The findings from this study support previous research indicating the importance of early numeracy skills, such as counting and number magnitude representations, for early math achievement. This suggests that screening for math difficulties at school-entry should assess early numeracy skills. Further, early math instruction should target these skills to foster math achievement (for an example of the benefits of teaching number magnitude and counting skills, see Codding, Chan-Iannetta, George, Ferreira, & Volpe, 2011). The current results also indicated that visuospatial working memory is related to math achievement in kindergarten. The significance of this in relation to the influences of other types of working memory can be elucidated with more research comparing the effects of the central executive and verbal working memory on math skills and achievement.

As mentioned, collection of data before kindergarten begins would provide a better evaluation of the comparability of students between the two schools at school-entry. Longitudinal studies also should be conducted to evaluate differences in rate of growth in students' math skill development and achievement as they receive the mathUP curriculum. These studies could reveal how the relations between math achievement, early numeracy skills, and visuospatial working memory change over time.

Additionally, to thoroughly consider the effects of the mathUP curriculum on math achievement, it would be informative to replicate this study with a second control school whose SES and ethnic population is comparable to that in the mathUP school. The findings would reveal how kindergarten and fifth-grade students from the mathUP school compare to other students from both high and low SES circumstances.

In conclusion, the present study provided preliminary evidence suggesting that the mathUP curriculum may offset math achievement gaps usually associated with lower SES circumstances. These results indicate the value of investigating the attributes and merit of the mathUP program more thoroughly in future work.

APPENDICES

Appendix A: Experimenter-Generated Fifth-Grade Math Test

Fifth Grade Problem Set

Name: ____

School: ____

Date: __________________________

Instructions

You are asked to complete the following questions. Some of them will be easy for you; others might be harder for you to do. Just try your best. The questions may be completed in any order. As well, your responses are confidential. This means that except for the researchers involved in this study, no one will know how you do on this problem set. Thank you for your time.

1. Without solving the equation, which of the following is the same as 2 x 4 + 3
    a. 2 x 2 x 2 + 3
    b. 2 x 3 + 4
    c. (2 x 2) + 3

2. Without solving the equation, which of the following is the same as 5 + (18 ÷ 3 + 8)
    a. 8 + 5 + 18
    b. 5 + 15 + 8
    c. 5 + 6 + 4 + 4

3. Which of the following is the same as 10 + (18 x 6)
    a. Multiply 18 and 6. Next, add 10 to that product.
    b. Add 10 and 18 and multiply the sum by 6.
    c. Multiply 18 and 6. Next, that product is decreased by 10.

Look at the numbers below. What are the next two numbers?

4. 3, 6, 9, 12, ______, ______
   Explain this pattern:

5. 1, 2, 4, 8, ______, ______
   Explain this pattern:

Compare the following numbers by writing <, >, or = for each. Explain why.

6. 94.7 __________ 94.4
   Explanation:

7. 19.22 __________ 25.17
   Explanation:

Calculate the following.

8.
$$\begin{array}{r} 35 \\ \underline{\times\ 84} \end{array}$$

9. There are 69 jellybeans. If there are 3 children, how many jellybeans would each child have?

10. Robert has $271 and wants to divide the money equally between his 5 children. How much money will each child get?

11. Julia earns $0.80 each day. How much money would she have after one week?

12. Complete the following table:

Number	**Place of underlined digit**	**Between ____ & ____**	**Number closest to**	**How do you know?**
$2.60	Ones	$2 and $3	$3	
$18.37				
1,391.462				

13. $\frac{1}{3} + \frac{1}{6} =$

14. $\frac{1}{3} + \frac{5}{7} =$

15. $\frac{3}{6} - \frac{2}{8} =$

16. $\frac{6}{9} - \frac{2}{6} =$

17. $\frac{2}{5} \times \frac{1}{4} =$

18. $\frac{1}{7} \div \frac{7}{8} =$

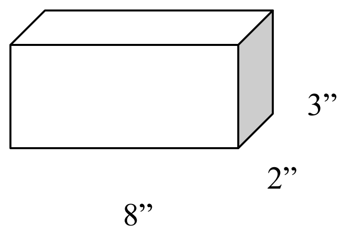
19. The distance between Catherine's house and the mall is $\frac{5}{7}$ miles. It was a very sunny day so Catherine only biked $\frac{2}{9}$ of the way to the mall. How many miles did Catherine travel?

20. Robbie has a set of stars and one third of them are red. If Robbie has 6 red stars, how many stars are in the set?

What is the volume of the following?

21. a

.



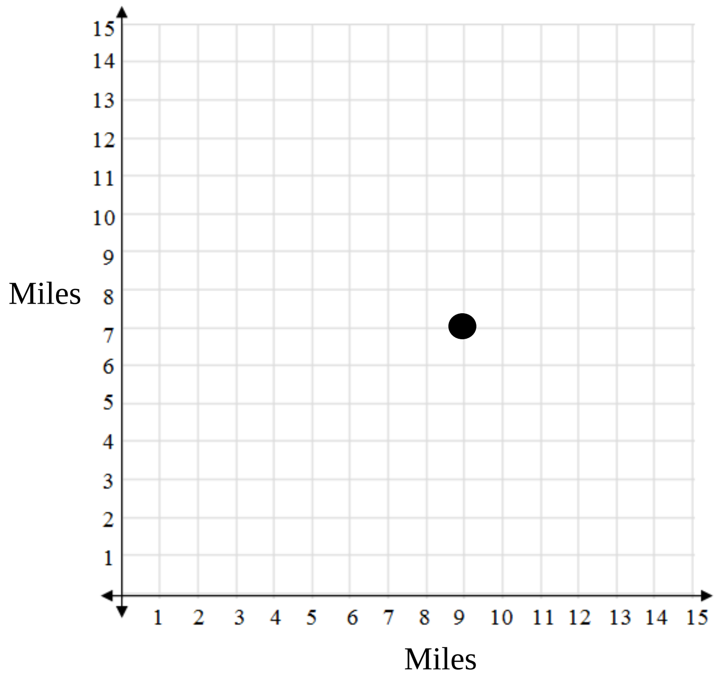
Volume = ________________

b. Vase A has the above shape and volume. What is the possible shape of Vase B that has the same volume but different shape?

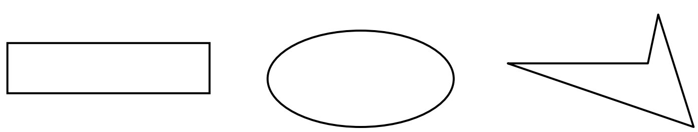
22. Billy found four Glicks. Each Glick held 3 glicos. On his way to the laboratory, he dropped the Glicks and 4 glicos broke. How many glicos did Billy have left?

23. Billy the scientist discovered that گ is a Glick and each holds 3 glicos. If there are three گ, how many glicos did Billy have?

24. Sarah went on a walk. She started at ●. If she walked 4 miles west and 2 miles south, where did she end up? Draw a dot to show where Sarah finished her walk.

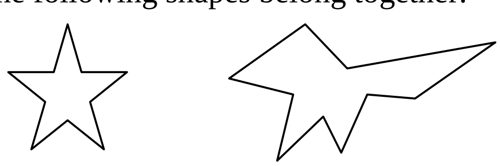


25. Which of the following shapes do not belong?



Why?

26. The following shapes belong together.



Why?

27. What is the mean, median, and mode of the following:
    1, 9, 3, 10, 37, 32, 2, 9, 3

    What is the difference between the smallest and largest value? _______________

    Median: _____________

    Mode: _______________

    Mean: _______________

Appendix B: Math Instruction Questionnaire for Kindergarten Teachers

Math Instruction Questionnaire

School: ____

Date: ______________________ Grade: ________________

Instructions

You are asked to complete a brief survey regarding math instruction in your classroom. The survey consists of questions regarding the math curriculum that you use. The information you provide will be used for a graduate student's thesis project at the University of Rhode Island examining the effects of math curricula on math achievement. Your responses are voluntary and confidential. No individual names will be identified in any subsequent reports or findings involving this survey. If you have any questions, you are encouraged to contact the persons responsible for this project, Dr. Susan Brady (Phone: 401-874-4258) or Stephanie Tang (Phone: 401-207-5119). Thank you for your time.

Questions

1. How many students are in your class?

   ____

2. Is math instruction provided to groups of students or to the whole class?

   ____

3. A) How much time (**in minutes**) is allotted for math instruction and math activities per day?

    ____

    B) Is this subdivided into different types of activities? Please describe.

    ____

    ____

    ____

    ____

    ____

    ____

    ____

    ____

4. A) Do students receive math homework? YES / NO

    B) If yes, how often is math homework assigned? (*Please check* ***<u>the best one</u>***)

    - ☐ Less than once a week
    - ☐ Once or twice a week
    - ☐ 3 or 4 times a week
    - ☐ 5 times a week

    C) If yes, for each day of math homework, how much time do you estimate it would take a student to complete the assignment?

    ____

5. A) Do students work in small groups or pairs? YES / NO

   B) If yes, how many students are in a group?

   ____

   C) How are these groups formed? E.g., Is grouping according to "math level" or in mixed ability groupings? Are groups maintained over time?

   ____

   ____

   ____

   ____

   ____

   ____

   ____

6. Do students in your class use computers during math lessons for instructional purposes?

   Never………....Rarely…………...Sometimes……..…..Often.…..………Always

7. Is student learning tracked via progress monitoring? YES / NO

   A) If yes, how much does this assessment influence the timing or sequence of math instruction?

   Never………....Rarely…………...Sometimes……..…..Often.…..………Always

8. Do students receive supplemental math instruction (e.g., RTI services)?

   YES / NO

9. Do you use a textbook to teach mathematics to your class? YES / NO

A) If so, which one?

____

B) How long has this textbook series been used in this school?

____

C) What do you like/dislike about this math program?

____

____

____

____

____

____

____

____

10. On average, how many days is spent teaching a complete unit or topic?

____

11. Is there direct teaching of concepts, rules, and problem-solving strategies?

YES / NO

12. Is the focus of instruction for students to learn a few core topics, concepts, and skills, or for students to learn a broad variety?

____

13. The math instruction that you teach focuses on helping students…. (*Please rate **all** that apply*):

- ☐ Learn the necessary math skills and strategies

  Poorly…….A Little……..Average……..Well……..Exceptionally Well

- ☐ Become proficient in performing math skills and strategies

  Poorly…….A Little……..Average……..Well……..Exceptionally Well

- ☐ Develop their problem solving skills

  Poorly…….A Little……..Average……..Well……..Exceptionally Well

- ☐ Apply their knowledge and skills to solve problems

  Poorly…….A Little……..Average……..Well……..Exceptionally Well

- ☐ Understand core math concepts and ideas

  Poorly…….A Little……..Average……..Well……..Exceptionally Well

- ☐ Engage in critical thinking

  Poorly…….A Little……..Average……..Well……..Exceptionally Well

- ☐ Other

  ____

  ____

  ____

  ____

  ____

14. How are concepts, topics, and strategies taught? (*Please rate **all** that apply*):

- ☐ Previously taught ideas are reviewed

  Never...…….Rarely...…….Sometimes...……..Often...……..Frequently

- ☐ The application of previously taught material and skills to current topics is discussed

  Never...…….Rarely...…….Sometimes...……..Often...……..Frequently

- ☐ Concepts and skills are taught solely based on a chapter-by-chapter organization

  Never...…….Rarely...…….Sometimes...……..Often...……..Frequently

- ☐ Concepts and skills are taught individually and then applied to problems and other contexts

  Never...…….Rarely...…….Sometimes...……..Often...……..Frequently

- ☐ There is a progression from less to more complex topics

  Never...…….Rarely...…….Sometimes...……..Often...……..Frequently

- ☐ Other:

____

____

____

____

____

____

____

15. Is it difficult to get through all the chapters/sections of your math program during the year?

YES / NO

16. What components of math do your average students learn well? (*Please check* ***<u>all</u>*** *that apply*):

- ☐ Count a number of objects
- ☐ Compare numbers
- ☐ Understand addition (e.g., addition involves putting together)
- ☐ Add simple small numbers
- ☐ Understand subtraction (e.g., subtraction involves taking apart and from)
- ☐ Subtract simple small numbers
- ☐ Understand place value for numbers 11-19 (e.g., 12 can be decomposed into ten ones and two ones).
- ☐ Describe and compare measurable properties of objects
- ☐ Classify objects and count the number of objects in each group
- ☐ Identify and describe shapes
- ☐ Analyze, compare, create, and compose shapes

---- Completion of Survey. Thank you. ----

Appendix C: Math Instruction Questionnaire for Fifth-Grade Teachers

Math Instruction Questionnaire

School: ____

Date: __________________________ Grade: ______________

Instructions

You are asked to complete a brief survey regarding math instruction in your classroom. The survey consists of questions regarding the math curriculum that you use. The information you provide will be used for a graduate student's thesis project at the University of Rhode Island examining the effects of math curricula on math achievement. Your responses are voluntary and confidential. No individual names will be identified in any subsequent reports or findings involving this survey. If you have any questions, you are encouraged to contact the persons responsible for this project, Dr. Susan Brady (Phone: 401-874-4258) or Stephanie Tang (Phone: 401-207-5119). Thank you for your time.

Questions

1. How many students are in your class?

   ____

2. Is math instruction provided to groups of students or to the whole class?

   ____

3. A) How much time (**in minutes**) is allotted for math instruction and math activities per day?

   ____

   B) Is this subdivided into different types of activities? Please describe.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

4. A) Do students receive math homework? YES / NO

   B) If yes, how often is math homework assigned? (*Please check* ***the best one***)

   - ☐ Less than once a week
   - ☐ Once or twice a week
   - ☐ 3 or 4 times a week
   - ☐ 5 times a week

   C) If yes, for each day of math homework, how much time do you estimate it would take a student to complete the assignment?

   ____

5. A) Do students work in small groups or pairs? YES / NO

   B) If yes, how many students are in a group?

   ____

   C) How are these groups formed? E.g., Is grouping according to “math level” or in mixed ability groupings? Are groups maintained over time?

   ____

   ____

   ____

   ____

   ____

   ____

   ____

6. Do students in your class use computers during math lessons for instructional purposes?

   Never………..….Rarely.……..….Sometimes…..……..Often.…..……..Always

7. Is student learning tracked via progress monitoring? YES / NO

   B) If yes, how much does this assessment influence the timing or sequence of math instruction?

   Never………..….Rarely.……..….Sometimes.……..….Often.……..….Always

8. Do students receive supplemental math instruction (e.g., RTI services)?

   YES / NO

9. Do you use a textbook to teach mathematics to your class? YES / NO

A) If so, which one?

____

B) How long has this textbook series been used in this school?

____

C) What do you like/dislike about this math program?

____

____

____

____

____

____

____

____

10. On average, how many days is spent teaching a complete unit or topic?

____

11. Is there direct teaching of concepts, rules, and problem-solving strategies?

YES / NO

12. Is the focus of instruction for students to learn a few core topics, concepts, and skills, or for students to learn a broad variety?

____

13. The math instruction that you teach focuses on helping students…. (*Please rate **all** that apply*):

- ☐ Learn the necessary math skills and strategies

  Poorly...……A Little....….Average....….Well..…..Exceptionally Well

- ☐ Become proficient in performing math skills and strategies

  Poorly...……A Little....….Average....….Well....….Exceptionally Well

- ☐ Develop their problem solving skills

  Poorly...……A Little....….Average....….Well....….Exceptionally Well

- ☐ Apply their knowledge and skills to solve problems

  Poorly...……A Little....….Average....….Well....….Exceptionally Well

- ☐ Understand core math concepts and ideas

  Poorly...……A Little....…. Average....….Well....….Exceptionally Well

- ☐ Engage in critical thinking

  Poorly...……A Little....….Average....….Well....….Exceptionally Well

- ☐ Other

  ____

  ____

  ____

  ____

  ____

14. How are concepts, topics, and strategies taught? (*Please rate **all** that apply*):

- ☐ Previously taught ideas are reviewed

  Never………Rarely………Sometimes.………Often.………Frequently

- ☐ The application of previously taught material and skills to current topics is discussed

  Never………Rarely………Sometimes.………Often.………Frequently

- ☐ Concepts and skills are taught solely based on a chapter-by-chapter organization

  Never………Rarely………Sometimes.………Often.………Frequently

- ☐ Concepts and skills are taught individually and then applied to problems and other contexts

  Never………Rarely………Sometimes.………Often.………Frequently

- ☐ There is a progression from less to more complex topics

  Never………Rarely………Sometimes.………Often.………Frequently

- ☐ Other:

____

____

____

____

____

____

____

15. Is it difficult to get through all the chapters/sections of your math program during the year?

    YES / NO

16. What components of math do your average students learn well? (*Please check **all** that apply*):

    - ☐ Write and interpret numerical expressions
    - ☐ Analyze patterns and relationships
    - ☐ Understand decimals and multi-digit numbers
    - ☐ Computation with multi-digit numbers and with decimals to hundredths
    - ☐ Use equivalent fractions to add and subtract fractions
    - ☐ Multiple and divide fractions
    - ☐ Convert measurement units (e.g,. convert 2 cm to 0.02 m)
    - ☐ Problem-solving
    - ☐ Understand and be able to calculate volume
    - ☐ Understand the coordinate system with its x- and y-axes
    - ☐ Sort two-dimensional figures into categories based on their properties (e.g., all rectangles have four right angles so a square would also be classified as a rectangle)

---- Completion of Survey. Thank you. ----

Appendix D: Kindergarten Teaching Practices

Table 8
Kindergarten Teaching Practices

Teaching Practice	mathUP School	Comparison School
Average class size	16	18
Structure of instruction		
Whole or group instruction	Both	Both
Math instruction time (min.)	50-60	30-40
Math activities	"5 min. word problem at quiet time; 45 min. math instruction and review through centers" "It's flexible time that allow for whole group instruction to introduce new topics and small group instruction when appropriate"	"Whole group learning, hands on manipulatives, written practice" "Sometimes/as needed; whole group instruction; small groups, computers"
Use of computers	Often	Rarely, Often
Use of groups	Yes	No, Yes
Number of students per group	4	Depends
How groups are formed	Kindergarten students are split into 2 groups by math level. These may change based on math assessments and how students progress. Within each group, the students rotate through centers in groups of 4 mixed ability groups (so mostly based on math level & areas of need)	Small groups are formed to help students who need additional assistance
Format of instruction[a]		
Previously taught ideas are reviewed	Often-Frequently	Often
Application of previously taught material and skills to current topics	Sometimes-Often	Sometimes-Often

Table 8 (Cont.)

Teaching Practice	mathUP School	Control School
Concepts and skills taught solely on a chapter-by-chapter organization	Rarely	Rarely-Sometimes
Concepts and skills taught individually and then applied	Sometimes	Sometimes
Progression from less to more complex topics	Rarely-Often	Sometimes
Days spent teaching a complete unit/topic	Depends	Difficult to say; 2 days per lesson
Direct teaching of concepts, rules, and strategies	Yes	Yes
Focus to learn a few core concepts and skills or on a broad variety of skills	Broad variety	Core concepts
Math instruction focuses on helping students:[b]		
Learn the necessary math skills and strategies	Average-Exceptionally well	Well-Exceptionally well
Become proficient in performing math skills and strategies	Average-Exceptionally well	Exceptionally well
Develop their problem solving skills	Average	Well-Exceptionally well
Apply their knowledge and skills to solve problems	Average	Well-Exceptionally well
Understand core math concepts and ideas	Average-Exceptionally well	Well-Exceptionally well
Engage in critical thinking	Average	Well-Exceptionally well
Use of textbook for instruction	No	Yes
How long textbook series has been used (in years)		1
Comments about the math program		"Not familiar enough to comment" "I love it! User friendly website, predictable routine, language from Common Core"
Supplemental math instruction (e.g., RTI)	Yes	Yes
Tracking of student learning	No, Yes	Yes
How much does this affect math instruction	Sometimes	Often-Never

Table 8 (Cont.)

Teaching Practice	mathUP School	Control School
Homework assigned	Yes	Yes
How often homework is assigned per week	3-4 times per week	Less than once a week; 3-4 times a week
Time to complete for each day of math homework (min.)	5-10	10
Is it difficult to get through all the sections of the math program in a year?	Yes, No	Not sure, Yes
Math components that average student learns well:		
Count a number of objects	Yes	Yes
Compare numbers	Yes	Yes
Understand addition	Yes	Yes
Add simple small numbers	Yes	Yes, No
Understand subtraction	Yes	Yes
Subtract simple small numbers	Yes	Yes, No
Understand place value for numbers 11-19	No	Yes, No
Describe and compare measurable properties of objects	No	Yes, No
Classify objects and count the number of objects in each group	No, Yes	Yes, No
Identify and describe shapes	Yes. No	Yes, No
Analyze, compare, create, and compose shapes	No	No

Note. If there were multiple responses from different teachers then each response was included in the table.
[a]Responses were rated on 5 item scale (Never, Rarely, Sometimes, Often, and Frequently).
[b]Responses were rated on a 5 item scale (Poorly, A Little, Average, Well, and Exceptionally Well).

Appendix E: Fifth-Grade Teaching Practices

Table 9

Fifth-Grade Teaching Practices

Teaching Practice	mathUP School	Comparison School
Average class size	18	24
Whole or group instruction	Both	Both
Math instruction time (min.)	60-72	75-90
Math activities	"60 min. math concept/wk; 30 min. 2x/wk for review of computational skills & previous units (toolbox)" "Overall we have two days/wk with 90 min. for math: 60 min. for main unit concepts, currently fractions and 30 min. for toolbox practice (foundations)"	"60 min. whole class instruction and 30 min. RTI" "class instruction and RTI groups" "Introduction to concepts; practice – together and in small groups; computer use, reteach using RTI, review homework"
Use of computers	Sometimes-Often	Rarely-Sometimes
Use of groups	Yes	Yes
Number of students per group	2-6	2-6
How groups are formed	They vary based on need. We form the groups to work on different skills when help is needed because of different learning styles. These groups change quite regularly based on performance or need.	Math level and mixed ability grouping. Different groups for different areas of content based on math screening results, chapter tests results, and daily participation mixed abilities - changes based on need flexible grouping depending on who needs help or excels
Format of instruction[a]		
Previously taught ideas are reviewed	Frequently	Often

Table 9 (Cont.)

Teaching Practice	mathUP School	Control School
Application of previously taught material and skills to current topics	Frequently	Often
Concepts and skills taught solely on a chapter-by-chapter organization	Rarely-Frequently	Sometimes
Concepts and skills taught individually and then applied	Often-Frequently	Sometimes-Often
Progression from less to more complex topics	Often-Frequently	Sometimes-Often
Days spent teaching a complete unit/topic	15-30	7-60
Direct teaching of concepts, rules, and strategies	Yes	Yes
Focus to learn a few core concepts and skills or on a broad variety of skills	Core concepts, both	Both
Math instruction focuses on helping students:[b]		
Learn the necessary math skills and strategies	Well	Average-Well
Become proficient in performing math skills and strategies	Well-Exceptionally well	Well
Develop their problem solving skills	Average-Exceptionally well	Well
Apply their knowledge and skills to solve problems	Average-Exceptionally well	Well
Understand core math concepts and ideas	Well-Exceptionally well	Well
Engage in critical thinking	A Little-Exceptionally well	Well
Use of textbook for instruction	No	Yes
How long textbook series has been used (in years)		1
Comments about the math program		Most like it. Dislike some of the lessons that don't seem age appropriate Really uses practice that applies Common Core

Table 9 (Cont.)

Teaching Practice	mathUP School	Control School
Supplemental math instruction (e.g., RTI)	Yes	Yes
Tracking of student learning	Yes	Yes
How much does this affect math instruction	Sometimes-Often	Sometimes-Often
Homework assigned	Yes	Yes
How often homework is assigned per week	3-4 times per week	3-4 times a week
Time to complete for each day of math homework (min.)	20-23	15-25
Is it difficult to get through all the sections of the math program in a year?	No, Yes	Yes
Math components that average student learns well:		
Write and interpret numerical expressions	Yes	Yes
Analyze patterns and relationships	No, Yes	Yes, No
Understand decimals and multi-digit numbers	Yes	Yes
Computation with multi-digit numbers and with decimals to hundredths	Yes	Yes
Use equivalent fractions to add and subtract fractions	Yes	Yes
Multiple and divide fractions	No, Yes	Yes
Convert measurement units	Yes	Yes, No
Problem-solving	No	Yes, No
Understand and be able to calculate volume	Yes	No
Understand the coordinate system	No, Yes	Yes
Classify figures based on their shape properties	Yes	Yes

Note. If there were multiple responses from different teachers then each response was included in the table.

[a]Responses were rated on 5 item scale (Never, Rarely, Sometimes, Often, and Frequently).

[b]Responses were rated on a 5 item scale (Poorly, A Little, Average, Well, and Exceptionally Well).

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