Challenging Minds: Enhancing the Mathematical Learning of African American Students through Games

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ABSTRACT

Minority Access to Revolutionary Instructional Extensions (MATRIX) is a two-part pilot project that couples parent engagement and supplemental mathematics instruction. The MATRIX supplemental mathematics curriculum is built around six games designed to foster the mathematical development of elementary students. This article describes the MATRIX mathematics curriculum and provides findings related to the project's impact on African American students' number sense and attitudes towards mathematics.

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"I learned that math games can help you too. I learned the game "*get to a 1,000*" will help you count and add."

"I love to play Mancala because it is really fun and because you can come with new strategies and it is really challenging."

"I learned how to play new games and learn at the same time."

The voices of African American 4th and 5th graders who participated in the Minority Access to Revolutionary Instructional Extensions (MATRIX) project suggests the power of games to support the mathematical learning of students. The MATRIX project is composed of two components: (1) supplemental elementary mathematics curriculum and (2) parent and community advocacy training. This paper describes the supplemental elementary mathematics curriculum and how this curriculum affected African American students' number sense and affective dispositions towards mathematics. First, we will provide a rationale for the MATRIX project and a brief review of the literature related to number sense, attitudes, and mathematical games. Next we provide an overview of the MATRIX project followed by a description of the data sources, data analyses, findings, discussion, and conclusions.

The gap in mathematics achievement between African American students and their peers is one of the more pronounced problems facing mathematics educators. It is also the problem that gives impetus to the present study. According to National Assessment of Educational Progress (NAEP) data, 46% of African American fourth graders scored below the basic level, 44% scored at the basic level, and 10% scored at the proficient or advanced levels (Lubienski & Crockett, 2007). Studies examining mathematics disparity have also shown that African Americans take fewer mathematics courses in high school (Griffin, 1990; Maple &

Stage, 1991; Reyes & Stanic, 1985; Thomas, 1984); are less likely to report being influenced by mathematics teachers (Griffin, 1990), and exhibit a lower self-confidence in their ability to do mathematics (Griffin, 1990; O'Brien, Martinez-Pons, & Kopala, 1999; Post, Stewart, & Smith, 1991). MATRIX was designed and implemented to address the disparities faced by African American students by improving the mathematics achievement of African American students. The goal of the project is to prepare elementary students for future enrollment in higher level math courses in middle and high school. The MATRIX curriculum exposes students to a variety of mathematical games that center on developing students' number sense and the continual development of self-confidence and attitudes toward mathematics.

REVIEW OF THE LITERATURE

Number Sense

In the Number and Operations Standard, the National Council of Teachers of Mathematics (NCTM) calls for a deep and fundamental understanding of and proficiency with counting, numbers, and understanding the number system. Central to this standard is an understanding of number sense which can be defined as "the ability to decompose numbers naturally, use particular numbers like 100 or ½ as referents, use the relationship among arithmetic operations to solve problems, understand the base-ten number system, estimate, make sense of numbers, and recognize the relative and absolute magnitude of number" (NCTM, 2000, p. 32). Another component of number sense is a student's general understanding of numerical operations coupled with the ability to use this understanding in flexible ways to make mathematical judgments and to develop conceptual strategies for solving mathematical problems in school and everyday life. These strategies may include mental computation and estimation (Yang, Reys, & Reys, 2007).

Historically, an understanding of number has served as the cornerstone of the entire mathematics curriculum. Almost all mathematics that students encounter from grades pre-kindergarten to grade twelve is grounded in an understanding of number (NCTM, 2000). For example, the system that governs equation solving in algebra is the same as the structural properties of number systems. As students progress through pre-kindergarten through grade twelve they should attain a rich understanding of number (NCTM, 2000). Number sense serves as a powerful indicator to later mathematics outcomes (e.g. applied problem solving and calculation) and therefore weak number sense can have a negative cumulative impact on students' mathematical development (Jordan, 2010).

A lack of understanding in this area can present barriers to learning mathematics because number sense involves the development of numerous relationships between mathematical concepts, skills, and facts (Reys, Reys, Emanuelsson, Johansson, McIntosh & Yang, 1999). Learning difficulties in mathematics have been linked to weakness in number sense competencies such as counting, number comparison, and manipulating sets of numbers (Mazzocco & Thompson, 2005). So for students who lack a strong foundation in number sense, mathematics is often seen as a set of isolated and disconnected facts that must be memorized. For these students, math has "little beauty, meaning, relevance or application" (Reys et al., 1999, p.62).

Number sense is a complex structure with multiple components (Reys et al., 1999). In this project, number sense is defined as the development of flexible strategies (mental or estimations) to solve problems and compute, judge the reasonableness of results from computations, and explain their strategies to others (NCTM, 2000; Yang & Tsai, 2010). Both the understanding of number structures (number sense) and affective factors outside of mathematics are extremely important to students' mathematical development.

Affective Dispositions (Attitudes)

A wide variety of factors—social, cultural, family and community based, as well as personal/individual factors—influence the development of students' mathematical understanding and competence. Students' perception of themselves as learners is strongly connected with the attitudes they have about mathematics. Moreover, attitudes and beliefs have been found to influence mathematics achievement more than effort (Ai, 2002; Schoenfeld, 1992). Beliefs are understood to be "an individual's understanding and feelings that shape the ways the individual conceptualizes and engages in mathematical behavior" (Schoenfeld, 1992, p. 358). Mathematical beliefs are divided into four components with one being belief about oneself (Lester et. al., 1998). In particular, a student's self-confidence is a predictor of students' success and orientation towards mathematics. Research has shown a strong connection between self-confidence (a belief about ones' abilities) and mathematical achievement (Tartre & Fennema, 1995; Meyer & Koehler, 1990) and cultural sensitivity (Martin, 2009).

A way to support the development of students' confidence in mathematics is for educators to establish learning environments that promote a sense of ownership among students. In this sense, ownership means that students develop the ability to articulate their knowledge about a concept, skill, strategy, or generalization (Zaslavsky, 1996). Ownership promotes a sense of empowerment, allowing students to use mathematical knowledge independently or with others while having the ability to direct their learning and approach new tasks with confidence (Zaslavsky, 1996). In order to empower students, it is important for mathematics to be presented in a meaningful context. This empowerment of students in a meaningful context can help increase students' computational, critical thinking and problem solving skills and increase their excitement and appreciation for mathematics.

According to the NCTM (2000), most students enter grade three with enthusiasm for, and interest in, learning mathematics. They are able to see the relevance and importance of the mathematics. If the mathematics studied in grades three through five is interesting and understandable, the increasingly sophisticated mathematical ideas at this level can maintain students' engagement and enthusiasm. However, if learning becomes a process of simply mimicking and memorizing, students may soon begin to lose interest. In order for students to make sense of the mathematics, instruction at this level must be active and intellectually stimulating (NCTM, 2000, p. 143). We believe that one way to create active and intellectually stimulating learning is through the use of games.

Games

Games engage students in completing interesting tasks and developing problem-solving strategies as students work out strategies, think ahead, and evaluate various "game play" moves. As Powell & Oshon (2001) note, games that involve strategies and numbers also help stimulate students' thinking: "Games often foster self-directed exploration. When children feel appropriately challenged by a game, they become intrinsically motivated to discover the secret of winning or losing the game" (p. 369). Yet this motivation also depends on teacher abilities to create environments that help students make sense of the mathematical ideas and strategies they use in the games and to support and encourage students' learning process through playing games (Dominick & Clark, 1996).

Students benefit specifically from selecting and participating in games that are an appropriate level of challenge for them (Peters, 1998). Playing games of strategy are similar to solving mathematics problems because students: (1) have to clearly identify a goal; (2) use a clear set of permissible actions to reach that goal; (3) are challenged to select an action and; (4) understand the logical implications of a chain of steps (Ascher, 1991). The process of playing games of strategy can help to develop students' mathematical thinking and identify students' misunderstandings (Parsons, 2008). Many authors have written about the use of games to improve students' number sense (Ann-Kim, 2003; Bresser & Holtzman, 1999; Young-Loveridgre, 2004). Powell & Temple (2001) note "Children are naturally attracted to and motivated by, games. Games that involve number or strategy stimulate children's mathematical imagination and thinking" (p.369). Therefore, with the importance of number sense (NCTM, 2000) and the knowledge that culturally sensitive instruction coupled with self-confidence improves mathematical achievement (Tartre & Fennema, 1995; Martin, 2009), the pilot project described in this article, the MATRIX, utilized games that enhanced number sense, logical deduction, and strategy development. This article will focus on the development of number sense and adds to the limited research on the intersection of using games with African American children. With this need for research in mind, the study addressed the following research question:

(1) How does an innovative mathematics curriculum utilizing mathematical games enhance the development of elementary students' numeracy understanding and their affective dispositions towards mathematics?

Study Context

Although the MATRIX project was housed in Rock Crest (place and individual names are pseudonyms), students from three school districts in the southeastern US participated in the project. Rock Crest was a rich context in which to receive MATRIX enrichment programming because rural regions have experienced particular challenges in meeting the academic needs of African American children (Beeson & Strange, 2000). The MATRIX project targeted schools in three school districts: Hamilton Public Schools, Oxford County Public Schools, and the Howard County School District. At the time of the MATRIX project implementation, 40.8% of children in Hamilton County public schools were African American, and 56.3% of children in the county were on free/reduced lunch with 20 percent of children in the county living in poverty. In Howard County, 57% of children enrolled in public schools were African American and 72.3% of children in county were on free/reduced lunch with 29% of children in Howard living in poverty. Oxford County reflected similar demographic trends. Fifty two percent of children in Oxford County public schools were African American with 68.6% of students receiving free/reduced lunch and approximately 24.7% of children living in poverty.

MATRIX Project Structure

During the MATRIX project students worked individually and in groups to learn the game challenges. Student groups were composed of students with varying ability levels. Thus, each group has a player that is roughly on the same level as a player in another group. This format allows for more peer teaching, which gives students an opportunity to share and solidify their knowledge. In the MATRIX project, students thereby learned to work as an intellectual team. In this pilot implementation, students met for three hours each Saturday morning for a month. Although the curriculum was implemented during a Saturday camp, it can be used within the context of an after school program, spring break, or summer camp. In addition, different components of the MATRIX math curriculum could be implemented within mathematics classrooms throughout the school year. The flexibility of how the curriculum can be utilized was designed as a major strength of this approach.

Before proceeding to our discussion of the curriculum, we want to briefly introduce the parent engagement component of the project. In addition to the mathematics curriculum, the MATRIX project provided support for parents and those in the larger community in becoming more effective advocates on behalf of children. Parents were provided a parent guide (Hill & Cook, 2007) explaining the MATRIX project and the games played with students. The parent guide provided a description of each game and information necessary for caregivers to play these games with their children.

In addition, a series of trainings were offered parents that cover topics such as organizing an advocacy group and understanding local and state education policy. More importantly, the topics addressed were generated by the parents of the students in the project and were designed to meet their particular needs. The goals of the parental involvement components were that parents will (1) know their rights and the rights of their children, (2) gain an increased understanding of how to negotiate the school system in order to better advocate for their students and (3) have research skills to find the information they need and access resources.

Curriculum

The MATRIX mathematics curriculum uses different mathematical games to create active, creative, and intellectually challenging instruction to help develop students' mathematical thinking and self-confidence. Games are selected and structured in ways that allow students to build on their existing knowledge and build new knowledge. The curriculum is also designed so that students will learn progressively difficult mathematical games. For example, the first games introduced in this curriculum focuses on developing students' numeracy and computational skills and the curriculum continues to build up to complex games which focus more heavily on logical deduction and strategy development (e.g. Gridworks and Mastermind). The curriculum is designed to help students develop, use, and articulate multiple strategic approaches in order to solve the game challenges. The curriculum consists of six types of game challenges presented in the following order: Oh No! 99, Get to 1000, Mancala, Gridworks, Sudoku, and Mastermind.

A major goal for students in grades three through five is the development of number sense that includes computational fluency with whole numbers. Students should become efficient and accurate in computations both mental and recorded thinking (NCTM, 2000). Mental mathematics serves as a tool to sharpen students' computational fluency (Rubenstein, 2001; p. 442-443). Each game discussed in this article required the use of mental mathematics on some level of game play. In each game, students were completing arithmetic calculation without the use of a calculator or paper and pencil and thinking divergently to generate strategies to win the game challenge. This article examines the first three games that focus on numeracy, computational skills and strategy development in the curriculum sequencing: Oh No! 99! Get to a 1,000, and Mancala. What follows is a brief description of each game (Oh No! 99! Get to a 1,000, and Mancala). Then we discuss the study methods and findings.

Overview of Number Sense Focused Games

Oh No! 99! In this game students have the opportunity to practice mental addition and subtraction of small numbers (Bresser and Holtzman, 1999). Two players attempted to force each other to push their accumulating score over a 99 limit. Students use mental mathematics to calculate the accumulated sum of the played cards and were given the opportunity to think strategically about the necessary moves to force their opponent over the limit.

Get to 1,000. In *Get to 1,000*, students have the opportunity to practice adding numbers and multiplying numbers by powers of ten (Bresser and Holtzman, 1999). In this two-person game, students roll a die ten times and multiply each number that comes up by one, ten, or 100. Students add the ten products, the total may be over or under 1,000 and the player who was closest to 1,000 wins the game. Students were encouraged to complete their calculations using mental math. *Get to 1,000* affords students the opportunity to enhance their computational skills as they multiply the total of the two rolled dice by the numbers one, ten, or 100.

Mancala. Mancala is a generic name for a group of African board games. The name, boards, and rules differ among regions of Africa. Wari is the two-row version of Mancala played by the Asante people of Ghana in West Africa and is the version most commonly played in the United States. Mancala provides students with opportunities to investigate numerical patterns, and build and extend arithmetical ideas and strategies. The goal of Mancala is to capture 25 or more stones (more than half the total stones). Successful players must use logic and pay close attention to their moves and the moves of their opponents (Zaslavsky, 1999; Krause, 2000;

Powell and Temple, 2001). Mancala also offers practice with computational skills (Zaslavsky, 1999).

METHODS

As previously stated, this article is part of a larger study of the MATRIX project. An explanation of the participants and data instruments follows.

Participants

Thirty-eight fourth and fifth grade students applied to participate in the MATRIX project, all being African American. There were 16 boys and 22 girls. Twenty-eight (70%) of those who applied, were present the first day of camp. On the first and last day of the MATRIX Saturday camp, students completed math and attitudes assessments. This article includes students that completed both the pre and post assessments totaling 17 participants. A description of each instrument follows.

Data Sources

In this paper, we draw on the results of three instruments to discuss our findings: (1) the pre-post mathematics assessment, (2) the Student pre-post attitude survey and (3) the teacher post survey. The *Pre-Post Mathematics Assessment* consisted of ten items, which were taken from NAEP and State End of Grade test released items. These items were a combination of third and fourth grade items that addressed the following objectives:

a. the development of number sense for rational numbers 0.01 to 99,999
b. using models, diagrams, and reasoning about fractions and relationships among fractions to solve problems

c. fluency with addition and subtraction of non negative rational numbers with like denominators including decimal fractions through hundredths (problems 8 & 10)
d. pattern recognition
e. permutation and combinations
f. logic

Knowing that perceptions can affect attitude, self-confidence and performance in academic subjects, the *Student Attitude Survey* was administered to students before and after the four week Saturday camp (See Appendix One). The aim of the survey was to assess students' confidence level as well as perceptions about mathematics. The survey asked students to respond to 20 questions (18 Likert scale questions and two open-ended questions). The students took the same survey at the beginning and end of the Saturday camp. After collecting all the data, using PASW Statistics 18 (formally SPSS), descriptive statistics and a paired sample t-test was performed in order to observe mean differences between initial and after-project attitudes. The open-ended questions were analyzed for themes and patterns.

The third instrument, the *Teacher Survey,* was administered to MATRIX teachers at the end of the four-week Saturday camp. Of the five schools in our sample, 19 out of 21 teachers completed surveys (i.e. a 90% response rate). The five questions on the Teacher Survey gauged teachers perception of 1) students attitude towards and confidence in mathematics, and 2) students computational ability (See Appendix Two).

FINDINGS

Pre-Post Math Assessment

Seventeen of the thirty-nine students completed the pre and post test. This included ten males and seven females. In general, students' overall post-test scores were statistically significantly higher than the pre-test scores at the .05 significance level. At the item level, more students provided a correct response for all items focusing on number sense skills with the exception of item seven (determining the rational number closest to one).

Teacher Post Survey

In general, the data implies that the teachers believe that the students' mathematical skills (e.g. computational skills) have improved after the four-week period, and students were more willing to try harder math, were more excited about mathematics, and contributed more to class discussions in math class.

The pre-post math assessment and teacher post survey suggests an increase in students' numeracy understanding and confidence and attitudes towards mathematics. These findings suggest that students' participation in the MATRIX project had an impact on their numeracy understanding and confidence and attitudes towards mathematics.

Pre-Post Student Attitude Survey

After collecting all the data, using PASW Statistics 18 (formally SPSS), a paired sample t-test was performed in order to observe mean differences between initial and after program attitudes. We chose the t-test because it highlights areas of significant change in attitude and we used a .05 significance level. Differences existed between all pre and post assessment for each item on the pre and post self-confidence assessment but only questions one (ease of math) and fourteen (not liking math) showed statistically significant differences This overall lack of statistical difference could be attributed to the small sample size and the amount of time the students had an opportunity to participate in the MATRIX project.

In most cases, the pre-test mean was slightly higher than the post, suggesting that for the most part, students remained faithful to their initial statements and views, with a minimal tendency towards positive change. In some items (“Math is fun” and “I like math better than reading”) were identical in the pre and post survey. In others, there was a more notable difference in pre and post-responses. For example to the first statement “math is easy,”50 % of the sample population agreed with the statement. After the program, that number increased to 65%. A similar trend was apparent for the statement “I don’t like math”. Twenty-two percent of the sample agreed with the statement in the pre survey compared to 12% in the post survey. Using Excel's "COUNTIF" function, the count for each answer type was recorded and compared to the general tendency of answers recorded in other questions. Most students restated that they liked or were excited about doing math (questions two and six). Along the same line, the majority of students stated that they have fun doing math (question nine). Sixty-seven percent of students agreed that “math is hard” in the pre-survey but in the post test, only 47% agreed. When we examined comments students made when asked to complete statement 18 (I like math because/I don’t like math because), words such as "scared,” “shaky,” “nervous,” and “get wrong" appeared consistently. In other questions, words like “fun” and “difficult” are recurrent denoting a certain malaise that the survey is unable to fully examine. Finally, the students’ pre-post attitudes survey suggest that after completing the program students appeared to have a boost in confidence. It is important to note that the study did not focus on eliciting the causes or origins of specific perceptions in students.

DISCUSSION AND CONCLUSION

MATRIX was a project designed to improve the mathematics achievement of African

American students. The MATRIX curriculum exposed students to a variety of mathematical games that centered on developing students' number sense and was implemented in an environment to help positively change students' attitudes and dispositions towards mathematics. The MATRIX project was designed to support students' continual development of self-confidence as a mathematics learner. Although the small sample size of participants in this study makes it difficult to make inferences to a larger population, it is important to note that students in this study showed gains in their understanding of number sense and in their level of self-confidence in themselves as mathematics learners. Post-surveys completed by teachers showed that students also experienced a positive change in their attitudes towards mathematics and their numeracy skills.

The students in the MATRIX project only attended four Saturday sessions which may have not been adequate time to make a sustaining impact on students' attitudes about mathematics. Still, the study warrants further research, particularly to examine the impact of MATRIX over a longer period of time. The long-range goal of the MATRIX project is to prepare African American elementary school students for future enrollment in higher-level math courses in middle and high school. Thus, another area of future research would be to examine participants in the MATRIX project through middle and high school to examine how participation in this program impacts their future mathematics course placements.

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APPENDIX ONE

Pre- Post-Math Survey [1]

Name____

This is **NOT** a test. There are no wrong answers. Please put an X in the box that shows how you feel about the statement.

Statements	Agree	Sort of Agree	Sort of Disagree	Disagree
1. Math is too easy.				
2. I like math.				
3.I wish we didn't have to do math in school				
4. Math is dumb.				
5. I always do well in math.				
6. I am excited about doing math.				
7. I worry about doing math in class.				
8. I am good at math.				
9. Math is fun.				
10. I like math better than reading.				
11. Math is hard.				
12. Math is important in everyday life.				
13. I understand everything in math.				
14. I don't like math.				
15. I like reading better than math.				
16. I feel scared during math test				

Please write out an answer to the questions in the box.

17. How do you feel when you are doing math?

Please write out an answer to the questions in the box.

18. Circle the sentence that explains how you feel. Tell me why.	
I like math because……	I don't like math because………..

Please circle your answer

19. I am:	Very good at math	Good at math	Not very good at math	Bad At Math
20. How important is it for you to do well in math?	Very important	Sort of Important	Not very important	Not important at all

[1] Modified from http://jumpmath.org/research/research-initiatives

APPENDIX TWO

Teacher Post Survey

MATRIX Project Saturday Math Camp

Teacher: ____

Student's Name: ____

To the Recommender:

The student named above participated in the MATRIX Project 2007 Saturday Camp program. This youth program offers mathematics enrichment in a camp setting for motivated 4th and 5th grade students. During the program, students attend classes and engage in fun and challenging mathematics games designed to enhance their mathematical reasoning. Your assessment will provide us with valuable information to help understand how to improve. **Please base your responses on any changes in the last month.**

1. **Student is more willing to try hard math problems.**

   Strongly Agree   Agree   Disagree   Strongly Disagree

2. **Student is more excited about doing math.**

   Strongly Agree   Agree   Disagree   Strongly Disagree

3. **Student adds more to the discussion in math class.**

   Strongly Agree   Agree   Disagree   Strongly Disagree

4. **Student's computation skills (adding, subtracting, etc.) have improved.**

   Strongly Agree   Agree   Disagree   Strongly Disagree

5. **Student talks about math more.**

   Strongly Agree   Agree   Disagree   Strongly Disagree

Additional Comments (if any):