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Benefits of the Michiana Daily Mathtracks Programme for students living in poverty

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This paper summarizes results from a math intervention implemented in a high-poverty urban community. Over 7,300 students from kindergarten to 4th grade in 1 low-socioeconomic-status school district participated in the study. Students from 13 different schools (36 different classroom) participated in the treatment. Comparisons were made to purposely selected control-group schools and all other students in the district. The aim of the intervention was to help early elementary-age students living in poverty learn essential math facts and master basic computational skills as a foundation for improving their math ability. The study used a pre-test/post-test quasi-experimental design with control and treatment groups. Achievement for both groups was compared to that of the school district as a whole, with analysis disaggregated by poverty status. The results found positive gains in the treatment group's math achievement at every grade level, transcending differences in socioeconomic status.

Keywords: mathematics instruction; automaticity; mathematics education; achievement gap

Introduction

Most developed countries provide basic educational opportunities to all children and youth regardless of their socioeconomic status (SES) or social standing; yet, the correlation between low SES and poor academic achievement has been well documented (Aikens & Barbarin, 2008; Evans, 2004; Jeynes, 2002; Morgan, Farkas, Hillemeier, & Maczuga, 2009). While any solution to the inequities in society due to poverty will be complicated, most researchers agree that education is critical in alleviating these effects (American Psychological Association [APA] Task Force on Socioeconomic Status, 2007). Inequities in educational opportunity (or its absence) have been the focus of many poverty programmes and initiatives. These efforts, while admirable, often fail to eliminate the achievement gap for students living in poverty (Palardy, 2008). A possible contributing explanation for this failure is inequity in the quality of the instruction and the preparation students receive. Providing children with the opportunity to attend school may be an important first step in overcoming the problems of poverty, but merely attending school does not provide an adequate solution to the problem if the instruction some children receive does

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not facilitate learning. As a result, Haberman (1991) suggested that more research is needed into what constitutes a quality educational opportunity (see also Schmidt, Houang, & Cogan, 2002).

By the time students reach fourth grade in the United States, they are expected to have a good grasp of basic math facts. These basics provide students with a foundation for attaining higher level mathematical abilities, including a conceptual understanding of mathematics, advanced computations, and problem-solving ability (Ball et al., 2005). Unfortunately, each year students come to fifth grade without automaticity of basic math fact recall; consequently, they have no foundation upon which to build higher level computational skills (Lehner, 2008). The achievement gap in mathematics for high-poverty students is of particular concern (Balfanz, McPartland, & Shaw, 2003; Beaton et al., 1996; Schmidt, McKnight, et al., 1999). Many researchers believe that poor mathematics achievement in general, and specifically for children living in poverty, can be traced in part to an inadequate curriculum and poor instruction (Schmidt, Houang, & Cogan, 2002). Regrettably, many students from low-SES families do not receive a proper educational foundation and as a result fall behind students who do (Aikens & Barbarin, 2008). A contributing solution to the achievement gap might be to provide a better foundation through targeted instruction including remedial help to students who have fallen behind (Baker, Gersten, & Lee, 2002; Slavin & Lake, 2008).

Project purpose and question

The purpose of this study was to explore the benefits of supplementing regular elementary-grade mathematics instruction with instruction and practice targeting basic math facts and computational skills considered foundational to learning advanced mathematics concepts (Ball et al., 2005). This report documents an analysis of achievement results for the Michiana Daily MathTracks (MDMT) programme currently being implemented in selected schools in the South Bend Community School Corporation (SBCSC), which serves a population of mostly low-SES students living in an urban area of northern Indiana. This evaluation was conducted to address the effectiveness of this mathematics intervention for low-SES students. The primary question addressed in this study focused on the extent to which students receiving MDMT training showed improvement in their math ability, as measured by MDMT assessments along with district and state assessments of mathematics. Researchers hypothesized that students receiving supplemental remedial instruction targeting basic math facts and computational skills would perform better on MDMT, district, and state mathematics assessments compared to similar students not receiving this instruction.

Project background

The MDMT programme is designed as an instructional supplement to regular mathematics curriculum instruction. Implemented from kindergarten (KG) to fourth grade, the programme provides differentiated whole classroom instruction intended to help students become proficient in basic math facts and computational skills. The targeted math skills vary from grade to grade (see Table 1); however, students engage in daily 20-min sessions with practice and instruction targeted to the individual student's ability level. This is in addition to regular math instruction provided by the classroom teacher as prescribed in the curriculum. It does not take time away from other subjects taught but was implemented at the end of math instruction time or during what teacher called workstation time. The

Table 1. MDMT concepts taught and tested by grade level.

Grade	Concepts
KG	Counting number 1 to 100, Next Number, Plus one, Minus one, Number formation practice.
1st Grade	Adding number 1 & 2 digit number with no carry, 2 digit number expansion, adding 2 digit number with carry.
2nd Grade	Addition review, Subtraction, place value, borrowing, 2 and 3 digit subtraction with borrowing.
3rd Grade	Addition and Subtraction review, Multiplication number 1 to 10, Multiplication with carrying, simple division.
4th Grade	Simple division, Long division, multiplying/dividing decimals, adding/subtracting fractions, Ratios

initiative involves a variety of activities including worksheets, targeted practice tasks, and timed assessments. See the MDMT website for additional information (http://www.michianamathtracks.org/). Progress is tracked, and students are tested at the beginning and end of the school year to measure improvement. The underlying premise for this instructional process is that students achieve best when they are able to perform routine basic math skills automatically. This automaticity allows students to focus on more advanced mathematical concepts and skills, thus improving their overall mathematics achievement.

For the past 5 years, the MDMT programme has been implemented in targeted schools within the SBCSC, being tested each year by comparing the results of MDMT assessments of students who received the treatment and those who did not. Analysis of the results has showed that MDMT students consistently outperformed non-MDMT students on this assessment; however, in order to adequately test the effectiveness of the programme, analysis needed to include results from district and state assessments designed to measure how well students could meet the more comprehensive learning outcomes in mathematics set by these entities for each grade level. This was the 1st year district and state assessment results were made available for such an analysis. While testing student performance on the MDMT assessment was valuable, knowing whether MDMT training impacted students' achievement as measured by district and state assessments was essential in determining programme effectiveness.

Background literature

Poverty is a complex social problem that exists to some extent in all world nations (World Bank, 2012). Obviously, differences between individuals will always exist within a society and is a function of a myriad of important factors (Huston & Bentley, 2010). At the core of the poverty problem, however, are extreme forms of inequity – notable differences in basic resources, opportunity, support, or services needed for an individual to live with dignity in that society. The hardships and distress individuals experience due to such disparity must be of global concern.

Solutions to the inequity problems are extremely complicated, involving political, economic, social, and individual aspects. Simplistic solutions that focus on only one aspect of the problem (e.g., financial aid alone) do not always have lasting effects and often have unintended consequences. Wilmot (2007) suggested that solutions must be contextualized to the society and circumstances in which a problem exists. If the solution were simple, research into poverty problems would be unnecessary. And while a systemic solution is likely required, studies typically focus on individual aspects of a holistic solution. For example, most individuals agree that education is a critical aspect in alleviating the effects of poverty, although they realize it may not completely solve the problem of world poverty (APA Task Force on Socioeconomic Status, 2007; Bruenig, 2013). Thus, while solving the problem of poverty in the world may be beyond the ability of educational researchers, efforts to better understand how teachers might alleviate some consequences of poverty through education is an important endeavour.

The correlation between low SES and poor academic achievement has been well documented (Aikens & Barbarin, 2008; Evans, 2004; Jeynes, 2002; Morgan et al., 2009). Noting a correlation, however, does not prove or improve our understanding of causal relationships. Still, researchers have suggested potential causes and related solutions (or partial solutions) to the problem. For example, poverty is related to inadequate resources. As a result, the Title 1 initiatives in the United States attempt to redistribute wealth to fund schools in areas of high poverty. Other researchers note that in order for students to learn, they must have their basic needs met (Maslow, 1943). Consequently, many school districts have implemented school lunch programmes to help alleviate hunger as a potential cause for poor scholastic achievement (Hinrichs, 2010). Solutions based on wealth redistribution also include programmes like the one-to-one computing initiative that provides technology to schools that serve large numbers of low-income families (Davies & West, 2014). Other solutions focus on establishing and reinforcing relationships among teachers, parents, and students. The basic premise for these programmes is that students need support from home in addition to school (Borup, Graham, & Davies, 2013). Each of these efforts has been successful to some extent. Still, the problem is complicated, and the solution likely multifaceted. The premise of this research is based on Haberman's (1991) assertion that good instruction will transcend a child's poverty status.

Many individuals believe that poor performance of students in mathematics can be traced to the methods used to teach math at elementary levels (Haberman, 1991; Hook, Bishop, & Hook, 2007; Organisation for Economic Co-operation and Development [OECD], 2010; The Education Alliance, 2006). Mathematics is a form of reasoning. Individuals with math competencies are able to make sense of things using mathematical equations and concepts. The ultimate goal of mathematics instruction is for students to gain a conceptual understanding of mathematics, which involves connecting and reasoning with facts, procedures, and ideas for the purpose of solving problems (Hiebert & Grouws, 2007). Critics of the current mathematics instruction provided in US schools believe that low test results are evidence that schools have students spend too much time memorizing math facts and not enough time obtaining conceptual understanding of mathematics. As a result, some advocate for more challenging courses (Adelman, 2006), which would require students to struggle with important mathematics problems and concepts. Advocates for a conceptual approach tend to criticize instructional methods and assessments that focus solely or primarily on attaining automaticity with basic math facts and procedural application skills for simple math problems.

The counter-argument is that certain mathematics procedures and knowledge are so basic that they should be practised to the point of automaticity. Automatic recall of basic number facts is a crucial aspect of computational fluency (Ball et al., 2005), which provides the foundation upon which higher level computational skills are developed (Lehner, 2008). Advocates for back-to-basics mathematics instruction believe that a more challenging conceptual understanding of mathematics which focuses on problem solving is unattainable for students who do not have a proper foundation in basic math facts (Ball et al., 2005; Daro, 2006; Wong & Evans, 2007).

The debate over a conceptual approach versus a back-to-basics approach is likely somewhat pedantic. A similar pedagogical debate has existed between advocates of whole language and phonics for reading instruction. Eventually, a more comprehensive expectation for reading instruction emerged including aspects of both approaches. The National Institute for Literacy in the US now advocates for a balanced approach that includes phonemic awareness, phonics, fluency, and vocabulary, in addition to the text comprehension supported by these skills (Center for the Improvement of Early Reading Achievement, 2001). Similarly, mathematics instruction might strive for automaticity of basic math facts as a foundation for gaining a conceptual understanding of mathematics that enables students to solve important problems mathematically.

Regardless of pedagogical stance, the tragedy of poverty remains: Even when students are provided with educational opportunities, overwhelming evidence shows that living in poverty affects their academic achievement (Aikens & Barbarin, 2008; Evans, 2004; Jeynes, 2002; Morgan et al., 2009; Palardy, 2008). Educators cannot change the SES of individual children or the apparent lack of preparation a student might have prior to entering their classroom. The important challenge is to determine what can be done in schools to compensate for inadequate preparation or learning deficit of an individual student.

Research on effective mathematics instruction for low-SES students includes several suggestions. Intervention programmes are more likely to be effective if they are implemented in schools serving disadvantaged and minority students. These programmes should provide remedial training and materials for low-performing schools in addition to the regular instruction students receive (Sconiers, Isaacs, Higgins, McBride, & Kelso, 2003). Supplementing regular classroom instruction with well-targeted differentiated lessons has strong evidence of success (Slavin & Lake, 2008). This includes strategies designed to develop generic problem-solving strategies and more classic direct-instruction approaches that have students involved in extensive practice sessions (Baker et al., 2002).

Evaluation activities

The main goal for this evaluation was to verify any impact the MDMT programme might have had on students' success in mathematics. In order to answer the impact question, evaluation activities included (a) comparing MDMT programme assessment results for treatment and control-group students; (b) determining the relationship between MDMT assessments and district and state achievement indicators; and (c) comparing MDMT, control-group, and other SBCSC students' achievement on district and state assessments disaggregated by students' SES. The comparison of MDMT scores is provided as evidence that the MDMT instruction is effective at increasing basic knowledge and computational skills. Correlating MDMT results with district and state math assessment results is intended to provide evidence of the degree to which the basic math skills measured by the MDMT assessments are associated with more comprehensive sets of math skills measured by district and state assessments. Comparing results of MDMT, control-group, and other SBCSC students is intended to demonstrate that MDMT instruction is an effective way to alleviate some of the noted effects of low SES on achievement. The combination of these three analyses is intended to more fully answer the primary research question: To what degree do students receiving MDMT training show improvement in their math ability as measured by MDMT, district, and state assessments of mathematics, and how do the scores compare to those of students receiving regular mathematics instruction alone?

Participants

This report includes information from an evaluation conducted in the 2011–2012 school year including students from kindergarten (KG) to fourth grade. Each of the MDMT schools had implemented the MDMT instruction for several years; thus, students in later grades would likely have had several years of experience with the programme. However, the assessments at each grade test different math concepts. Details regarding the specific number of students in each grade and group are presented in Table 2. Selected MDMT schools all had large numbers of students identified as living in poverty and a history of their students performing poorly on district and state assessments. Their selection was also based on their willingness to implement the MDMT programme. Control-group schools were selected based on being comparable to the treatment schools in numbers of students with low SES and minority status, performance history, and school type (i.e., public or private). Analysis of the results showed that students participating in the MDMT programme tended to have similar pre-test scores on MDMT assessments compared to students in the control-group schools. This result led us to believe the purposive sampling methods used to create comparison groups had been somewhat effective.

The SBCSC serves a population consisting mainly of low-SES students living in an urban area of northern Indiana. The SBCSC includes 63% minority students and 72% students identified as low SES. The district population is fairly transient, and students often transfer between schools, as well as in and out of the district. Students transferring from an MDMT school to a non-MDMT school were excluded from the analysis to control for any intervention interaction bias. Students who failed to complete one of the assessments were likewise excluded, as the data required for the analysis were unavailable.

Table 3 presents the participation rates for the district and state assessment including the percent of students designated as Title 1 (or low SES). For schools in the United States, a Title 1 designation is an indicator that the student is from a low-SES family. To identify a student who might suffer in terms of academic achievement due to low SES can be a challenge (Huston & Bentley, 2010); in fact, schools often struggle to properly identify students who truly should be placed in the low-SES category. A Title 1 designation is based on a student's eligibility for free or reduced-price lunch based on the families income. The other SCCSC students referred to in this table include all students in the district not in the MDMT or control group that took the district and state exams. All students are required

Table 2. MDMT and control-group participation statistics by grade, group, and SES designation.

Grade	Group	Total Students Included	% Low SES	Missing Data*	Classrooms (schools) Involved
KG	MDMT	240	77	25	13 (4)
	Control	177	58	32	10 (3)
1st Grade	MDMT	230	65	31	13 (3)
	Control	149	44	67	9 (3)
2nd Grade	MDMT	75	29	11	6 (3)
	Control	151	46	24	11 (4)
3rd Grade	MDMT	41	59	17	2 (1)
	Control	137	45	64	12 (4)
4th Grade	MDMT	18	23	28	2 (1)
	Control	85	21	67	8 (3)

* Students who did not complete both pre- and post-tests were excluded from the analysis and were not counted in the total number of students for each group.

Table 3. District and state exam participation statistics by grade, group, and SES designation.

Grade	Group	Total Students Included	% Low SES (Title 1)
KG	MDMT	262	78
	Control	202	76
	Other SBCSC	1136	61
1st Grade	MDMT	250	75
	Control	206	47
	Other SBCSC	1072	55
2nd Grade	MDMT	72	21
	Control	172	66
	Other SBCSC	1212	64
3rd Grade	MDMT	54	59
	Control	195	45
	Other SBCSC	1179	65
4th Grade	MDMT	44	70
	Control	149	85
	Other SBCSC	1163	78

to take district and state assessments; however, for a variety of reasons not all students take the district and state exam. Missing data for these tests was unavailable but is assumed to be low.

Data collection and analysis

All students were assessed using district and state tests assigned for each grade. ISTEP+ testing is done for third and fourth grades; district math assessments (i.e., mClass benchmark tests) are administered to all KG through second-grade students. The mClass data are district benchmark assessment results designed to assess the degree to which students have met math learning goals set by the district. This exam is administered by teachers often individually for the lower grades. ISTEP+ data are achievement results collected yearly by the state of Indiana for all students in third grade and above. The ISTEP+ is a summative assessment of student performance measuring students' math achievement for each grade level for accountability purposes. This is a standardized test administered by the state.

All students in this study received regular math instruction provided by their teachers. MDMT students received additional differentiated MDMT practice and instruction for 20 min a day, three to five times a week. This intervention was administered by the same two individuals at a team so as to control for any teacher effect that might adversely affect results. All students in the MDMT and control groups were tested at the beginning and end of the year using MDMT assessments, timed tests of basic math knowledge and computational skills aligned with the MDMT instruction. These assessments focus primarily on students' ability to complete basic problems designated for each grade as well as testing students' knowledge of basic mathematical concepts.

In summary, data points used in this analysis included pre- and post-test MDMT assessment data for treatment and control groups, end-of-year district mClass math assessment data for all SBCSC students in KG second grade, and state math ISTEP+ data for students in third and fourth grades. This allowed us to explore the degree to which MDMT instruction has impacted student achievement as measured by these district and state success indicators disaggregated by students' SES.

Student scores were compared using descriptive and inferential statistics. MDMT assessment scores at each grade level were examined using an analysis of covariance (ANCOVA); pre-test scores were used as a covariate to control for any differences in students' ability that might have existed prior to instruction. A bi-variate Pearson correlation was used to determine the relationship between the MDMT assessments and district and state assessments. The purpose of this correlation was to find out whether these assessments measured similar constructs of mathematical ability and thus could be used to determine any impact MDMT instruction might have on student success in mathematics. An analysis of variance (ANOVA) was used to compare the district and state assessment results of each group. Post-hoc tests were conducted for significant results. Effect size (ES) estimates were computed using Cohen's *d* and an eta-squared calculation as appropriate. These results were disaggregated by SES. Assumptions regulating the use of these statistical technics were tested and found to be within acceptable parameters. Because data collection involved gathering student test scores, institutional review board (IRB) approval was obtained for this study.

Results

Evaluation results for each grade level compared (a) the MDMT assessment results for MDMT students and control-group students; (b) the relationship between MDMT assessment and district and state achievement indicators; and (c) district and state achievement indicators for MDMT students, control-group students, and all other SBCSC students.

MDMT assessment results

The MDMT assessment tests math automaticity on the specific math skills designated for each grade (see Table 1). These results are present for the groups as a whole, then disaggregated based on SES designation within each of the groups at each grade level.

Group comparison result for the MDMT assessment

The results for this assessment are presented in Figures 1 through 5. The results confirm what would be reasonably expected. Students that receive specific automaticity training on basic skills in addition to regular classroom instruction outperform students who

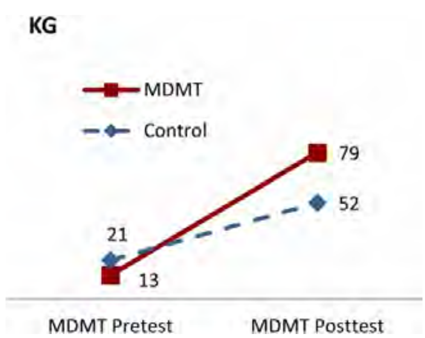

Figure 1. KG MDMT assessment results by group.

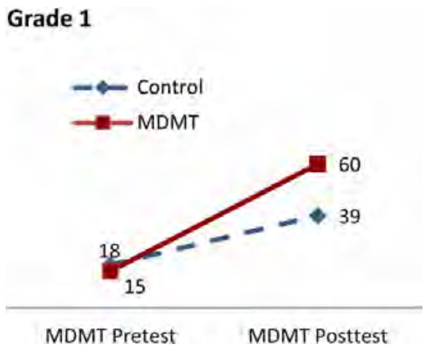

Figure 2. First-grade MDMT scores compared by group.

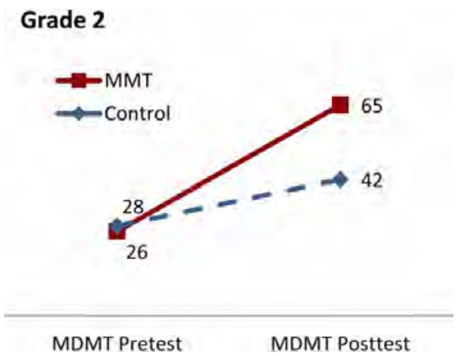

Figure 3. Second-grade MDMT results compared by group.

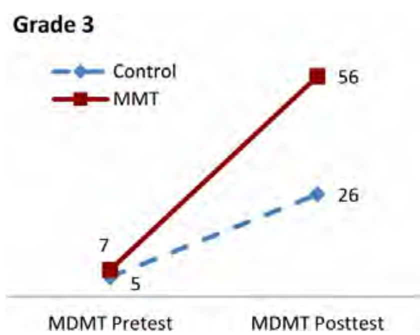

Figure 4. Third-grade MDMT assessment results by group.

receive regular classroom instruction alone. Details of the specific statistical analysis for each grade level are presented in the grade-delineated subsections below.

Overall KG results MDMT assessment

Initial group means, obtained at the beginning of the year, were statistically different based on treatment and control-group pairings $F(1{,}415) = 40.2$, $p < .001$; control-group students

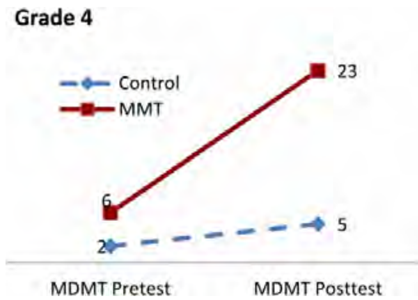

Figure 5. Average fourth-grade MDMT score comparison by group.

scored slightly higher (8 points) on average. However, the results of an ANCOVA using pre-test scores as a covariate to control for any student differences in ability prior to instruction suggest that after participating in the initiative, MDMT students demonstrated a statistically significant improvement in achievement $F(1,414) = 344.0$, $p < .001$. The post-test scores for the MDMT group were 27 points higher on average than those of the control-group students ($M_t = 23$, $SD_t = 2.9$, $M_c = 5$, $SD_c = 7.3$). Using Cohen's d to calculate an effect size, the researchers found that the mean difference between groups was large ($d = 1.55$). Using an eta-square calculation for the effect size, an analysis of the result indicated that approximately 45% of the variance in the final assessment could be attributed to the MDMT programme. The prior ability of the student was also a significant factor: Based on an effect-size calculation, 27% of the variance in math achievement could be attributed to students' previous or natural ability and effort as measured by the pre-test.

Overall first-grade results MDMT assessment

Pre-test scores were not statistically different based on treatment and control groupings $F(1,377) = 1.7$, $p = .194$; control-group students scored only slightly higher (3 points) on average. However, the results of an ANCOVA using pre-test scores as a covariate suggest that after participating in the initiative the MDMT students demonstrated a statistically significant improvement in achievement $F(1,376) = 181.5$, $p < .001$; the post-test scores for the MDMT group were 21 points higher on average compared to those of control-group students ($M_t = 60$, $SD_t = 22.1$, $M_c = 39$, $SD_c = 19.7$). Using Cohen's d to calculate an effect size, the researchers found that the mean difference between the groups was large ($d = 1.28$). Using an eta-square calculation for the effect size, they determined that approximately 33% of the variance in the final assessment could be attributed to the MDMT programme. The prior ability of the student was also a significant factor in his or her achievement. Based on an effect-size calculation, 42% of the variance in math achievement could be attributed to students' previous ability and effort as measured by the pre-test.

Overall second-grade results MDMT assessment

Again, pre-test scores were not statistically different based on treatment and control groupings $F(1,224) = 1.6$, $p = .202$; control-group students scored slightly higher (2 points) on average. However, the results of an ANCOVA using pre-test scores as a covariate to control for any student differences in ability prior to instruction suggested that after participating in the initiative, the MDMT students demonstrated a statistically significant improvement in achievement $F(1,223) = 109.2$, $p < .001$. The post-test scores for the MDMT group were 23 points higher on average compared to those of control-group students ($M_t = 65$, $SD_t = 23.7$, $M_c = 42$, $SD_c = 17.2$). Using Cohen's *d* to do an effect-size calculation, the researchers found that the mean difference between the two groups was large ($d = 1.57$). Using an eta-square calculation for the effect size, an analysis of the result indicates that approximately 33% of the variance in final assessment could be attributed to the MDMT programme. The prior ability of the student was also a significant factor in his or her achievement. Based on an effect-size calculation, 21% of the variance in math achievement could be attributed to students' previous or natural ability and effort as measured by the pre-test.

Overall third-grade results MDMT assessment

Initial pre-test scores, obtained at the beginning of the year, were statistically different according to treatment and control groupings $F(1,176) = 8.4$, $p = .004$; MDMT-group students scored slightly higher (2 points) on average. However, the results of an ANCOVA using pre-test scores as a covariate to control for any student differences in ability prior to instruction suggest that after participating in the initiative, the MDMT students demonstrated a statistically significant improvement in achievement $F(1,175) = 74.8$, $p < .001$. The post-test scores for the MDMT group were 30 points higher on average compared to those of control-group students ($M_t = 56$, $SD_t = 21.3$, $M_c = 26$, $SD_c = 16.7$). Using Cohen's *d* to calculate an effect size, the researchers again found the mean difference was large ($d = 1.66$). Using an eta-square calculation for the effect size, an analysis of the result by the researchers indicates that approximately 30% of the variance in final assessment could be attributed to the MDMT programme. The prior ability of the student was also a significant factor in his or her achievement. Based on an effect-size calculation, 31% of the variance in math achievement could be attributed to students' previous or natural ability and effort as measured by the pre-test.

Overall fourth-grade results MDMT assessment

Pre-test scores obtained at the beginning of the year were statistically different in the treatment and control groupings $F(1,125) = 5.5$, $p = .021$; MDMT-group students scored slightly higher (4 points) on average. However, the results of an ANCOVA using pre-test scores as a covariate to control for any student differences in ability prior to instruction suggest that after participating in the initiative the MDMT students demonstrated a statistically significant improvement in achievement $F(1,124) = 37.7$, $p < .001$; the post-test scores for the MDMT group were 18 points higher on average compared to those of control-group students ($M_t = 23$, $SD_t = 7.9$, $M_c = 5$, $SD_c = 8.2$). Using Cohen's *d* for the effect size ($d = 1.96$), the researchers found that the mean difference was large. Using an eta-square calculation for the effect size, an analysis of the result indicates that approximately 23% of the variance in final assessment could be attributed to the MDMT programme. The prior ability of the student was also a significant factor in his or her achievement. Based on an effect-size calculation, 27% of the variance in math achievement could be attributed to students' previous or natural ability and effort as measured by the pre-test.

MDMT assessment results disaggregated by SES designation

The results of the MDMT assessment were disaggregated by SES designation. In the United States, the term Title 1 student is used for those determined to be in the low-SES category. Regular MDMT students refers to those determined to be in a higher SES category.

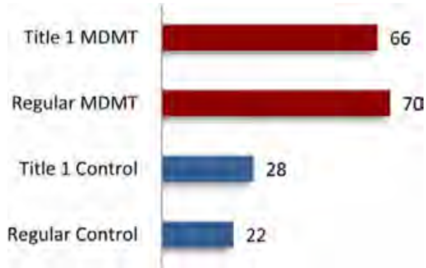

Figure 6. KG average MMDT gain by SES.

Low-SES (Title 1) MDMT students' achievement accounting for pre-test scores, in most cases, was equal to or better than those of regular students who also received MDMT instruction. Of importance is the fact that Title 1 MDMT students' gains were notably larger compared to the control group regardless of the students' SES designation in that group. MDMT training seemed to have a positive impact on students' performance regardless of Title 1 low-SES designation (see Figures 6 through 10).

Alignment between the MDMT assessment and the district/state assessments

The purpose of this investigation was to find out whether the assessments used in this study measured similar constructs of mathematical ability; and thus the degree to which MDMT assessment results predicted student success in mathematics as measured by district and state tests. A common method for doing this is to use a bi-variate correlation. A strong correlation provides evidence that there is a relationship between the MDMT assessments and district or state assessments. Such a result would indicate the tests measure, in some respect, similar constructs. A low correlation would indicate that the district and state assessments were likely unaffected by whatever the MDMT assessment was testing. In almost each case for each grade, there was a moderate to strong correlation between the MDMT assessment results and the district and state assessments used to determine student achievement in mathematics.

KG MDMT assessment alignment with district benchmark tests

On the basis of a Pearson correlation calculation, we concluded that the MDMT post-test correlated well with each of the district mClass assessments, suggesting that they do measure similar math constructs (see Table 4). Students who did well on MDMT

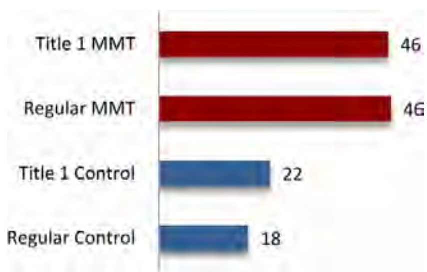

Figure 7. First-grade average MMDT gain by SES.

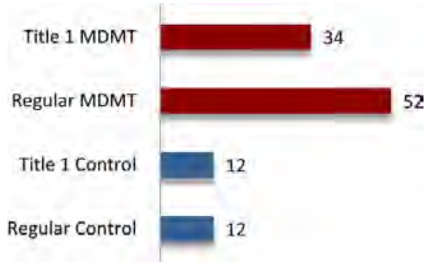

Figure 8. Second-grade MDMT gains by SES designation.

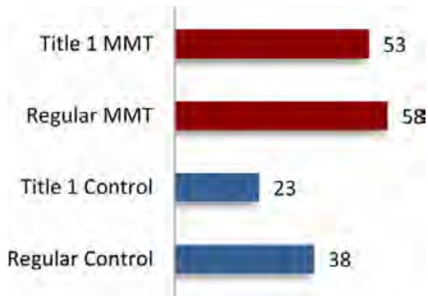

Figure 9. Average Grade 3 gain comparison by SES designation.

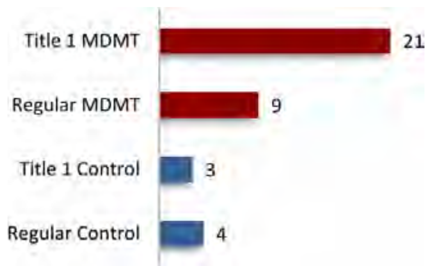

Figure 10. Average fourth-grade gain comparison by SES designation.

assessments tended to do well on district assessments measuring similar math concepts and vice versa. Thus, the MDMT assessments were a fairly good predictor of students' success on district benchmark assessments.

First-grade MDMT assessment alignment with district assessments

The first-grade mClass assessment has six components. On the basis of a Pearson correlation calculation, we found that the MDMT post-test results correlated strongly with only two of the mClass assessments (see Table 5). Correlations were only moderate for the other assessments. These results suggest that while these assessments do likely measure similar math constructs, other factors may be affecting the result. In all cases, there was a positive correlation; students who did well on MDMT assessments tended to

Table 4. Strength of relationship between KG assessments (MDMT post-test vs. mClass tests).

	Number identification	Quantity discrimination	Counting	Missing number
Pearson Correlation	**.660**	**.623**	**.627**	**.643**
Sig. (2-tailed)	.000	.000	.000	.000
N	435	435	435	435

Table 5. Correlation between MDMT post-test and mClass results.

		Number identification	Number facts	Quantity discrimination	Counting	Missing number	Next number
MDMT post-test	Pearson correlation	**.486**	**.655**	**.576**	**.383**	**.409**	**.487**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	384	384	384	384	384	384

do well on district benchmark assessments, leading us to believe the MDMT assessments are a fairly good predictor of student success as measured by these instruments.

Second-grade MDMT assessment alignment with district assessments

The second-grade mClass assessment has five components. On the basis of a Pearson correlation calculation, we concluded that the MDMT post-test correlated highly with all of the mClass assessments with the exception of quantity discrimination, which had only a small positive correlation (see Table 6). Students who did well on MDMT assessments tended to do well on district benchmark assessments measuring similar math concepts. This result suggests that the MDMT assessment is likely a good predictor of district benchmark assessments.

Third-grade MDMT assessment alignment with state ISTEP+ assessment

Based on a Pearson correlation calculation, the MDMT post-test assessment correlated well with the ISTEP+ state assessments, suggesting that they do measure similar aspects of student's ability to do math ($r = .725$). Students who did well on MDMT assessments tended to do well on state ISTEP+ assessments. This result suggests that the MDMT is a good predictor of student success as measured by the state ISTEP+ exam.

Table 6. Second-grade correlation between MDMT post-test and mClass tests.

	Number facts	Quantity discrimination	Missing number	Math computation	Math concepts
Pearson correlation	**.688**	**.246**	**.542**	**.617**	**.525**
Sig. (2-tailed)	.000	.000	.000	.000	.000
N	218	218	218	218	218

Fourth-grade MDMT assessment alignment with state ISTEP+ assessment

Based on a Pearson correlation calculation, the MDMT post-test assessment correlated well with the ISTEP+ state assessments, suggesting that these assessments do measure similar aspects of students' ability to do math (r = .563). Students who did well on MMT assessments tended to do well on district benchmark assessments measuring similar math concepts. This result suggests that the MDMT is a good predictor of student success as measured by the state ISTEP+ exam.

District and state assessment results

The primary question for this study was to determine whether MDMT instruction might have an effect on students' math ability as measured by district and state assessments.

District KG mClass results by group

An ANOVA calculation was run to determine whether there were any significant differences in the means of district mClass assessments based on group membership. As illustrated in Table 7, all of the comparisons between groups were statistically significant; KG students who received MDMT training on average demonstrated greater math ability as measured by mClass assessments than control-group students, and (as determined by post-hoc analysis) these students performed as well or better than other SBCSC students who completed mClass assessments. The effect size (ES) in each case was small.

An ANOVA calculation was run to determine whether there were any significant differences in groups disaggregated by SES designation. In general, the test did not find large differences between Title 1 and non-Title 1 students in any of the groups. However, an analysis of the results indicates that both Title 1 and non-Title 1 KG students who received MMT training performed on average as well or better than non-Title 1 students in the control-group and other SBCSC schools who completed mClass assessments. Title 1

Table 7. KG average mClass results compared by group and SES designation.

mClass subtest	Group	n	Mean for Regular Students	Mean for Title 1 Students	Combined Mean (SD)	Group Difference Results
Number identification	MDMT	262	40	32	33 (13.0)	$F(2,1597) = 23.7$, $p < .001$, ES = .03
	Control	202	32	25	25 (12.9)	
	Other SBCSC	1136	35	30	31 (13.0)	
Quantity discrimination	MDMT	262	29	27	27 (9.2)	$F(2,1597) = 26.6$, $p < .001$, ES =.03
	Control	202	25	21	22 (9.8)	
	Other SBCSC	1136	30	25	26 (8.5)	
Counting	MDMT	262	93	88	89 (18.7)	$F(2,1597) = 36.0$, $p < .001$, ES = .04
	Control	202	77	74	74 (24.2)	
	Other SBCSC	1136	91	85	87 (20.4)	
Missing number	MDMT	262	17	16	16 (5.9)	$F(2,1597) = 15.1$, $p < .001$, ES = .02
	Control	202	16	13	13 (6.7)	
	Other SBCSC	1136	16	14	15 (6.3)	

students in control-group schools and in most cases Title 1 students in other SBCSC schools tended to have significantly lower performance on average. This result seems to suggest that MDMT training had a positive impact on students' performance regardless of their SES.

Comparison of district first-grade mClass assessments by group

An ANOVA was run to determine whether there were any significant differences in the means of district mClass assessments based on group membership. As presented in Table 8, only two of the comparisons were statistically significant. In the mClass assessments for number facts and quantity discrimination, MDMT students did significantly better statistically compared to control-group and other SBCSC students. On all of the other mClass assessments, MDMT students scored slightly higher on average, but the results were not statistically different.

There were few statistically significant differences in the results of this comparison. In general, the test did not find large differences between Title 1 and non-Title 1 students in any of the groups. However, first-grade students designated as Title 1 who received MDMT training on average performed as well or better than non-Title 1 students. Title 1 students in control-group schools tended on average to have significantly lower scores.

Comparison of second-grade district mClass assessments by group

An ANOVA was run to determine whether there were any significant differences in the means of district mClass assessments based on group membership. As illustrated in

Table 8. First-grade mClass comparison by group and SES.

mClass subtest	Group	*n*	Mean for Regular Students	Mean for Title 1 Students	Combined Mean (*SD*)	Group Difference Results
Number identification	MMT	250	52	50	50 (14.1)	$F(2,1525) = 2.5$, $p = .079$
	Control	206	52	47	48 (13.2)	
	Other SBCSC	1072	52	50	50 (13.4)	
Number facts	MMT	250	13	13	13 (3.7)	$F(2,1525) = 10.0$, $p < .001$, ES = .01
	Control	206	12	11	11 (3.1)	
	Other SBCSC	1072	12	12	12 (3.7)	
Quantity discrimination	MMT	250	42	40	40 (9.5)	$F(2,1525) = 4.0$, $p = .018$, ES = .01
	Control	206	43	37	38 (9.5)	
	Other SBCSC	1072	39	39	39 (9.2)	
Counting	MMT	250	106	105	105 (14.7)	$F(2,1525) = 0.41$, $p = .662$
	Control	206	102	105	104 (14.1)	
	Other SBCSC	1072	104	106	105 (15.3)	
Missing numbers	MMT	250	22	23	23 (6.6)	$F(2,1525) = 0.20$, $p = .815$
	Control	206	25	22	23 (7.2)	
	Other SBCSC	1072	23	23	23 (6.9)	
Next numbers	MMT	250	22	22	22 (5.7)	$F(2,1525) = 0.80$, $p = .450$
	Control	206	23	21	21 (7.2)	
	Other SBCSC	1072	22	21	21 (6.9)	

Table 9. Second-grade mClass comparison by group.

mClass subtest	Group	*n*	Mean for Regular Students	Mean for Title 1 Students	Combined Mean (*SD*)	Group Difference Results
Number facts	MMT	73	34	29	33 (15.1)	$F(2,1454) = 8.3$,
	Control	172	32	19	26 (14.1)	$p < .001$, ES = .01
	Other SBCSC	1212	31	26	28 (11.9)	
Quantity discrimination	MMT	73	19	22	19 (11.9)	$F(2,1454) = 10.0$,
	Control	172	17	11	14 (9.7)	$p < .001$, ES = .01
	Other SBCSC	1212	15	16	15 (7.9)	
Missing numbers	MMT	73	11	7	10 (7.4)	$F(2,1454) = 4.2$,
	Control	172	11	5	8 (6.2)	$p = .016$, ES = .01
	Other SBCSC	1212	9	8	9 (5.6)	
Math computation	MMT	73	25	13	22 (12.6)	$F(2,1454) = 24.9$,
	Control	172	16	13	15 (8.7)	$p < .001$, ES = .01
	Other SBCSC	1212	16	14	15 (8.7)	
Math concepts	MMT	73	18	13	17 (4.8)	$F(2,1454) = 14.9$,
	Control	172	17	10	14 (6.2)	$p < .001$, ES = .01
	Other SBCSC	1212	15	13	14 (4.8)	

Table 9, all of the comparisons were statistically significant; second-grade students who received MDMT training on average demonstrated greater math ability as measured by mClass assessments than control-group students and other SBCSC students who completed mClass assessments. Effect size indicators were small.

An ANOVA calculation was run to determine whether there were any significant differences in groups disaggregated by SES designation. In general, the test did not find large differences between Title 1 and non-Title 1 students in any of the groups. However, among Title 1 and non-Title 1 second-grade students who completed mClass assessments, those who received MDMT training performed on average as well or better than non-Title 1 students in the control-group and other SBCSC schools. Title 1 students in control-group schools, and in some cases Title 1 students in other SBCSC schools, tended to score significantly lower on average.

Comparison of state third-grade ISTEP+ assessments by group

An ANOVA was run with post-hoc analysis to determine whether there were any significant differences in the ISTEP+ scores based on group membership. As illustrated in Table 10 below, the comparisons were statistically significant; in general, third-grade students who received MDMT training demonstrated on average greater math ability as measured by ISTEP+ assessments than either the control-group students or other SBCSC students who completed the ISTEP+ assessments.

An ANOVA was run with post-hoc analysis to determine whether there were any significant differences in the ISTEP+ scores based on group membership and SES designation. The results were statistically significant $F(5,1422) = 39.5$, $p < .001$, ES = .22. The average ISTEP+ scores for Title 1 students in the control and SBCSC groups were significantly

Table 10. Third-grade ISTEP+ comparison by group.

Group	n	Mean for Regular Students	Mean for Title 1 Students	Combined Mean (*SD*)	Group Differences Results
MDMT	54	507	475	488 (63.2)	$F(2,1425) = 28.3$,
Control	195	471	396	411 (87.1)	$p < .001$, ES = .04
Other SBCSC	1179	490	437	449 (77.0)	

Figure 11. Third-grade state ISTEP+ comparison by SES designation.

lower statistically compared to those of students in the other four groups (see Figure 11). No statistical difference in scores was found between Title 1 MDMT students and non-Title 1 students from any of the other groups.

Comparison of state fourth-grade ISTEP+ assessments by group

An ANOVA was run with post-hoc analysis to determine whether there were any significant differences in the ISTEP+ scores based on group membership. As illustrated in Table 11 below, the comparisons were statistically significant; in general, fourth-grade students who received MDMT training demonstrated on average greater math ability as measured by ISTEP+ assessments than both the control-group students and the other SBCSC students who completed the ISTEP+ assessments.

An ANOVA was run with post-hoc analysis to determine whether there were any significant differences in the ISTEP+ scores based on group membership and SES designation.

Table 11. Fourth-grade ISTEP+ comparison by group.

Test group	n	Mean for Regular Students	Mean for Title 1 Students	Combined Mean (*SD*)	Group Difference Results
MDMT	44	533	509	516 (51.6)	$F(2,1353) = 13.1$,
Control	149	513	447	456 (60.7)	$p < .001$, ES = .02
Other SBCSC	1163	518	467	478 (73.3)	

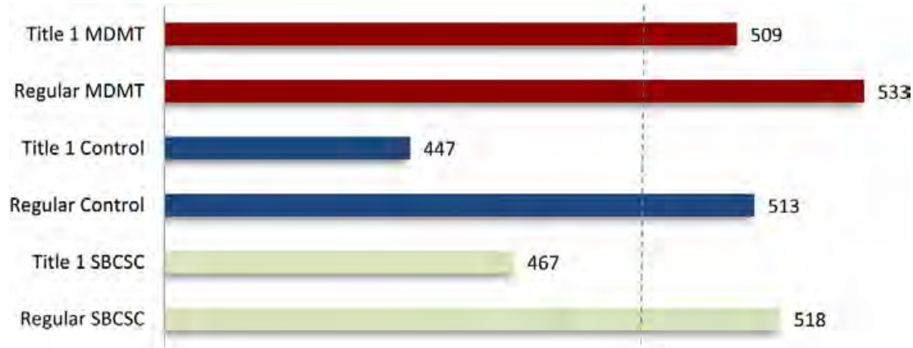

Figure 12. Average state fourth-grade ISTEP+ score comparison by SES designation.

The results were statistically significant $F(5,1350) = 31.5$, $p < .001$, ES = .11. The average ISTEP+ scores for Title 1 students in the control and SBCSC groups were significantly lower statistically compared to students in the other four groups (see Figure 12). On the basis of a post-hoc analysis of the results, no statistical difference in scores was found between Title 1 MDMT students and non-Title 1 students from any of the other groups.

Conclusions

Evaluation results for each grade level compared (a) the MDMT assessment results for MDMT students and control-group students; (b) the relationship between MDMT assessment and district and state achievement indicators; and (c) district and state achievement indicators for MDMT students, control-group students, and all other SBCSC students.

Benefits of MDMT training in automaticity of basic math skills

The results of this evaluation provide clear evidence that the MDMT programme was effective at each grade level in improving the automaticity of target math skills. This result in and of itself is not surprising. It is logical to assume that students who practise basic math skills are more likely to perform better on assessments that measure automaticity of these skills. Clearly, the MDMT programme was effective in this regard. Students who participated in the MDMT programme performed significantly better on the MDMT test than students receiving classroom instruction alone. One explanation for this might be that, for a variety of reasons, the regular classroom instruction does not include automaticity of basic math skills.

Benefits of the MDMT programme were not limited by SES designation. Title 1 MDMT students' gains, in most cases, were equal to or better than those of regular students who also received MDMT instruction. Title 1 MDMT-students' gains were significantly larger than those of control-group students. MDMT training in this respect seems to work equally well for students regardless of their SES designation.

The relationship between MDMT, district, and state assessments

The purpose of this specific investigation was to find out whether the assessments used in this study measured similar constructs of mathematical ability; and thus the degree to which

MDMT assessment results might predict student success in mathematics as measured by district and state tests. Moderate to strong correlations were found when comparing the results of the MDMT assessment with district and state assessments, suggesting a potential link between the MDMT programme and math achievement as measured by district and state tests. Establishing a relationship between the two is the first step in determining a causal link. This is important not only because it suggests that students with better automaticity skills tend to do better on district and state exams. This result suggests that some part of the district and state exams measures similar constructs to those measured by the MDMT assessments.

The benefits of MDMT training on district and state assessments

Overall student achievement, as measured by the district mClass benchmark tests, and state ISTEP+ exams, was improved significantly for students participating in the MDMT initiative. However, the benefit was slightly more evident in the third- and fourth-grade state exams than in the KG, first-, and second-grade district exams. While there were statistically significant differences in the KG and second-grade results based on MDMT participation, the results of the first-grade exam were significant with only a few of the components being measured. In addition, the differences were small, only a few points on the exam. Likely due to the lack of variance in scoring, the results were also not significant based on SES designation. Student results were slightly different by group but not by SES designation within groups. One explanation for this might be that the district exam as it is administered does not discriminate sufficiently between student performances. The district mClass test seems to produce fairly homogeneous results (little variation in scores based on a small range in scores); thus, it may be unable to identify differences in students' performance should they exist. The MDMT and state exams tended to have a wider range of scores (more variance); thus, they were able to discriminate between performances.

State assessments, given to third- and fourth-grade students, produced results that varied greatly between individuals (i.e., the range of scores was much greater). An analysis of these data suggests that students with low-SES designations (i.e., Title 1, eligible for free and reduced-price lunch based on parents income) benefited from the MDMT programme far more than students with the same designation who did not receive the training; and scoring equal to or higher than students with high-SES designations. Based on an analysis of the individual grade-level results, there was a clear pattern of benefit for students living in poverty. These results support the hypothesis that students receiving supplemental remedial instruction targeting basic math facts and computational skills would perform better on MDMT, district, and state mathematics assessments compared to similar students not receiving this instruction.

Conclusion summary

While these results do not provide strong causal evidence of effect (as a randomized control study was not feasible), this study was able to demonstrate the potential benefit of gaining automaticity of basic math fact as a foundation to more advanced mathematic instruction. Consistent with research on the achievement gap in advanced math competencies, students who had not gained automaticity in basic math facts tended to lag behind students who had gained these skills (Aikens & Barbarin, 2008). In fact, a cumulative effect seems to be involved. Results from these analyses provided evidence that students who had not gained basic math fact competencies early were far less likely to get them in later grades and more likely to perform below the proficiency levels of state tests as a result. Students who received basic math facts practice over a period of time (e.g., KG to fourth grade) showed a residual benefit. Likewise, students who did not receive ongoing practice in basic math facts of various topics tended to fall further and further behind each year as new mathematical concepts and competencies were introduced. While ensuring automaticity of basic mathematics skills may not guarantee a student's future success in advanced mathematics courses, the results of this study support the recommendation that strategies designed to provide remedial instruction to students involving extensive practice of mathematics basics in addition to instruction designed to develop problem-solving strategies and a broader conceptualization of mathematics principles is warranted (Baker et al., 2002; Sconiers et al., 2003; Waite, 2000). It also supports Haberman's (1991) assertion that good instruction will transcend a child's poverty status.

Given the complexity of the problem, there is no simple solution to poverty nor to the adverse effects that living in poverty has on a child's academic achievement. Still, the results of this study are promising. Overcoming a child's lack of preparation in mastering basic math facts can be overcome through targeted remedial instruction. In accordance with these research findings, this type of remediation should be done over time and reinforced through practice with feedback as a supplement to regular math instruction.

Future studies

Current and future evaluation efforts for this project include improving the scalability of the intervention and integrating technology to facilitate efficiency of implementation. Because the project is being conducted by a limited number of project staff, a training programme for teachers is needed to prepare them to provide the training, improving the scalability of the initiative. In addition, the programme administrators are looking for ways to best use technology. Much of the intervention could be more efficiently administered if assessments and practice training were automated using technology.

Limitations

Cronbach and Shapiro (1982) asserted that there are many good evaluation designs, but no perfect ones. This was a quasi-experimental study being conducted in an existing schools setting. Random controls were not possible, and alternative statistical methods might have been used; however, the methods and statistical procedures were deemed appropriate. In theory, quasi-experimental studies cannot produce causal evidence because they have no way of controlling for all potentially confounding variables (Davies, Williams, & Yanchar, 2008). In educational settings, there will always be many uncontrolled factors that may have confounded the results making it difficult to produce strong causal evidence of any generalizable effect. As with previous research cited in this study, deficiencies will always interfere with our ability to obtain and interpret data. For example, due to the transience of students in this school district and surrounding area, not all students completed each assessment. While completion of the state ISTEP+ test is required, district and MDMT assessments often had lower completion rates. In addition, we could not control for the numbers of students from low-SES circumstances in each class. As random assignment of individual students to treatment and control groups was not possible due to practical considerations and the potential for treatment interaction bias, purposive sampling of intact groups was used. As a result, the number of low-performing and Title 1 eligible students in classes and schools varied. However, on the basis of an analysis of treatment and control-group students on pre-test MDMT test scores, we believe the purposive sampling methods used to create comparison groups was somewhat effective. And we were pleased that these results were fairly consistent for each grade and the evidence they do provide.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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