Evaluation of a Math Tutoring Program Implemented with Community Support: A Systematic Replication & Extension

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Abstract

The current study evaluated the impact of a math tutoring program delivered in schools by community members over a full academic year. Students in 20 participating schools were randomly assigned to treatment and control groups, and outcome data were obtained for three measures aligned with the tutoring program's theory of change. Linear and logistic regression were used to evaluate group differences in post-test scores and the probability of attaining the spring proficiency benchmark on each of the three outcomes. Intent-to-treat analyses revealed higher achievement scores and a higher probability of meeting the end-of-year proficiency benchmark for a measure of fact fluency and a computer-adaptive broad-based test among students assigned to treatment. No statistically significant effects were observed on a state proficiency test. Overall, the observed results provide additional support for the use of community support to deliver evidence-based intervention in schools. Implications and potential reasons for significant and null findings are discussed within the context of intervention content and delivery.

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According to the most recent National Assessment of Educational Progress (NCES, 2017), only 40% of fourth graders and 34% of eighth graders in the United States are proficient in mathematics and performance declined for students at or below the 25th percentile.

These data suggest that a large number of students experience difficulties with mathematics in school. As many as 17% of school-age children experience substantial mathematics difficulties, 7% of children will be diagnosed as having a mathematics learning disability, and an additional 5% to 10% experience persistent low achievement (Berch & Mazzocco, 2007; Geary et al., 2007; Shalev et al., 2005). Collectively, students that struggle with mathematics in school face several negative outcomes. These students are not as likely as their peers to succeed in or even complete high school and they lack the quantitative literacy necessary for a variety of careers (Claessens & Engel, 2013; Parsons & Bynner, 1997). Unfortunately, mathematics difficulties begin as early as pre-school and, without intervention, persist through intermediate grades (e.g., Duncan et al., 2007; Morgan et al., 2011). Such realities for math education in the United States illustrate the need to provide students who are at-risk for mathematics failure with supplemental school-based supports.

Evidence-based Math Intervention

Schools are increasingly turning to educational frameworks that focus on prevention and early intervention (Jimerson, Burns, & VanDerHeyden, 2016), because such frameworks represent a promising and systematic approach to address the needs of more students with academic difficulties sooner than traditional frameworks of service-delivery. Often referred to as response to intervention or multi-tiered systems of support, such frameworks are comprehensive approaches to improving educational systems. They prescribe high-quality, research-based core instructional practices for all students; intervention and progress monitoring for students who are low-achieving; and individualized, high-intensity support for students requiring special education (Burns, Jimerson, VanDerHeyden, & Deno, 2016). Data are used within these frameworks to inform decisions and supplemental interventions are provided to students who demonstrate risk for academic failure based on screening measures or minimal progress in response to core instruction (Gersten et al., 2009). Although every state has an initiative to promote and expand these frameworks (Jimerson, Burns, & VanDerHeyden, 2016), only about 59% of elementary schools and 48% of middle schools report implementation in math (Spectrum K-12, AASA, CASE, NASDSE, 2010).

One of the most significant implementation barriers for such frameworks is the lack of intervention resources (Long et al., 2016; Spectrum K-12, AASA, CASE, NASDSE, 2010), which is particularly problematic for math. Intervention delivery for prevention and early intervention frameworks has been conceptualized as either an individualized problem-solving approach or a standard protocol approach, with standard protocol approaches having advantages both logistically and evidentiary for at-risk students not yet identified for special education (Fuchs & Vaughn, 2012). For math, there are a limited number of evidence-based standard protocol mathematics interventions designed to target foundational mathematics skills for students beyond third grade. According to *What Works Clearinghouse* (WWC; 2016), when filtering by grade and either supplemental or small group intervention, there are only two interventions that have received a rating of potentially positive or positive that provide math intervention for students in grades four through eight. Other evidence summaries report a similar state for math interventions. The *National Center on Intensive Intervention* includes 10 individual or small group intervention programs or strategies directed toward the elementary or middle school levels as offering convincing or partially convincing evidence of effectiveness. Further, although there are many peer-refereed articles published on mathematics intervention outcomes, in 51.5% of these studies researchers rather than school professionals were the implementers, suggesting that these interventions might be in the development phase and therefore not widely available for practitioner use (DeFouw, Codding, Collier-Meek, & Gould, 2018). Finally, the majority of these intervention studies addressed whole number knowledge and skills appropriate for students within the early elementary school grades. Interventions with strong evidence for improving rational number skills for older students are comparatively rare.

Even when evidence-based standard protocol interventions are available, teachers report that finding time and resources to integrate the intervention within existing routines is a substantial barrier, and almost 89% indicated a need for additional implementation support (Long et al., 2016). These data correspond with other surveys suggesting that time is a powerful constraint for school personnel when it comes to providing students with additional academic supports outside of core instruction (e.g., Bosworth et al., 1999; Bambara et al., 2009; Durlak & Dupre, 2008). Unfortunately the persistence of these barriers impacts the integrity with which prevention and early intervention frameworks are successful. In one national evaluation of the frameworks, nearly 40% of schools neglected to administer intervention supports as intended resulting in an overall failure to observe positive effects of the framework (Balu et al., 2015; Fuchs & Fuchs, 2017).

Encouragingly, recent research shows that K-5 validated math intervention programs delivered by *either* teachers or paraprofessionals produced the strong effects, particularly for low achieving students and students from low income backgrounds (Pelligrini, Lake, Inns, & Slavin, 2018). This suggests that educational professionals may not be required to deliver evidence-based intervention programs in order to produce positive outcomes for students. The status of the research base suggests more research is necessary to identify math interventions with evidence for effectiveness in typical school settings, as opposed to efficacy evidence produced with strong involvement of research teams, particularly for intermediate elementary and middle school students. Further, given the high numbers of students that need additional mathematics supports and the limited time and support presently available in schools to provide students with evidence-based interventions, it also appears necessary to identify feasible delivery mechanisms for such interventions. Community-based tutoring might be a reasonable alternative.

Community-supported Tutoring

The idea of using community-based volunteers or non-educators to provide substantive academic supports in schools is neither novel nor without evidence. Most schools have access to multiple community- or business-based volunteers, and these volunteers can make a significant positive impact on student learning outcomes (Ritter, Barnett, Denny, & Albin, 2009; Slavin, Lake, Davis, & Madden, 2011). Moreover, some community organizations offer fully-developed interventions that align with educational best practices and closely resemble standard protocol interventions (Jacob, Armstrong, Bowden, & Pan, 2016; Markovitz et al., 2014). The potential for such programs is particularly promising in the context of the logistical and knowledge barriers many schools face when attempting to deliver educational interventions. Early intervention is often a paradigm-shift in educational settings that rely on conventional wait-to-fail models for educational service delivery (Fuchs & Fuchs, 2006). The experience and knowledge required for effective resource reallocation can be a considerable challenge (Noell & Gansle, 2016). Moreover, few practitioners appear adequately familiar with the concepts and practices necessary for successful intervention within prevention and early intervention frameworks (Vujnovic et al., 2014). These knowledge barriers are exacerbated by basic resource demands for providing evidence-based interventions, which in math require schools to provide each struggling student up to 90 minutes of intervention support per week (Gersten et al., 2009).

Community-based organizations help address these barriers by providing schools with resources, time, and expertise. Such organizations also have the advantage of being able to specialize their topic area. In math, this translates to knowledge about evidence-based math interventions and technically adequate and instructionally informative data-based decision-making practices, as well as being able to generate resources necessary for implementation. Community-based organizations that develop specialized expertise in an educational area can form inter-organizational partnerships with schools that facilitate effective implementation of math interventions (Aarons, Hulburt, & Horwitz, 2011). In other academic domains, such as reading, inter-organizational partnerships using community support have also proven to be cost-effective ways to deliver intervention supports within the school context (Hollands et al., 2016).

Math Corps

The ecology of student development includes macro-level structures that influence student outcomes (Bronfrenner, 1987). Within this broader ecology, public policy is inherently designed to influence issues of the broader public interest, and the federal AmeriCorps program is an example of a policy initiative that translates to increased local community-based resources for implementing educational interventions. The AmeriCorps program helps generate nearly seven billion hours of community service annually (Corporation for National and Community Service, 2018), and a portion of that time has been allocated to educational programs that exist to deliver standard protocol interventions for struggling students. The Math Corps program is an intervention program for students in grades four through eight that uses AmeriCorps members to deliver math intervention support to struggling students. It provides schools with materials for implementing evidence-based interventions, recruits and trains tutors and school staff, and engages in ongoing coaching (see Method section for details).

Previously, a wait-list randomized control trial of the Math Corps program was conducted with 550 students in grades who were at-risk for mathematics failure over the course of one semester (AUTHOR, 2018). Results on a computer-adaptive, comprehensive measure of mathematics performance indicated that students receiving Math Corps tutoring outperformed the control group, yielding a small positive effect size (d = .17). Effect sizes were larger (d = .24) when the designated optimal dose of the intervention was achieved. This study represents initial research in the area of mathematics regarding the promise of community-supported delivery of evidence-based interventions. However, the prior study did not examine outcomes on other measures of interest, such as math skills more proximal to the intervention focus or distal outcomes of policy importance like state math tests. Given that mathematics is hierarchical and builds upon core foundational skills, analysis of the extent to which other math skills improve would be useful. Previous research has indicated that the amount of exposure to and the number of opportunities to practice any given mathematics subskill can be substantial before mastery occurs across both basic (Burns, Ysseldyke, Nelson, & Kaive, 2015; Stickney et al., 2012) and complex (Nelson, Parker, & Van Norman., 2018) tasks. In particular whole number fact fluency appears to be a central underpinning of overall mathematics proficiency, permitting greater access to higher level content including more complex whole and rational number operations and understanding (Bailey, Seigler, & Geary, 2014; Jordan, Resnick, Rodrigues, Hansen, & Dyson, 2017). Such considerations reflect increasingly important aspects of replication studies for intervention research (Travers, Cook, Therrien, & Coyne, 2016).

Purpose

The purpose of the present study was to evaluate the impact of Math Corps as a supplemental math intervention delivered by AmeriCorps members across the 2017-2018 academic year. The study was guided by the overall goal of evaluating the extent to which end-of-year math achievement differed for students randomly identified to be served by the program or not served by the program. There were three primary math outcomes of interest arranged from most proximal to most distal based on the program's theory of change: basic fact fluency, broad-based math achievement as measured by a computer adaptive test, and end-of-year performance on the state test. The following research questions framed the study: (1) to what extent do students assigned to Math Corps demonstrate higher test scores on a basic fact fluency measure relative to students assigned to a control group ? (2) to what extent do students assigned to Math Corps demonstrate higher posttest scores on a computer adaptive measure of math achievement relative to students assigned to a control group? (3) to what extent do students assigned to Math Corps demonstrate higher posttest scores on the end-of-year state achievement test relative to students assigned to a control group? In addition to addressing the above research questions by comparing the performance of students in both groups on each measure, we also compared the performance of students in each group to criterion-based levels of proficiency for each measure.

Method

Participants

Schools and school districts across one state in the mid-western region of the United States were recruited. All schools that received Math Corps services in the 2017-2018 school year and served enough struggling students to support a treatment and control group were invited to participate. Approximately 50% of the eligible students agreed to participate, resulting in 20 schools. Demographic data separated by group assignment are displayed in Table 1. The student distribution across elementary and middle school was generally commensurate with the overall distribution of students served by Math Corps. There were slightly more female students relative to male students in the sample. Across both groups, a majority of students were White (53.4% and 52.9%) followed by Black (24.5% and 23.3%) Hispanic (10.6% and 12%), Asian (8.9% and 6.9%), American Indian (1.2% and 0.5%), and Other (0.7% and 2.3%). Students were served across 20 schools in Minnesota, including six middle schools, one intermediate school, and 13 elementary schools. Nine schools in the sample were suburban (45%), five were urban (25%), and six were rural (30%).

Intervention Overview

The instructional focus of Math Corps is on improving whole and rational number understanding. It uses evidence-based intervention strategies that target specific skills (e.g., adding fractions with like and unlike denominators) required to effectively work with whole and rational numbers. In the present study, Math Corps was implemented by full-time AmeriCorps members who operated as interventionists embedded within each school. Math Corps interventionists had no preexisting professional preparation in evidence-based standard protocol interventions for math. Each interventionist attended a three-day training session in late summer, two additional days of training in the fall (October and November), and received monthly coaching sessions from a school-based coach and a program coach, both of whom were fully-trained in the Math Corps program model.

During all observations, coaches used a standardized observation form in which implementation fidelity was assessed using a checklist with 19 items aligned with various components of the intervention. In addition, coaches assigned an engagement quality rating and instructional delivery quality rating to interventionists after each observation. Both ratings were scaled from one to five with five representing the highest quality rating. In the present study, interventionists tended to implement the intervention as intended with average adherence equal to 91%, delivery quality equal to 4.32 (*SD* = 0.75), and engagement quality equal to 4.44 (*SD* = 0.56).

Math Corps content. Math Corps delivers intervention in the form of instructional lessons, which varied in number from 22 in fourth grade to 31 in sixth grade. Lessons used one of several intervention components to improve targeted subskills required to work effectively with whole and rational numbers. The first component included conceptual-based instruction using the Concrete, Representational, Abstract (CRA) approach (e.g., Witzel et al., 2003). The second component focused on procedural accuracy and includes direct instruction followed by supervised practice with Cover, Copy, and Compare (CCC; Skinner, Turco, Beatty, & Rasavage, 1989). The third component used Cognitive Strategy Instruction to support development of the skill for word problem solving (Montague, 1997). Intervention components were applied in a sequence for each skill. For example, students first received CRA to better develop the conceptual basis for adding fractions with dissimilar denominators; then received CCC to become efficient at accurately applying the corresponding computational strategies; and then received CSI to be able to solve word problems involving fractions with unlike denominators. Students were required to demonstrate mastery—defined as 85% correct on a brief informal assessment of intervention content—before advancing among the intervention components.

Interventionists also delivered short duration fact fluency practice using Explicit Timing (e.g. Van Houten & Thompson, 1976) at the end of intervention sessions.

All intervention support was provided during the school day to groups of two students, consistent with standard Math Corps program procedures. Student pairs were determined by performance on a brief pretest as well as the scheduling constraints of the school. Interventionists worked with school staff to provide student pairs either three 30-min or two 45-min intervention sessions per week. Across the academic year, and accounting for short weeks and interventionist or student absences, the average min per week for students was equal to 69.33 (SD = 18.93) over an average of 21.89 weeks (SD = 10.34). This dosage information relates only to students that were assigned to receive Math Corps and actually received the intervention. An additional 59 students did not have any treatment time recorded, but were included in analyses.

Control. Students assigned to the control group in the present study did not receive Math Corps interventions but were allowed to receive other school-based services. Surveys were sent to school staff two times during the study to determine the frequency and type of other mathematics services throughout the school year. Approximately 43% of control group students received more than 30 minutes per week of supplemental support for at least one month during the year. The nature of additional support varied between sites, but most frequently took the form of supplemental small-group pre-teaching/re-teaching activities with a teacher or teaching assistant; no evidence-based practices were reported.

Randomization

Students who are eligible for Math Corps must (1) score below proficiency on the state test from the previous year and (2) score below a grade-level benchmark on the fall administration of STAR Math (Renaissance Learning, 2018). In the current study, a total of 924 students were identified as eligible for Math Corps at the 20 participating schools. Of those students, 750 were randomly assigned to treatment (n = 484) and control (n = 266) groups. An additional 174 students were assigned to a waitlist group to ensure interventionist caseloads would remain full if treatment students moved or withdrew consent from participating. Data for waitlist students were not retained for the current study. Following randomization, 37 students (34 from treatment and three from control) withdrew consent and four students (three from treatment and one from control) were determined ineligible due to receipt of special education math services.

A series of analyses were conducted on the resulting sample to establish baseline equivalence. Chi-square analyses revealed no statistically significant differences between groups on the distribution of grade, gender, or ethnicity. Further, a paired t-test examining state test scores from the previous year revealed no significant differences between groups. However, tests for baseline equivalence conducted on STAR Math pretest scores revealed a significant difference between groups ($t(693) = 2.79$, $p = .005$). The mean fall STAR Math score for students in the treatment group was equal to 646.77 (SD = 102.91) and the mean score for students in the control group was equal to 667.70 (SD = 83.79). An analysis of the distribution of fall STAR Math scores revealed a disproportionate number of students in the treatment group with scores far below the mean in each grade level.

After examining potential reasons for this difference, it was discovered that although assignment to treatment condition was random, aspects of the randomization process resulted in disproportionate assignment across conditions in which more students with very low STAR Math scores were assigned to the treatment condition. This occurred because the evaluation team established two blocks of students by median score within a school, rank-ordered the scores lowest-to-greatest within block, assigned random numbers to each case within the block, re-ordered lowest-to-greatest, and then made condition assignments starting with treatment. For this process, a single fixed ‘seed order’ of random numbers was assigned across all blocks that—by chance—had more lower values earlier in the seed order, which meant more students with low STAR Math scores were assigned to treatment. A number of potential solutions were explored to address this issue, including re-randomization and propensity score weighting; however, the most effective approach included trimming potential outliers from the data file (i.e, STAR pre-test scores outside of two standard deviations from the mean). This resulted in the exclusion of 31 students originally assigned to the treatment group and one student originally assigned to the control group. After trimming the data file for potential outliers, there were no significant differences in baseline STAR scores between groups. The resulting file for analysis included 416 students assigned to Math Corps and 259 students assigned to the comparison group (N = 675).

Measures

Minnesota Comprehensive Assessment (MCA). Students completed the MCA in math at the end of the academic year. The MCAs are the statewide accountability tests used by the state of Minnesota. Beginning in the third grade and extending to eighth grade, students in Minnesota complete the MCA in math. The MCA is a standards-based assessment—the items on the test are constructed to align with the curricular standards for the state of Minnesota. Thus, students’ scores on the MCA are interpreted as the degree to which students have mastered grade level content. MCA scores for math and reading range from 0-100, with scores of 50 and above signifying proficiency. The MCA-III has adequate evidence for internal consistency (r = .78 to .95; Minnesota Department of Education, 2017). Because the MCA is a standards-based assessment, validity evidence is primarily derived from content-related evidence (e.g., test blueprint aligned with standards, expert item writers) and construct-related evidence (e.g., inter-scale correlations, high functioning items). In the present study, MCA testing was conducted by trained test officials at school sites in accordance with state guidelines.

STAR Math. Students completed STAR Math at the beginning and end of the academic year. STAR Math is a computer-adaptive test (CAT) with scaled scores ranging from 0-1400. The vendor reported split-half reliability estimate for grades 1-12 is equal to .94 (Renaissance Learning, 2013). In a recent evaluation, concurrent validity correlations between STAR Math and the Minnesota state test were equal to .74 (grade three) and .73 (grade five). Predictive validity coefficients (fall to spring) were equal to .60 (grade three) and .75 (grade five). The publisher for STAR Math provides spring benchmarks for performance that were derived using diagnostic accuracy analyses using MCA proficiency as the criterion. Those benchmarks are used to identify students as on-track for proficiency or below proficiency. In the present study, we used those benchmarks as the metric of interest in the proficiency analyses. Pre-test STAR Math data were obtained by interventionists in the present in the study in accordance with program guidelines for screening—those data are used to identify students for Math Corps support. Post-test STAR Math data were largely obtained by research assistants who were blind to group assignment; however, some sites regularly used STAR Math as part of their universal screening procedures. In those cases, school officials oversaw post-test data collection using their standard school-wide procedures.

Math fact fluency. Students completed a timed (1-min) test of fact fluency in the fall and spring of the academic year. Parallel eighty-item mixed computation measures (Foegen, 2000; Foegen & Deno, 2001) were used to assess fluency with basic facts. The fact fluency probes required students to solve single-digit combinations (0-9) in addition, subtraction, multiplication, and division. All probes were scored as the number of problems correct in one min. Math Corps uses a fluency proficiency goal of 30 problems correct in one min, which approximates the rate at which previous research using the fact fluency probes provides sufficient reliability evidence (internal consistency r = .91-.92; test-retest r = .85; alternate forms r = .82). In the present study, the correlation between students' fall fact fluency scores and STAR Math was .57, which is generally consistent with studies examining the relationship between basic computation skills and broad measures of achievement (Foegen, 2000; Jitendra, Sczesniak, & Deatline-Buchman, 2005; Thurber, Shinn, & Smolkowski, 2002). In the present study, fact fluency data were obtained immediately before STAR Math testing.

Analysis Procedures

Missing data. Missing data differed by posttest outcome. The largest instances of missing data were observed for pre (12%) and post (13%) fact fluency tests. Approximately 10% of cases were missing MCA data. Lower levels of missing data were observed for STAR Math at pre-test (2%) and post-test (8%). There were no differences in missing data across group assignment for STAR Math or MCA data; however, students assigned to the control group were more likely to have missing fact fluency data at post-test (22%) relative to students assigned to receive Math Corps (7%). This was largely due to a small number of sites that opted to oversee STAR Math testing, but failed to uniformly administer the fact fluency test. Regardless it is not likely that data were missing completely at random (MCAR) and instead were missing based on factors known in the data set (MAR). To account for missing data in the analytic models we used multiple imputation to simulate 40 additional data sets with estimated values for missing data (Graham, Olchowski, & Gilreath, 2007; Rubin, 2004). The multiple imputation procedure was run using SPSS (v. 25) and included multivariate normal regression paired with an iterative Markov chain Monte Carlo simulation process. To facilitate accurate estimation, imputation models included a series of predictors including STAR Math data, MCA data, fact fluency data, gender, ethnicity, grade level, site, and group assignment. Estimates from each simulated data set were pooled to provide a single estimate. Results from analytic models using the pooled estimates were compared to identical models in which listwise deletion was used. No differences were observed in the statistical significance or magnitude of effects between models that used imputed data and those that used listwise deletion.

Analytic models. As discussed, the three outcomes of interest in the present study were evaluated on continuous and dichotomous (criterion-referenced) scales. Thus, both linear regression and logistic regression models were used to evaluate the impact of Math Corps on student achievement. In addition to a dichotomous variable indicating treatment assignment, each model included students' pre-intervention scores and dichotomous variables for gender and race. Linear regression models included a series of dichotomous variables for each site to adjust for site-based clustering. The variance observed between sites was non-significant when evaluating the log-odds of meeting proficiency on any of three outcomes. All analyses followed an intent-to-treat framework in which all students were included in the analysis according to their original group assignment regardless of their experiences during the school year.

Results

Descriptive

Means and standard deviations for outcomes across time and groups are displayed in Table 2. On average, students in both groups tended to answer between 16 and 17 problems correct on the timed fact fluency pre-test. All students increased their fact fluency scores across the academic year; however, the average number of problems answered correctly at post-test was slightly larger for students assigned to receive Math Corps (M = 23.29) compared to students in the control group (M = 19.46). Likewise, a larger percentage of students assigned to Math Corps met the proficiency criterion for fact fluency (23%) relative to students in the control group (11%).

As discussed, students assigned to Math Corps had slightly lower STAR Math scores (approximately 10 points) at pre-test relative to students in the control group. At post-test, the average score for students in Math Corps was 11.22 scaled score points higher than the average score for students in the control group. Similar to the fact fluency results, a greater percentage of students assigned to Math Corps met the end-of-year benchmark for STAR Math (27%) relative to students in the control group (15%). There were small descriptive differences between groups on the Minnesota state test in math—the average MCA score for students assigned to Math Corps was 0.72 points higher than control students. Likewise, the percentage of students meeting proficiency criteria on the MCA was 4% higher for Math Corp students.

Linear Regression

The first set of research questions was related to student outcomes on a continuous scale. That is, to what degree did student scores on the fact fluency test, STAR Math test, and state test differ as a function of group assignment? Results from the three linear regression models of interest are displayed in Table 3. All models controlled for students' prior achievement (mean centered), grade level, gender, race, and school. The referent for grade was always fourth grade and the referent for race was always White.

In regard to fact fluency, statistically significant and positive associations with post-test fact fluency scores were observed for pre-test fact fluency scores (B = 0.69), sixth grade enrollment (*B* = 2.94), eighth grade enrollment (*B* = 3.21), and Asian students (*B* = 2.91). Assignment to Math Corps was associated with a statistically significant and positive effect on post-test fact fluency scores. Specifically, assignment to Math Corps was associated with a 3.16 increase in the number of problems correct on the fact fluency post-test relative to students assigned to the control group (*B* = 0.16).

When examining STAR Math scores, statistically significant and positive effects were observed for fifth through eighth grade. That is, students in later grades had significantly larger scores, which is generally consistent with the scaling of STAR Math. In addition, being a male student was associated with a 12.81 scaled score increase in post-test STAR Math scores. Assignment to Math Corps was associated with a statistically significant and positive impact on post-test scores equivalent to an advantage 15.78 scaled score points (*B* = 0.08).

In regard to students' state test scores, statistically significant and negative effects were observed for all grades relative to fourth grade. In other words, students tended to score lower on the state test if they were in fifth (*B* = -5.54), sixth (*B* = -7.27), seventh (*B* = -7.77), or eighth grade (*B* = -7.41) relative to fourth grade. Black students were also associated with lower state test scores relative to White students (*B* = -2.75). Unlike the models examining fact fluency and STAR Math, group assignment was not a significant predictor of students' MCA scores.

Logistic Regression

Each of the three outcomes of interest was also examined in dichotomous terms—students either met (1) or did not meet (0) a predefined criterion of proficiency on each outcome measure. Results from the three logistic regression models of interest are displayed in Table 4. All effects are expressed as the log-odds of attaining proficiency.

The observed results for fact fluency proficiency—defined as 30 problems correct in one min—were generally consistent with those observed for linear regression; however, the probability of meeting the proficiency criterion did not differ across grades. Thus, the only significant effects were observed for the fall fact fluency score and assignment condition. More specifically, an increase of one problem correct was associated with a log odds increase of 0.15 and assignment to Math Corps was associated with a log odds increase of 1.00. To facilitate interpretation, log-odds can be converted to predicted probabilities. For example, the predicted probability of meeting the fact fluency proficiency criterion was approximately .05 among students in the control group and .12 among students in Math Corps.

In regard to STAR Math, the log odds of meeting the grade-level spring benchmark significantly increased for every scaled score unit increase above the fall grade-level mean. Relative to fourth grade students, students in fifth (-0.72), seventh (-1.33), and eighth grade (-0.97) had a lower log-odds of meeting the end-of-year benchmark for proficiency. For example, the predicted probability of success among fourth grade students assigned to the control group was 0.15, compared with .08 among fifth grade students, .05 among seventh grade students, and .07 among eighth grade students. The predicted probability of success for sixth grade students assigned to the control group was .18, which, based on the observed results using fourth grade as the referent, was significantly different from students in fifth, seventh, and eighth grade. The predicted probability of meeting the end-of-year benchmark was higher among students assigned to Math Corps. Among sixth grade students assigned to Math Corps, the predicted probability of success was .35, followed by fourth grade (P = .32), fifth grade (P = .18), eighth grade (P = .15), and seventh grade (P = .11). Thus, when examining STAR Math proficiency, assignment to

Math Corps was associated with an increase in predicted probability of success between .17 and .06.

When examining MCA proficiency (i.e., scores at or above 50), an increase of one fall STAR Math scaled score above the grade-level mean was associated with a small increase in the log-odds of meeting MCA proficiency (.01). Further, students in fifth grade had a lower log odds of meeting the MCA benchmark relative to fourth grade students. Black students also had a lower log odds of success relative to White students. For example, the predicted probability of a White fourth grade student with an average fall STAR Math score meeting MCA proficiency was equal to .21, which was higher than the predicted probability of a Black student with the same STAR Math score (P = .12). Similar to the linear regression results, the impact of group assignment on the probability of meeting the MCA benchmark was non-significant.

Discussion

In the present study we evaluated the impact of Math Corps, a community-supported supplemental math intervention program, on three outcomes aligned with the program's instructional focus. All analyses adopted an intent-to-treat approach in which students were included in the analysis regardless of their exposure to Math Corps. Statistically significant and positive results were observed for Math Corps' impact on the two more proximal outcomes of interest—fact fluency performance and STAR Math performance. Yet state test scores for students assigned to receive Math Corps were not statistically different from those of students not assigned to Math Corps. These effects are discussed in detail below.

Math Corps and Student Math Achievement

Fact Fluency. Of the three outcomes considered in the present study, fact fluency performance was most closely aligned with Math Corps support. That is, interventionists were trained to deliver 3-5 min of explicit fact fluency support as part of each session. In the present study, assignment to Math Corps was associated with an unstandardized effect size of 3.16 problems. The effect of Math Corps on fact fluency scores is particularly notable when contextualized by the average growth rate of control students across the full year—3.09 problems. In other words, the effect size observed for Math Corps was larger than the average annual growth of control students in the present study. The impact of Math Corps on students' fact fluency performance was also evident when considering the proportion of students reaching the mastery criterion for fluency as Math Corps students were twice as likely to reach that benchmark by the end of the year. Yet it is also worth noting that an overwhelmingly large proportion of students across groups failed to correctly answer 30 or more fact fluency problems within one minute. This is relevant because automatic retrieval of basic math facts is generally considered to hold value for more complex math operations as well as a variety of tasks outside of school (Fuchs et al., 2014; Nelson, Parker, & Zaslofsky, 2016). The relatively low levels of automaticity among the students included in the present study generally conforms to findings that students who struggle on grade-level math assessments may also struggle with foundational skills (Jordan et al. 2013; Vukovic et al., 2014).

STAR Math. STAR Math covers a full range of grade-level standards, many of which fall outside the scope of the Math Corps intervention which focuses on whole and rational number understanding. The underlying assumption of Math Corps is that advancing whole and rational number skills will confer benefits to the those skills, but also other skills that rely on whole and rational number understanding (e.g., geometry; Gersten et al., 2009; NMAP, 2008). Although STAR Math assesses a broad range of content, the test is vertically scaled and grade independent, making it a useful broad-based measure of student growth.

In the present study, the impact of assignment to Math Corps was approximately 16 scaled score points. The expected weekly growth among students in the sample (based on initial scaled score and grade level) ranged from .80 to 3.30 with an average of 1.76 (SD = .60). Thus, one interpretation of the unstandardized effect of group assignment is to consider the amount of additional growth added by the intervention. By this interpretation, the average student who received Math Corps demonstrated post-test scores that were the equivalent of 4.85 to 20 weeks (M = 9.09 weeks) of additional math growth compared to the average student who did not receive Math Corps. The impact on STAR Math scores also translated into an increased probability of meeting the end-of-year benchmark among students receiving Math Corps support.

MCA. Unlike the results observed for fact fluency and STAR Math, the impact on students' state test scores—including the rate at which students met proficiency criteria—was not statistically significant. Performance on the state test was the most distal outcome of interest in the present study. The Minnesota state test assesses a limited range of content—items are created to align with specific grade-level standards and do not explicitly address content that falls above or below those standards. Thus, improvements in understanding of precursor concepts (e.g., fraction arithmetic among eighth grade students) may be assumed and not directly tested. The nature of state test construction is relevant because many students who qualify for supplemental support are far behind grade-level expectations. For those students, relative to computer adaptive tests such as STAR Math, the state test may not be sensitive to gains in math skills outside the grade-level standards. As such, the state test is not designed to capture student growth, but proficiency on grade-level standards at the conclusion of the academic year (Shapiro & Gebhardt, 2012). In the present study, Math Corps resulted in significant improvement in math achievement as measured by STAR Math, but not the state test. Thus, although students improved their overall math achievement as a result of Math Corps, that improvement was not sufficient to produce differences on the state test. Intervention studies do not often evaluate impact on distal standardized measures, and thus the current findings are generally consistent with other findings that greater effects are typically observed for measures more closely aligned to treatment (DeFouw et al., 2018; Gersten et al., 2009; Jitendra et al., 2018).

As discussed, Math Corps is composed of a series of lessons for each grade level. Those lessons were created to align with state standards in the domain of numbers and operations, but they were not yoked to a single grade level so as to permit students to receive needed intervention on precursor skills. For example, the current sixth grade lesson sequence includes 31 lessons. Yet only 10 of those lessons are directly aligned with sixth grade content, 9 of which are the last lessons in the entire sequence. This progression was by design insofar as many students who qualify for Math Corps have deficits on skills that precede grade level content, and math learning is generally characterized by progressive skill development that assumes precursor skill levels are established for more complex levels to be obtained (NMAP, 2008). Yet because Math Corps provides support for precursor skills and has a mastery learning orientation, many students did not receive intervention on grade-level skills. For example, data from the program showed that only 10% of sixth grade students reached grade-level content.

Implications for Community-Supported Educational Intervention

Overall, these findings add to the literature for community-supported math interventions in several ways. First, these findings support the potential for inter-organizational partnerships to implement evidence-based interventions in math (Aarons et al., 2011). Math Corps provided all training, data collection systems, and materials, but both Math Corps and schools worked to identify the community-based AmeriCorps member to serve as an interventionist, acclimate them to the local school environment, and ensure they received sufficient coaching support for success. The mutual contribution of resources occurred across common phases of implementation and serves as a model for how inter-organizational partnerships could feasibly implement evidence-based practices in public service settings (Aarons et al., 2011).

These findings also extend the overall empirical support for service-based educational interventions that employ tutoring. When service-based interventions utilize tutoring, they employ a form of educational instruction for struggling or at-risk students that has increasingly robust evidence. Previous research syntheses identified tutoring as among the most effective strategies for reading (Slavin et al. 2011), and updated syntheses have found similar results (Inns, Lake, Pelligrini, & Slavin, 2018). The current findings contribute to a smaller but growing evidence-base for the promise of tutoring for math outcomes (Pelligrini et al., 2018). Similarly, although sufficient research has been conducted on volunteer-based literacy tutoring programs to conduct meta-analytic research with positive findings for effects on reading and writing outcomes (Ritter et al., 2009), additional individual studies are necessary in math. Relatedly, research for community-supported math interventions needs to be conducted with different age and grade levels, including a focus on understanding the role and potential for community-based interventions to support early math outcomes (Mazzocco & Myers, 2003). In addition to research on the direct effects of community-based interventions on math outcomes, research is necessary to better understand the variables and conditions of effective inter-organizational partnerships for math interventions (Aarons et al., 2011). Such research holds potential to support efficacious implementation as well as identify ways to sustain implementation in a cost-effective manner long-term (e.g., Hollands et al., 2016).

Limitations

There are a number of limitations to consider when interpreting results from the present study. First, the present evaluation was of a specific math intervention program. It is unclear if similar programs or subcomponents of Math Corps would produce comparable results. Second, it is common for math researchers to include a direct assessment of the set of skills targeted during intervention (e.g., Jitendra et al., 2015; Poncy, Skinner, & Jaspers, 2007; Witzel et al., 2003), yet no such measure was included in the current study. Math Corps provides support for a wide range of skills that vary across grades. Although we might have created an assessment directly aligned with the intervention program for each grade, the procedures for test creation were considered to be too burdensome and not of long-term relevance to either educator or policymaker stakeholders interested on grade-level performance. Further, the use of STAR Math and the state test is likely a more rigorous approach to estimating intervention effects than an assessment designed to assess the exact content included for intervention.

Finally, it is important to note the issue that the randomization procedures resulted in baseline differences in STAR Math scores between students assigned to Math Corps and students assigned to the control group. In addition to our final approach to analysis, which included trimming cases outside of two standard deviations of the mean, we conducted a series of sensitivity tests that included making no modifications to the analytic model, propensity score weighting, and fitting a model with no adjustment for pre-test scores (i.e., placing students assigned to Math Corps at a disadvantage). These sensitivity analyses showed no substantive changes to statistical significance and the corresponding effects and thus we opted to retain the trimmed model which eliminated baseline differences.

Conclusion

Improved math outcomes are needed for more students to experience math success and the accompanying the educational and life benefits. The current study suggests Math Corps can improve foundational math skills necessary for working with whole and rational numbers, but additional research is needed to extend those benefits to societally-endorsed outcomes like state proficiency tests. Nonetheless, this study adds to the general research base for both evidence-based math interventions and the delivery of such interventions via community-based resources.

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Table 1

Student Demographics across Conditions

Demographic Category	Math Corps (n = 416)	Control (n = 259)
Grade		
Fourth	17.5%	17.0%
Fifth	21.9%	20.5%
Sixth	29.6%	30.1%
Seventh	19.3%	19.3%
Eighth	13.1%	13.1%
Gender		
Male	48.8%	44.0%
Ethnicity		
White	53.4%	52.9%
African American	24.5%	23.2%
Hispanic	10.6%	12.0%
Asian	8.9%	6.9%
American Indian	1.2%	0.5%
Other/Unknown	0.7%	2.3%

Table 2.

Descriptive Outcomes by Assessment Period and Condition

		Fact Fluency			STAR Math			State Test		
		M	*SD*	Met Benchmark	*M*	*SD*	Met Benchmark	*M*	*SD*	Met Benchmark
Pre	Control	16.38	7.91	-	669.26	81.51	-	-	-	-
	Math Corps	16.99	0.45	-	659.47	89.71	-	-	-	-
Post	Control	19.46	8.58	11%	716.87	80.43	15%	41.47	8.33	15%
	Math Corps	23.29	8.31	23%	728.09	90.58	27%	42.19	8.73	19%

Table 3

Linear Regression Results across Outcomes

	Fact Fluency		STAR Math		MCA	
Variable	B	SE	B	SE	B	SE
Intercept	15.88**	1.71	577.76**	15.48	48.05**	2.09
Prior Achievement	0.69**	0.05	0.54**	0.06	0.05**	0.01
Grade Level						
Fifth	0.82	1.02	63.90**	8.68	-5.54**	1.24
Sixth	2.94*	1.18	134.19**	9.74	-7.27**	1.64
Seventh	1.16	1.51	144.30**	12.32	-7.77**	2.02
Eighth	3.21*	1.50	153.00**	12.11	-7.41**	2.14
Gender						
Male	-0.06	0.57	12.81*	5.21	0.10	0.64
Race						
American Indian	0.09	3.43	4.04	32.29	-0.88	4.00
Asian	2.91*	1.20	15.12	10.76	-1.18	1.30
Black	0.40	0.81	-11.56	7.41	-2.75**	0.91
Latino	-0.44	0.98	-5.02	8.96	-0.83	1.08
Other	1.39	2.88	-4.01	24.34	-2.38	3.00
Group Assignment						
Math Corps	3.16**	0.62	15.78**	5.56	0.90	0.67

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

Note: Sample sizes for each model equal to those reported in Table 2. Prior Achievement = grade-mean centered fall STAR Math score or mean centered fall fact fluency score. Across all three outcomes, model included dichotomous predictors for each of the 20 sites included in the study to adjust for clustering. Fixed effects for sites are not displayed in the interest of clarity.

Table 4

Logistic Regression Results across Outcomes

	Fact Fluency		STAR Math		MCA	
Variable	Log-Odds	SE	Log-Odds	SE	Log-Odds	SE
Intercept	-3.00**	0.67	-1.72**	0.31	-1.36	0.31
Prior Achievement	0.15**	0.02	0.02**	0.00	0.01**	0.00
Grade Level						
Fifth	0.95	0.67	-0.72*	0.30	-0.84*	0.38
Sixth	0.57	0.65	0.15	0.30	-0.27	0.32
Seventh	-0.09	0.74	-1.33**	0.43	-0.34	0.38
Eighth	0.85	0.70	-0.97*	0.40	0.40	0.35
Gender						
Male	-0.04	0.25	0.40	0.21	-0.06	0.22
Race						
American Indian	-18.87	19108.30	-19.65	19153.08	-19.52	19588.77
Asian	0.24	0.44	0.59	0.34	0.05	0.38
Black	-0.34	0.30	-0.38	0.28	-0.68*	0.29
Latino	-0.49	0.46	-0.47	0.38	-0.62	0.39
Other	0.51	0.98	-16.77	11598.66	-17.43	12557.15
Group Assignment						
Math Corps	1.00**	0.29	0.92**	0.24	0.34	0.23

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

Note: Large standard errors are present for "American Indian" and "Other" designations under race due to small samples and no occurrences of students meeting benchmark criteria.