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Math for All: Exploring the impact of a professional development program to improve mathematics learning for students with disabilities

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Math for All (MFA) is an intensive professional development (PD) program for in-service teachers. It consists of five one-day workshops and classroom-based assignments, providing a total of 40 hours of PD. MFA engages teams of general and special education teachers in adapting math lessons collaboratively to help all students, including those with disabilities, achieve high-quality learning outcomes in mathematics. A cluster randomized controlled trial (RCT) was used to test the efficacy of MFA; it included 32 schools, 98 4th and 5th grade teachers, and approximately 1,500 4th and 5th grade students. MFA had statistically significant, positive effects on teachers' self-reports of their preparedness and comfort with teaching mathematics to students with disabilities. A school-level analysis found a moderate MFA effect on student achievement. Quasi-experimental analyses of a subgroup of teachers showed initial evidence of MFA impacts on their classroom practices.

Keywords: Mathematics teacher professional development, mathematics teacher beliefs, mathematics teacher self-efficacy, mathematics teaching practice, mathematics achievement.

Introduction

This paper presents the results of a randomized controlled trial (RCT) that tested the efficacy of a professional development (PD) program called Math for All (MFA). MFA is an intensive PD program designed to help general and special education teachers in Grades K–5 to personalize rigorous mathematics instruction for a wide range of learners, including students who are low performing, and students with disabilities. MFA consists of five full-day PD sessions and related assignments (a total of 40 hours of PD) carried out at regular intervals throughout the school year. The program is designed to have a direct impact on teachers' knowledge, beliefs, and classroom practice. The PD introduces teachers to a neurodevelopmental framework¹ (Barringer et al., 2010) as a lens for better

¹ This framework describes eight constructs related to learning processes (i.e., attention, temporal-sequential ordering, spatial-ordering, memory, language, neuromotor function, social cognition, and higher order cognition). Those who use the framework are encouraged to think through how these constructs interact when student learn, and to adapt mathematics lessons based on individual students' neurodevelopmental learning profiles.

understanding individual students' strengths and challenges and the demands of mathematical activities. The PD also engages teachers in in-depth analyses of mathematics lessons, including examination of their mathematical goals, and different instructional strategies and teaching practices that support the attainment of these goals while attuning to individual students' strengths and needs. MFA was developed by Bank Street College and EDC with funding from the National Science Foundation and is published by Corwin Press (Moeller et al., 2012; 2013). MFA incorporates several components that RCTs or quasi-experimental studies (QEDs) have shown to be effective for supporting elementary school teachers' professional learning and for improving achievement of struggling students, such as teacher collaboration for instructional planning and peer coaching (e.g., Stevens & Slavin, 1995), formative assessment and progress monitoring of students (Gersten et al., 2009), and lesson study (Lewis & Perry, 2017).

MFA is not tied to any specific K–5 mathematics curriculum. Rather, it helps teachers to use and adapt their existing mathematics curriculum to make it more accessible to a wide range of learners. With funding from the Institute of Education Sciences at the U.S. Department of Education researchers carried out an RCT in collaboration with a large urban school district in a midwestern state in the U.S. In this paper we report findings relating to three main research questions, which probed for the impact of MFA on (a) teachers' comfort and preparedness to teach mathematics to students with disabilities, (b) teachers' classroom practice, and (c) student performance on a standardized mathematics achievement test.

Theoretical framework and related literature

A number of factors influence student achievement (as measured by performance on standardized achievement tests), with teacher quality being the most powerful (e.g., Nye et al., 2004; O'Dwyer et al., 2010). Various teacher characteristics such as experience, education background, dispositions (beliefs and motivations), as well as their knowledge (content knowledge, pedagogical content knowledge, general pedagogical knowledge), have been shown to impact student outcomes to varying degrees (e.g., Clark et al., 2014). Classroom practice is another factor that has been linked to student achievement (e.g., Clements et al., 2013). Research has helped to identify key features and principles of instructional practices that are associated with higher student achievement in mathematics, such as strategies for teaching students who struggle in mathematics (Gersten et al., 2009).

However, major questions remain with respect to how PD can play a role in improving teacher quality, practice, and student achievement, given the mixed findings often generated. Recent reviews of research on teacher PD (e.g., Darling-Hammond et al., 2017; Gersten et al., 2014; Yoon et al., 2007) attest to the paucity of rigorous evidence that links PD to improved student outcomes in mathematics and other subject areas. Moreover, little is known about the specific aspects of teacher quality that PD can most effectively target. Although there is general consensus that teachers must have mathematics content and pedagogical content knowledge to effectively teach mathematics, and many PD efforts target these teacher qualities, evidence that attests to the effectiveness of content-focused PD has been difficult to come by. Three recent studies (e.g., Garet et al., 2016; Jayanthi et al., 2017; Jacob et al., 2017) found only limited evidence of the impact of content-focused PD on

teachers' mathematical and pedagogical content knowledge and instructional practices, and no effects on student outcomes.

In assessing the efficacy of MFA, we were particularly interested in understanding its impact on teachers' dispositions. Teacher dispositions are related to teachers' professional background and experiences, knowledge, and teaching contexts, and to characteristics of the students they teach (Clark et al., 2014). Research has demonstrated that teachers who have negative self-efficacy about mathematics (math anxiety) can have negative effects on the mathematics achievement of their students (Beilock et al., 2010; Ramirez et al., 2018). Because teachers draw on cognitive and affective resources during instruction (e.g., Anderson et al., 2018), teacher dispositions constitute an important outcome to measure when assessing the impact of professional development.

To assess teacher dispositions, we constructed two eleven-item scales that measure teacher comfort and preparedness with various practices that have been associated with differentiated mathematics teaching practices (see Table 1). These scales have been used in multiple studies of MFA (Duncan, et al., 2022) and have demonstrated high internal consistency with Cronbach alphas ranging from .85 to .95.

Table 1: Comfort and preparedness scales

Question stem: How prepared/comfortable do you feel about the following?

-
- a. Teaching standards-based math to students with disabilities.
 - b. Identifying the math strengths of students with disabilities.
 - c. Identifying the math needs of students with disabilities.
 - d. Understanding the mathematics of the lessons I teach.
 - e. Analyzing the demands of mathematical tasks on students.
 - f. Determining the goals of the math lessons I teach.
 - g. Understanding learning trajectories in mathematics (how the math I teach relates to what students learned before and what they will learn later).
 - h. Selecting specific strategies to address the strengths of students with disabilities in math.
 - i. Selecting specific strategies to address the needs of students with disabilities in math.
 - j. Adapting math lessons for students with disabilities to help them meet standards-based goals.
 - k. Collaborating with my colleagues when planning math lessons.
-

Note. Items are rated on 1-5 Likert scales, anchored by 1=not at all prepared to 5=very prepared, or 1=not at all comfortable to 5=very comfortable

We hypothesized that improved comfort with and preparedness for teaching mathematics to students with disabilities will result in high-quality classroom practices, which are differentiated based on individual students' strengths and needs without undermining the rigor of the mathematics to be taught. This in turn would lead to improved student mathematics achievement (as measured by performance on standardized achievement tests), so we expected coordinated improvements in teachers' dispositions, classroom practices, and student achievement.

Methods

An RCT of MFA was conducted from 2015 to 2017 to help build the evidence base around the impact of PD interventions. Schools were randomized by a statistician blinded to study condition into either the MFA PD treatment group or business-as-usual (BAU) control group. The sample included 32 schools from a large, midwestern urban school district in the U.S., 98 4th and 5th grade general and special education teachers, and approximately 1,500 4th and 5th grade students. This study focused on estimating MFA impacts on teacher outcomes after one year of PD because this was the point when the maximum MFA-BAU contrast was expected. For student-level outcomes, a two-year study was originally planned but findings presented here describe outcomes after Year 1 because there were challenges in maintaining the sample across both years, largely because of student mobility and difficulties with collecting parent consent to use achievement data collected by the school district. Key Year 1 findings are supported by a strong design and allow for solid causal inference.

Research Questions and Outcome Measures

The study's first research question was: *Does participation in MFA PD, compared to business-as-usual (BAU) experiences of a control group, improve teachers' comfort and preparedness to teach mathematics to diverse students (including those with disabilities) after the completion of the PD?* Separate measures of teachers' self-reported comfort-level and preparedness were used as dependent variables to address this research question. Two researcher-developed 11-item scales were used (see Table 1), and corresponding Cronbach alphas were .886 and .950. The scales were included in a larger teacher survey that was administered at the beginning and end of the school year.

Research Question #2. Does participation in MFA PD, compared to the BAU experiences of a control group, result in improved mathematics classroom practice after the completion of the PD? A subsample of 40 classrooms were observed at the beginning and end of the school year using the Classroom Assessment Scoring System (CLASS). The CLASS, a widely used and psychometrically sound observation approach (Pianta et al., 2012), was used to generate dependent variable data for this question. Unfortunately, only 40 teachers agreed to be observed and this undermines the benefit of randomization. Therefore, related analyses were conducted using a quasi-experimental design wherein the strength of causal inference is predicated on showing that teachers across the two study conditions were similar on baseline assessments of their classroom teaching practice.

Research Question #3. Does the use of an MFA approach in the classroom result in improved student achievement in mathematics after one year of intervention exposure? The NWEA MAP assessment, used by the school district in which the study was carried out, was the measure used to assess student mathematics achievement. Coefficient alphas for this measure's related subtests range from .92 to .96 and test-retest reliabilities range from .77 to .94; there is also strong evidence of the measure's construct and concurrent validity (see Malone et al., 2020 for details).

Data Analyses

Impact analyses for Research Questions 1 and 2 entailed using a two-level hierarchical linear model with teachers clustered by schools, and a term for assessing the treatment impact at level two (i.e., schools, the unit of randomization). Impact analyses for Research Question 3 were conducted using three strategies: (1) a school-level analysis; (2) a student-level hierarchical analysis that accounted for student clustering within schools; and (3) a hierarchical student-level analysis that included grade

level as a moderator. The first strategy was used because of the difficulties with attrition. This school-level impact model entailed using each school's mean achievement at post-test as a dependent variable to assess MFA's impact on student achievement at grades 4 and 5. This analysis included all 32 study schools and does not have cluster-level missing data. The second two strategies both accounted for student clustering in schools and included a term for assessing the treatment impact at the school level. All mean contrasts presented here adjusted for baseline differences. These baseline differences were observed using the same measures that produced dependent variable data. Missing data (and by extension Year 1 attrition) were addressed by using multiple imputation procedures, which we consider to be our primary analyses. We did however re-run impact models using listwise procedures (i.e., no imputed data) to perform sensitivity checks (see Enders, 2010). For Research Question 3, school-level impact analyses did not formally have missing data; furthermore, Grade 4 subsample analysis yielded inconsistent results across imputed and listwise analyses, so we present related findings from both approaches. All required assumptions for impact modeling were met.

Key findings

Research Question #1

The pattern of results was the same for both scales: the MFA group reported lower levels of preparedness and comfort at the pretest, compared to BAU teachers, but there was a steep increase from fall to spring. The opposite pattern was observed for the BAU group. Results were statistically significant. Effect sizes using the Hedges' g statistic were $g = .54$ ($p < .05$; $M_{diff} = .803$; $SD_{pooled} = 1.48$) for preparedness and $g = .67$ for comfort ($p < .05$; $M_{diff} = 1.08$; $SD_{pooled} = 1.621$). To summarize, MFA teachers increased their senses of preparedness and comfort in teaching students with disabilities, as compared to BAU teachers.

Research Question #2

Unfortunately, there was a large baseline difference favoring the MFA group, which undermined causal inference, and Bonferroni corrections for multiple comparisons rendered results from this small sample not statistically significant. Analyses showed that at the posttest (and after adjusting for pretest levels), MFA teachers scored higher in the domains of Emotional Support ($g = .98$; $p > .05$; $M_{diff} = 1.115$; $SD_{pooled} = 1.118$), Instructional Support ($g = .69$; $p > .05$; $M_{diff} = .526$; $SD_{pooled} = .765$), Classroom Organization ($.78$; $p > .05$; $M_{diff} = .733$; $SD_{pooled} = .94$), and Student Engagement ($.54$; $p > .05$; $M_{diff} = .435$; $SD_{pooled} = .8$). These contrasts should be interpreted with caution, but they do suggest MFA had a positive impact on teachers' classroom practices.

Research Question #3

The resulting g from the first school-level analytic strategy was $.33$ ($p > .05$; $M_{diff} = 1.82$; $SD_{pooled} = 5.45$), favoring MFA schools. This finding was however not statistically significant, which likely stems from the analysis being underpowered given there were only 32 school-level means. The student-level analyses mirror the pattern shown in the cluster-level analysis; that is, while the results favor the treatment group ($g = .11$; $p > .05$; $M_{diff} = 1.54$; $SD_{pooled} = 14.46$), the differences were, again, not statistically significant. When grade level was examined as a moderator, different patterns between grade 4 and grade 5 students were found. In grade 4, students whose teachers participated in

the MFA PD had higher posttest scores than students whose teachers were in the BAU group and results based on analyses with imputed datasets were statistically significant ($g = .26; p < .05; M_{\text{diff}} = 3.62; SD_{\text{pooled}} = 13.9$). However, impact analyses that did not entail use of imputed data did not allow for rejecting a null hypothesis ($g = .20; p > .05; M_{\text{diff}} = 2.77; SD_{\text{pooled}} = 13.6$). In grade 5, there were small mean differences between the MFA and BAU groups. The overall pattern of findings suggests MFA PD might have had a positive impact on student achievement, but student attrition prevent conclusive findings.

Discussion

This study yielded evidence that MFA had a positive impact on teacher's self-reported sense of comfort and preparedness with respect to teaching students with diverse learning needs. While the evidence that MFA impacted teacher classroom practice and student achievement is less strong, it is still compelling. As we seek to better understand the impacts of PD on teacher and student outcomes, it is important to "open the black box" and flesh out the mechanisms by which PD can affect teacher practice, which in turn, affects student achievement (cf., Clarke & Hollingsworth, 2002; Goldsmith et al., 2014). The data presented here converges with other recent studies that have demonstrated that teacher dispositions may be key mediators to consider in our models of teacher PD (e.g., Miele, et al., 2019; Schoen & LaVenia, 2019).

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