



Developing elementary mathematics specialists as teacher leaders during a preparation program

Susan Swars Auslander¹ · Gary E. Bingham¹ · Carla L. Tanguay¹ ·
Debra S. Fuentes¹

Accepted: 12 April 2023

© The Author(s), under exclusive licence to Springer Nature B.V. 2023

Abstract

This 5-year mathematics professional development project involves 27 elementary teachers prepared and supported as Elementary Mathematics Specialists (EMSs) in high-need, urban schools. Our inquiry centers on their experiences in the EMS preparation program and the development of important outcomes, specifically productive beliefs and teacher leadership. Data were gathered at the end of Year 1 via surveys of mathematical beliefs, coaching beliefs, and coaching practices, as well as individual and focus group interviews. The findings provide insights into participants' growth and work as a *more knowledgeable other*, illuminating specific emphases of their efforts and influences of the project. When it comes to mathematical beliefs, as participants shifted toward embracing cognitively-oriented pedagogical beliefs, they became more efficacious in this learner-centered pedagogy. The findings also show variability in specific mathematics coaching practices, including those most participants were and were not using, and areas for improvement. Several themes are evident in the interview data: *growing confidence for the uncomfortable, creating and finding spaces for stepping up, advocating for learned mathematics pedagogy, and building teacher capacity through interactions.*

Keywords Elementary mathematics specialists · Mathematics teacher leaders · Teacher beliefs · Professional development · Mathematics teacher education

✉ Susan Swars Auslander
sauslander@gsu.edu

Gary E. Bingham
gbingham@gsu.edu

Carla L. Tanguay
ctanguay@gsu.edu

Debra S. Fuentes
dfuentes5@gsu.edu

¹ Department of Early Childhood and Elementary Education, Georgia State University, P.O. Box 3978, Atlanta, GA 30302-3978, USA

Introduction

A growing strategy for improving elementary teacher effectiveness is the development and use of subject area specialists, with initiatives occurring in countries such as Australia, the UK, and the USA (Mills et al., 2020). In the USA, which is the context for this study, there has been increased advocacy for specialists at the elementary school level who focus on mathematics, called Elementary Mathematics Specialists (EMSs) (Association of Mathematics Teacher Educators [AMTE], 2013). EMSs are considered to be teachers, teacher leaders, or coaches with expertise in using and helping others use effective and equitable elementary mathematics instruction so all students learn important mathematics. Several prominent mathematics education organizations, such as AMTE and the National Council of Teachers of Mathematics (NCTM) (AMTE, 2022), recently issued a renewed call for every elementary school to have access to a well-prepared EMS.

EMS preparation programs should have a twofold emphasis, including fostering expertise as a: (a) teacher of mathematics, and (b) teacher leader who serves as a *more knowledgeable other* by supporting colleagues' instruction and other efforts within mathematics education (AMTE, 2013). While there has been much interest in EMSs and establishment of preparation programs (Hjalmarson & Baker, 2020), the extant literature offers relatively limited research on their preparation. Further, while standards and recommendations for EMS preparation programs exist (AMTE, 2013), the actualization of these programs across states yields differing models of implementation that have variable goals (EMSs & Teacher Leaders Project, 2022). Understanding how these models reflect exemplary elements, while being responsive to local context and need, is critical. There is a need for study of rigorous EMS preparation programs (AMTE, 2013, 2022), so the field can develop a professional knowledge base on what makes a difference in EMSs' preparation in order to guide program development, improvement, and scale-up. This study involves elementary teachers who are completing a robust EMS preparation program, exploring the important outcomes of productive beliefs and teacher leadership. Notably, EMSs' development and work as teacher leaders during program experiences, including as coaches, are especially understudied (Reys et al., 2017; Yopp et al., 2019).

Currently, 19 states and the District of Columbia have established routes for EMS licensure, certification, or endorsement, with 10 other states in the process of developing pathways (EMS & Teacher Leaders Project, 2022). Our state provides a K-5 Mathematics Endorsement (K-5 ME) and a Teacher Support & Coaching Endorsement (TSCE). The context of this study is a 5-year professional development project for 27 elementary teachers in high-need, urban schools who are prepared and supported as EMSs in part through completion of these two endorsement programs. Project goals include the development of EMSs who deliver effective and equitable mathematics instruction and serve as mathematics teacher leaders in a variety of ways, especially coaching. For the EMSs in this project, their primary responsibility is teaching students, thus they are a distinctive population as *informal teacher leaders*. They are largely teachers of color, working in urban schools that serve students historically marginalized and underserved in mathematics education. At the time of this study, they had completed Year 1 of the project and were developing their understandings and capabilities as EMSs. Notably, this project's K-5 ME program has been extensively studied and shown to produce significant positive changes in participants' mathematical knowledge and beliefs, along with substantial implementation of effective and equitable instructional practices (e.g., Myers et al., 2020, 2021; Swars Auslander et al., 2018, 2019, 2022). This study extends the current body of inquiry by focusing on those

who are completing both the K-5 ME and the TSCE, centering on their *productive disposition for teaching mathematics* (Jacobson & Kilpatrick, 2015), beliefs about their coaching effectiveness, their coaching practices, and the influences of the project on their teacher leadership.

Theoretical Perspectives and Related Research

Elementary mathematics specialist preparation

AMTE's (2013) *Standards for Elementary Mathematics Specialists* has guided EMS preparation, with recommended program areas of content knowledge for teaching, pedagogical knowledge for teaching, and leadership knowledge and skills. Another suggestion is a supervised internship working with a range of learners, including elementary students and teachers. Learning experiences should be embedded in practice within EMSs' classrooms, schools, and/or school districts (Reys et al., 2017). Programs should foster understandings and capabilities as a teacher of mathematics and as a teacher leader who helps others in using effective, responsive instructional practices and who supports school-wide efforts such as outreach to families and the community.

EMSs' development as highly effective and equitable mathematics teachers in part includes a *productive disposition for teaching mathematics* (Jacobson & Kilpatrick, 2015), which encompasses beliefs, attitudes, and emotions about mathematics and its teaching and learning that are productive because of their positive influences on students' mathematical learning. Though some argue that the teacher beliefs–practice link is less causal and more dynamic (Schoenfeld, 2015; Skott, 2015), with the impact of beliefs molded by other mental constructs (e.g., knowledge) and modified by contextual constraints, over time researchers have documented a relationship between teachers' mathematical beliefs and teaching. Specifically, beliefs shape teacher thinking and behaviors, including instructional decision-making and use of curriculum materials (Buehl & Fives, 2009; Clark & Peterson, 1986; Swars Auslander et al., 2019; Philipp, 2007; Polly et al., 2013; Romberg & Carpenter, 1986; Thompson, 1992; Wilkins, 2008; Wilson & Cooney, 2002). Further, beliefs about mathematics play a filtering role for elementary teachers developing new knowledge of the subject and its teaching, influencing the understandings and skills they choose to develop (Maasepp & Bobis, 2014/2015). With elementary teachers too often having nonproductive beliefs about mathematics and its teaching and learning, attention to these beliefs is critical during learning experiences in mathematics for this population (Swars Auslander, 2016).

Beliefs represent mental constructs that are: (a) subjectively true for an individual, (b) value-laden, (c) held with a certain degree of commitment and relatively stable, and (d) “expected to significantly influence individuals’ perceptions and interpretations of experiential encounters and their contributions to the practices in which they engage” (Skott, 2015, p. 6). Two beliefs constructs relevant to this study include pedagogical beliefs (i.e., beliefs about teaching and learning) and teaching efficacy beliefs (i.e., beliefs about capabilities to teach effectively and influence student learning). Also pertinent to this inquiry are beliefs about coaching mathematics, specifically beliefs in one’s mathematics coaching effectiveness. Though not widely studied, Yopp and colleagues’ (2019) research showed that increases in mathematics coaches’ ($n = 51$) beliefs about their own effectiveness were

linked with improvements in teachers' mathematical knowledge, instructional practices, attitudes, and self-efficacy of whom they coached ($n=180$).

When considering EMSs' preparation as teacher leaders, there are a number of important understandings and capabilities to be developed (AMTE, 2013). They need knowledge of teacher development trajectories to create differentiated learning experiences and specific long-term goals for teacher growth (Costa & Garmston, 2016). Programs should foster capabilities for: (a) developing trusting relationships with teachers, (b) engaging in goal setting, (c) asking productive questions, and (d) providing continuous, targeted opportunities for collaboration and feedback. Further, programs should develop a deep knowledge of instructional practice and related theory and research, so EMSs can support teachers in making instructional decisions grounded in these understandings (AMTE, 2013; McGatha et al., 2015). Broadly, program experiences should focus on: (a) effective ways of coaching teachers, such as cognitive coaching (Costa & Garmston, 2016), co-teaching, and modeling (Gibbons & Cobb, 2017); and (b) planning, developing, facilitating, and evaluating effective professional development (AMTE, 2013).

When examining pathways for advanced specialist certification across states, there are notable differences in EMS preparation programs related to duration, number of course hours, course emphases, field practicum experiences, and delivery (EMS and Teacher Leaders Project, 2022; Spangler & Ovrick, 2017). This variability is linked in part to differences in program goals and provides a warrant for study of EMS preparation programs. Researchers have largely examined participants' content knowledge, beliefs, instructional practices, and perceptions of the program (Campbell & Malkus, 2011, 2014; Harrington et al., 2017; Kutaka et al., 2017; Nickerson, 2010; Myers et al., 2020, 2021; Swars Auslander et al., 2018, 2019, 2022). Evident are positive findings for beliefs and instructional practices and some mixed findings related to content knowledge. Related to this study, one inquiry investigated the effects of Primarily Math, an EMS preparation program designed to develop the mathematical knowledge of elementary teachers (Kutaka et al., 2018). Primarily Math was offered over 13 months in three content and three pedagogy courses. Participants were three cohorts of K-3 teachers ($n=126$) who completed the program and a matched comparison group ($n=92$). Those completing the program had less mathematics anxiety and more motivation to learn the subject and endorsed more student-centered beliefs about the teaching and learning of mathematics. Another inquiry examined the influences of a 15-month preparation program including five mathematics courses team-taught by a mathematician and mathematics educator and a leadership-coaching course, plus a second leadership-coaching course during the first year as a specialist coach (Campbell & Malkus, 2014). There were significant positive changes in participants' ($n=12$) beliefs about mathematics pedagogy as a sensemaking endeavor, with this changed state persisting throughout their first 2 to 3 years serving as a specialist coach.

An important yet under-studied program outcome is teacher leadership, including how learning experiences prepare and position EMSs in both formal and informal roles to successfully engage as teacher leaders (Baker et al., 2022; McGatha et al., 2015; Yopp et al., 2019). The development of this competency is critical to the effective use of EMSs, given the potential for promoting systemic change. Relatedly, Campbell and Malkus' (2011) inquiry involved a preparation program for EMSs ($N=24$) who were formal instructional coaches logging their professional activities (though the central focus of the study was student achievement). They determined that the variability in time spent on activities was linked to contextual factors (e.g., demands of district assessments, requirements/requests of

school administration), though most time was devoted to coaching teachers, preparing for teaching/coaching, supporting assessment, and engaging in personal professional activity.

Elementary mathematics specialists: roles and responsibilities

Increasing research shows EMSs and the roles and responsibilities they fulfill make an impact in schools. Researchers have investigated EMSs' interactions with teachers as well as their influences on teachers' instructional practices and student achievement, with results showing positive effects of these professionals on teacher development and student learning (Campbell & Malkus, 2011; Harbour & Saclarides, 2020; Harbour et al., 2018; Kutaka et al., 2017; McGatha et al., 2015; Meyers & Harris, 2008; Mudzimiri et al., 2014; Yopp et al., 2019). The specific roles and responsibilities of EMSs vary (Baker et al., 2022) and are dependent upon the contextual needs and plans of schools, school districts, and states (McGatha et al., 2015). For example, EMSs can serve as classroom teachers, instructional interventionists, and informal or formal teacher leaders.

In their work as informal or formal teacher leaders, they may serve as coaches of other teachers. Based on review of extant studies, McGatha (2015, 2017) posited that coaches' ways of interacting with individual teachers are on a continuum from more-directive (e.g., modeling lessons, providing resources) to less-directive (a process of collecting data from observed lessons, providing feedback, and engaging teachers in thought reflection), with the latter more powerful for prompting teacher change. Relatedly, a systematic review of research (Gibbons & Cobb, 2017) illuminated potentially productive activities for mathematics coaches. Activities with groups of teachers include engaging in the discipline, examining student work, analyzing classroom video, and participating in lesson study, while those with individual teachers include co-teaching and modeling instruction. There are several coaching models evident in the extant literature (Yopp et al., 2019). Cognitive coaching, an emphasis of this project, is a particularly powerful, facilitative approach that relies heavily on coaches' use of reflective questions to encourage teachers to refine their professional knowledge base, stressing the cultivation of self-assessment and self-direction and a collaborative partnership between coach and mentee (Costa & Garmston, 2016). This approach to supporting instructional change stands in contrast to top-down teacher evaluation systems found in most schools, with a body of research on cognitive coaching illuminating positive outcomes for teachers, students, administrators, and school climate (Edwards, 2021).

Research Questions

These questions guided the study of elementary teachers who are developing as EMSs during a mathematics professional development project:

- To what extent did the first year of the project support change in EMSs' beliefs about their mathematics coaching effectiveness, mathematics pedagogy, and mathematics teaching efficacy? What are their mathematics coaching practices? What are the relationships between these beliefs and practices?

- How has participation in the first year of the project supported the EMSs as teacher leaders?

Methodology

The design of this study includes a descriptive, holistic singular-case approach (Yin, 2014), focusing on in-depth investigation of a case within a real-world context. Multiple sources of data, both quantitative and qualitative in nature, were collected to form the descriptive findings. It is important to note that this inquiry occurred during the COVID-19 pandemic, and the researchers were mindful of this contextual element throughout the study.

Participants and context

This study's context was a mathematics professional development project focused on the development of 27 elementary teachers as EMSs in high-need, urban schools. Multiple partners are involved, including a university, school district, and non-profit organization. Project goals include the development of EMSs who deliver effective and equitable mathematics instruction and serve as mathematics teacher leaders in a variety of ways. The project also aims to promote equity and access in mathematics education, support teacher retention in high-need schools, and situate teacher candidates in a hiring pipeline. Since the EMSs' primary responsibility is teaching students (i.e., at least 4.5 out of 5-days-per-week), their role as a mathematics teacher leader is an informal one. The project is 5 years in duration and at the time of this study, they had completed 1 year and were emergent EMSs.

Teachers were selected for participation based on criteria applied to a variety of application documents and small group interviews that identified them as successful, experienced teachers of mathematics with strong potential for development as teacher leaders. The Selection Team was composed of three university faculty, the project's program director, and two school district representatives. The project's recruitment efforts had concentrated on the highest need elementary schools in the district, as determined by federally-funded free and reduced lunch program rates. To be considered for the project, applicants submitted a resume, goals statement, letter of recommendation from a school administrator (that in part addressed student achievement in mathematics of the applicant), transcripts (minimum of master's degree with 3.0 graduate GPA required), state-mandated teacher effectiveness score (minimum of proficient required), and a standardized test score focusing on mathematics. In conjunction with responses from small group interviews, these application materials were reviewed for meritorious professional achievement (e.g., awards or recognitions such as Teacher of the Year, presentations at conferences), academic accomplishment (e.g., high GPA, advanced degrees), knowledge of mathematics (i.e., proficient or higher score on standardized test), commitment to teaching mathematics (e.g., 3+ years of teaching mathematics), and evidence of/desire for teacher leadership (e.g., experiences leading professional development, serving as grade chair, mentoring teacher candidates). These criteria, plus consideration of race/ethnicity, gender, grade level, and school site with the aim of assuring participation of underrepresented groups and diverse school sites and grade levels, informed the selection of the 27 teachers in the project.

All participants were employed in a large, urban school district in the southeastern USA. They taught in 22 elementary schools, collectively serving 91% students of color, with the largest populations being 44% Hispanic and 36% Black; 69% of students were eligible for the federally-funded free and reduced lunch program. The participants self-described as 24 females and 3 males, with 70% self-identifying as persons of color (41% Black, 7% Hispanic, 7% Asian, 7% Hispanic/White, 4% Hispanic/Black, 4% Black/White). The average age was 39 years (range of 28–62 years). They were a highly educated group, with 100% having a master's degree and 33% holding an educational specialist degree. Further, they were experienced teachers, on average having 10.5 years of teaching experience (range of 5–22 years). Teaching positions varied and included: three kindergarten, one 1st grade, two 2nd grade, five 3rd grade, one 4th grade, seven 5th grade, four STEM/Math Specials, one English to Speakers of Other Languages, one Special Education, one Early Intervention Program, and one Accelerated Content. Of these participants, two taught in Dual Language Immersion settings, including Spanish (2nd grade) and French (5th grade). Within these differing grade levels and foci, all taught mathematics, including some for part and some for all of the day. Notably, this group of participants represents the diversity of teachers from which students learn mathematics in elementary schools.

The participants are prepared and supported through completion of a university's K-5 ME and TSCE programs during the first 2 years, along with participation in Professional Learning Communities (PLCs) and individual mentoring for the entire 5 years (see Table 1). The endorsement programs include four elementary mathematics content courses integrating pedagogy, one course focusing on teacher leadership and coaching, and two internship courses, with one emphasizing mathematics and the other coaching. Overall goals of both programs (AMTE, 2013, 2017) are development of: (a) effective and equitable mathematics instructional practices (Carpenter et al., 2015; NCTM, 2014, 2020); (b) deep and broad knowledge of elementary mathematics, including *specialized content knowledge* (Ball et al., 2008); (c) productive mathematical beliefs and professional agency; and (d) teacher leader capabilities, including coaching skills.

K-5 mathematics endorsement

In the K-5 ME program, the development of effective and equitable instructional practices focuses on learner-centered, responsive instruction (Carpenter et al., 2015; Jacobs & Empson, 2016) and the eight mathematics teaching practices in NCTM's *Principles to Actions* (NCTM, 2014). These include: (a) selection and implementation of instructional tasks with high levels of cognitive demand; (b) use of multiple representations and tools; (c) promotion of problem solving and reasoning, explanation and justification, and connections and applications typical of standards-based learning environments; and (d) use of children's thinking and understandings to guide instruction. There is explicit emphasis on equity-based, identity-affirming, justice-oriented pedagogy, including fostering of practices that provide access, support, and challenge in learning rigorous mathematics for every student (AMTE, 2017). EMSs learn about planning for and enacting instruction that leverages children's mathematical, cultural, and linguistic resources/strengths, while nurturing positive student identity in mathematics (Aguirre et al., 2013; AMTE, 2017; Bartell et al., 2017; NCTM, 2020, 2021). Learning during class sessions occurs through: (a) active engagement in and analysis of the mathematics in the elementary curriculum, especially through cognitively demanding instructional tasks; (b) study of children's thinking and learning via

Table 1 Timeline and project elements aimed at preparing and supporting EMSs

Year 1	Year 2		Years 3–5
	Spring 2021	Summer 2021	Spring 2022
Fall 2020			
1 TSCE course (Teacher Leadership & Coaching)	1 K-5 ME course (Number & Operations)	1 K-5 ME course (Data Analysis & Probability, 2-week summer institute)	1 K-5 ME course (Algebra & Rational Number) and 1 TSCE course (the Internship)
PLC and Mentoring	PLC and Mentoring	PLC and Mentoring	2 K-5 ME courses (Geometry & Measurement and the Internship) PLC and Mentoring

video clips and written work samples; (c) examination of classroom practice via video clips and written teaching cases; and (d) scrutiny of the research base on elementary mathematics education and of critical aspects of equity and access with connections to classroom practice and schools (e.g., culturally responsive teaching, instruction for multilingual learners, and teaching mathematics for social justice). There is a substantial focus on the professional development materials from *Cognitively Guided Instruction* (CGI) (e.g., Carpenter et al., 2015) and *Developing Mathematical Ideas* (e.g., Shifter et al., 2018).

Teacher support and coaching endorsement

The TSCE program has a concentrated focus on the EMSs' preparation as teacher leaders by developing their understandings of teacher development, coaching, and facilitation of professional development. It aims to develop: knowledge of adult learning and the continuum of teacher development across the career span; and coaching skills that support instructional change through cognitive coaching (Costa & Garmston, 2016), observations of classroom practice, analysis of student work, and examination of lesson components. The cognitive coaching cycle is an iterative process that includes a pre-conference focused on goal setting, followed by a lesson observation using specific data collection techniques, and then a post-conference involving sharing of data with connection to goals and actionable feedback, with the coach encouraging reflection and decision-making centered on the mentee's concerns. Coupled with cognitive coaching, there is a focus on coaching for equity, specifically a transformational approach (Aguilar, 2020) involving coaches' and their mentees' continual analysis of behaviors (what we do), beliefs (what we think), and ways of being (who we are). EMSs are immersed in these understandings and approaches during the first course, Teacher Leadership & Coaching.

Then in the second course, the EMSs apply their learning in an internship focused on coaching a teacher candidate or novice teacher. With an understanding of adult learning and teacher development, the EMSs differentiate their coaching approach (Aguilar, 2020; Orland-Barak & Wang, 2020), as needed, to alleviate resistance and to promote mentee reflection and self-direction (Costa & Garmston, 2016). They aim to develop a trusting relationship with their mentee, engage in goal setting, and provide continuous, targeted opportunities for collaboration and sharing feedback. The EMSs implement the cognitive coaching cycle at least three times across the course with their mentee, and provide support through teacher development activities dependent on the differentiated needs of their mentees (e.g., curriculum and lesson plan support, data analysis focused on student learning, modeling, co-teaching, scaffolding, video self-study). These coaching expectations are a model for coaching mentees across the project.

Professional learning communities and individual mentoring: support for teacher leader activities

In addition to preparation for teacher leadership in the endorsement programs, support for the EMSs as they serve as teacher leaders is provided through a PLC and individual mentoring, both facilitated by the project's program director. PLCs and individual mentoring focus on: building a community of learners within each PLC, augmented support for developing effective and equitable mathematics instruction, and targeted support for their selection and implementation of what is called in this project teacher leader activities. The three

PLCs, with nine EMSs each, are clustered around grade levels/teaching focus and meet monthly eight times across the school year.

To lead instructional change and support wide-ranging improvements, the EMSs engage in a number of teacher leader activities across the 5 years in their school, district, community, and other contexts, applying their teacher leader understandings and capabilities learned in the K-5 ME and TSCE programs and the PLC. Two primary teacher leader activities include: (a) coaching a teacher candidate each year, and (b) supporting the non-profit's after-school tutoring program for at least 1 of the 5 years. Other teacher leader activities are selected based upon the needs of the school and in consultation with school leadership. The PLC serves as a context for collaborative selection, planning, and reporting on teacher leader activities, in addition to individual conferences with the program director.

Toward the beginning of the school year, each EMS proposes 3–6 specific teacher leader activities in writing to the program director, describing in detail the anticipated activities (i.e., Teacher Leader Plans), after discussion with school leadership. The program director consults with the project's Leadership Team and collaboratively refines with each EMS a plan for specific teacher leader activities to accomplish across that school year. Check-ins related to progress across the school year are included in both PLC meetings and individual conferences. PLC meetings also include time for EMSs to collaborate on these activities, as there are often multiple EMSs implementing similar efforts. This collaborative planning time aims to cultivate support for individuals, productive brainstorming on shared ideas, and positive working relationships between EMSs, who because they are in various schools across the district would not otherwise interact. Each EMS provides documentation at the end of each year of this work in a Teacher Leader Record.

The project's timeline is shown in Table 1, and at the time of this study the EMSs had completed Year 1, including the Teacher Leadership & Coaching and Number & Operations courses, eight PLC meetings, and individual mentoring. Due to the pandemic, all class sessions and meetings occurred virtually and synchronously. In addition to the fore-described focus of the PLCs, during Year 1 there was protracted emphasis on developing student identity in mathematics with collective reading and discussion of *The Impact of Identity in K-8 Mathematics Teaching: Rethinking Equity-based Practices* (Aguirre et al., 2013). Individual mentoring included the program director conducting classroom observations using the Standard-Based Learning Environment Observation Protocol (Tarr et al., 2008) as a guide, along with other planned and emergent one-on-one meetings. When it comes to their teacher leader activities during Year 1, all 27 coached a teacher candidate, serving as a classroom mentor teacher and/or university coach. For those who served in the role of classroom mentor teacher, they hosted and coached teacher candidates in their classrooms, while those who served solely as a university coach supported teacher candidates through submission of videos of instruction with reflection and feedback via online meetings. Across Year 1, the EMSs provided teacher leadership in other ways, mostly choosing to: lead mathematics-focused professional development for teachers, revise the mathematics curriculum of the non-profit's after-school tutoring program, coach novice teachers at their school sites, facilitate Math or STEM Community Events, and lead workshops and create resources for families and caregivers in support of students' mathematics learning.

Data collection and instruments

Quantitative data were collected from all participants via surveys of mathematics: coaching effectiveness beliefs (Coaching Skills Inventory [CSI], Yopp et al., 2019); coaching

practices (Coaching Practices Survey [CPS], Yopp et al., 2019); pedagogical beliefs (Mathematics Beliefs Instrument [MBI], Peterson et al., 1989, as modified by the CGI Project); and teaching efficacy beliefs (Mathematics Teaching Efficacy Beliefs Instrument [MTEBI], Enochs et al., 2000). Qualitative data were gathered through individual interviews of eight randomly selected participants, as well as three focus group interviews of those who did not participate in the individual interviews. Due to the pandemic, data were collected using virtual means. The CSI, MBI, and MTEBI were administered at the beginning and end of Year 1 of the project. Data were gathered via the CPS and interviews at the end of Year 1.

The CSI measures mathematics coaches' beliefs about their own level of effectiveness with various coaching responsibilities (Yopp et al., 2019). The survey has 20 items measured on a 5-point Likert-type scale, with a higher rating indicating a higher level of self-reported effectiveness (ranging from "very effective" to "not at all effective"). Exploratory factor analysis (varimax rotation) revealed three subscales: (a) mathematics content and mathematics-specific pedagogy, (b) student-centered pedagogy, and (c) building coaching relationships. For these factors, internal reliability scales were high (Cronbach's $\alpha=0.94, 0.93$, and 0.82 , respectively).

The CPS is designed to capture the extent to which a coach uses certain practices related to instructional coaching in mathematics that were drawn from coaching models in the extant literature (Yopp et al., 2019). The instrument contains 20 items and uses a 7-point Likert-type scale, with a higher rating indicating more self-report of particular coaching practices (ranging from "very descriptive of my coaching" to "not at all descriptive of my coaching"). This collection of 20 items exhibits good internal consistency (Cronbach's α estimated at 0.81).

The MBI is designed to assess teachers' beliefs about the teaching and learning of mathematics and the degree to which these beliefs are cognitively aligned (Peterson et al., 1989, as modified by the CGI project). The 48-item instrument includes three subscales: (a) role of the learner (Learner), (b) relationship between skills and understanding (Curriculum), and (c) role of the teacher (Teacher). The five Likert-type scale response categories range from "strongly agree" to "strongly disagree," with higher scores indicating beliefs that are more cognitively oriented. The subscales have high reliability (Cronbach's $\alpha=0.89$ for Learner, 0.80 for Curriculum, and 0.90 for Teacher) and represent independent constructs based on confirmatory factor analysis.

The MTEBI measures teachers' beliefs in their individual capabilities to be effective mathematics teachers and influence student learning (Enochs et al., 2000). The 21-item instrument includes two subscales: Personal Mathematics Teaching Efficacy (PMTE) and Mathematics Teaching Outcome Expectancy (MTOE). The instrument uses a Likert-type scale with five response categories, ranging from "strongly agree" to "strongly disagree," with higher scores indicating greater teaching efficacy. The subscales have high reliability (Cronbach's $\alpha=0.88$ for PMTE and 0.81 for MTOE) and represent independent constructs based on confirmatory factor analysis.

All individual and focus group interviews were approximately 1 h in length. Both interview protocols include questions about participants' teacher leadership, coaching, and project experiences. The prepared questions provided a starting point, with the interviewer asking questions for elaboration. The interviews were audiotaped and videotaped, which were transcribed for analysis.

Data analysis

The research team includes four university professors and the project's program director, collectively holding expertise in a variety of methodologies, as well as two doctoral students. The survey data were analyzed using descriptive and inferential statistics. Additionally, data from the CPS were dichotomized for analysis in order to identify practices that are descriptive or not descriptive of participants' coaching. For an item, if the response was descriptive at all (rating of 7, 6, or 5) it was assigned a 1, and the other responses of not descriptive or equally not descriptive and descriptive (rating of 4, 3, 2, or 1) were assigned a 0.

Four members of the team analyzed the qualitative data. Line-by-line open coding was used to analyze each of the individual and focus group interview transcripts, while focusing on particular segments of data aimed at addressing the research questions. This coding generated numerous meaning units (i.e., embedded coherent and distinct meanings), with this process supported and documented in the software program NVivo. Applying constant comparative methods (Corbin & Strauss, 2008), those meaning units were then compared across participants as the research team collapsed and renamed coded meaning units until they collectively reached consensus and determined final shared themes. For example, codes focused on *struggle for confidence as a teacher leader*, *shifts in this confidence*, and *project elements supporting these shifts*, were collapsed to form the theme *growing confidence for the uncomfortable*.

Results

Quantitative findings

To examine the extent to which the project supported changes in participants' beliefs, their coaching practices, and relationships between these constructs (RQ1), data from the CSI, MBI, MTEBI, and CPS were analyzed. Participants' pre- and post-beliefs about their effectiveness with various coaching responsibilities (CSI) are presented in Table 2. Average response values on the 5-point Likert-type scale are included, with higher scores indicating beliefs more oriented toward effectiveness. Across each subscale, mean score differences increase, and the standard deviations are smaller, indicating

Table 2 Mean scores, ranges, and standard deviations for coaching effectiveness beliefs (CSI)

CSI	MCMP		SP		BCR		All Subscales	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	3.14	3.87	3.63	4.08	3.38	3.83	3.34	3.93
Range	1.30–4.30	2.40–5.00	1.67–4.83	1.67–5.00	1.25–4.75	1.50–5.00	1.40–4.50	2.00–5.00
Standard Deviation	0.65	0.62	0.79	0.69	0.95	0.79	0.70	0.60

MCMP Mathematics Content and Mathematics-specific Pedagogy, SP Student-centered Pedagogy, BCR Building Coaching Relationships

Table 3 Mean scores, ranges, and standard deviations for pedagogical beliefs (MBI)

MBI	Learner		Curriculum		Teacher		All Subscales	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	3.48	4.04	3.78	4.07	3.82	4.22	3.70	4.11
Range	2.40–4.27	3.33–4.73	3.13–4.75	3.25–4.94	2.76–4.53	3.47–4.76	2.83–4.44	3.46–4.81
Standard Deviation	0.48	0.40	0.52	0.44	0.40	0.39	0.40	0.38

Table 4 Mean scores, ranges, and standard deviations for mathematics teaching efficacy (MTEBI)

MTEBI	PMTE		MTOE		All Subscales	
	Pre	Post	Pre	Post	Pre	Post
Mean	4.32	4.46	3.43	3.50	3.98	4.09
Range	3.69–5.00	3.31–5.00	2.38–4.38	2.00–4.25	3.57–4.52	3.43–4.71
Standard Deviation	0.34	0.41	0.48	0.58	0.24	0.30

PMTE Personal Mathematics Teaching Efficacy, *MTOE* Mathematics Teaching Outcome Expectancy

less dispersion. When examining teachers' reflections on each of the subscales, findings demonstrate that teachers felt the most effective related to coaching focused on student-centered pedagogy, which is evident in both the pre- and post-test mean scores. The subscale that evidences the largest increase in mean scores from pre- to post-test focuses on beliefs about coaching effectiveness related to mathematics content and mathematics-specific pedagogy.

Analysis using a paired sample t-test reveals statistically significant increases between pre- and post-data across all subscales: (a) MCMP with $t=5.99$ (26), $p<0.001$; (b) SP with $t=4.11$ (26), $p<0.001$; and (c) BCR with $t=3.24$ (26), $p<0.01$. For each construct, the effect size is moderate ($d=0.63$, $d=0.57$, and $d=0.73$, respectively). A paired sample t-test also reveals a significant difference between pre- and post-data for the overall scale $t=5.56$ (26), $p<0.001$ with a moderate effect size ($d=0.55$). All in all, the participants' beliefs in their effectiveness with various coaching responsibilities evidence significant, positive shifts across Year 1 of the project.

Participants' pre- and post-beliefs about the teaching and learning of mathematics (MBI) are shown in Table 3. Average response values on the 5-point Likert-type scale are included, with higher scores indicating more cognitively-oriented pedagogical beliefs. Across each subscale, mean score differences increase, and the standards deviations are smaller, indicating less dispersion. When examining each of the subscales, both pre- and post-test mean scores show that participants' beliefs related to the role of the teacher, including that mathematics instruction should be organized to facilitate children's construction of knowledge, are the most cognitively oriented. The subscale that evidences the largest increase in mean score from pre- to post-test focuses on beliefs about the role of the learner, specifically that children can construct their own mathematical knowledge.

Analysis using a paired sample t-test reveals statistically significant increases between pre-and post-data across all subscales. For the Learner subscale, the difference is statically

significant, $t=5.53(26)$, $p<0.001$. The effect size ($d=0.52$) indicates a moderate effect. Similarly, the differences in the Curriculum and Teacher subscales are also statistically significant, $t=3.15(26)$, $p=0.004$ and $t=5.53(26)$, $p<0.001$, respectively. The effect sizes are slightly smaller for Curriculum and Teacher at $d=0.47$ and $d=0.38$, respectively, indicating a small to moderate effect. The overall mean score for the MBI shows an increase in the rating that is statistically significant $t=5.46(26)$, $p<0.001$ with an effect size of $d=0.39$.

Participants' pre- and post-mathematics teaching efficacy beliefs (MTEBI) are displayed in Table 4. Average response values on the 5-point Likert-type scale are included, with higher scores indicating stronger mathematics teaching efficacy. Across the two subscales, mean score differences increase; however, the standard deviations also increase, indicating a greater dispersion of ratings in the post scores. When examining each of the subscales, findings show that participants had a strong sense of personal mathematics teaching efficacy (PMTE) at both pre- and post-administration. However, both pre- and post-test mean scores on the MTOE subscale reveal that the teachers are uncertain that their effective teaching of mathematics positively influences students' mathematical learning.

The increase in ratings for the PMTE subscale is statistically significant $t=2.14(26)$, $p=0.042$ with an effect size $d=0.35$. In contrast, the increase in MTOE ratings is not statistically significant $t=0.90(26)$, $p=0.38$, though the effect size is slightly larger $d=0.38$. Overall, the MTEBI mean rating increase is statistically significant $t=2.56(26)$, $p=0.017$ with an effect size of $d=0.38$.

Data were collected at the end of Year 1 on participants' mathematics coaching practices (CPS). When considering the sum of the ratings (1 to 7) for each of the 20 items, a rating of 140 is the maximum (very descriptive of coaching practices) and a rating of 20 is the minimum (not at all descriptive of coaching practices). For these participants, the maximum observed rating was 119 points. Eight participants rated the CPS at 100 or higher, indicating that the majority of the items are descriptive of their practices. However, three participants had ratings at 52 or less and indicated that five or fewer of the items are descriptive of their coaching practices. The mean rating for the participants was 86.33, which is slightly toward the desirable range, indicating the CPS items are more descriptive of their mathematics coaching practices than not.

Additional examination of CPS data provides insights into participants' most and least frequently used mathematics coaching practices. The four lowest-rated items, which 26%-33% of participants indicated as descriptive of practices, are related to collaboration and communication with the principal or other school administrators about mathematics

Table 5 Most prevalent coaching practices on the CPS ($\geq 70\%$)

- | |
|--|
| 3. I coach teachers on needs that I observe in the teacher, even when the teacher is unaware of these needs |
| 5. I always make sure that coaching conversations with mathematics teachers are grounded in the mathematics content |
| 9. I try to provide the teachers I coach with an understanding of how the mathematics they teach supports learning beyond the grade level they teach |
| 11. I encourage the teachers I coach to reflect on similarities and differences among mathematics topics in the curriculum |
| 12. I help teachers plan their lessons |
| 16. I reflect on state assessment data to identify curriculum areas that need to be strengthened |
| 19. I encourage teachers to set personal improvement goals for mathematics |

coaching (e.g., discussing the school's vision for mathematics instruction, progress being made toward that vision, and teachers' needs; collaborating to ensure a clear message about effective mathematics instruction). Given that these data were collected at the end of Year 1 of the project and the participants were still developing in their informal teacher leader role, this pattern is not especially surprising. In contrast, the seven highest-rated items, which 70% or more of the participants indicated as descriptive of practices, largely focus on those designed to support teachers' content knowledge or pedagogical practice (see Table 5).

A Pearson correlation analysis was applied to the post-test mean scores on the CSI (coaching effectiveness beliefs) and CPS (coaching practices) and to the pre- and post-test mean scores on the MBI (pedagogical beliefs) and MTEBI (teaching efficacy beliefs). At the end of Year 1, there is a strong positive correlation between scores on the CSI and CPS ($r=0.65$, $p=0.000$). Those who held stronger beliefs in their effectiveness as coaches reported more use of the identified effective coaching practices. Data from the MBI and MTEBI pre-test administration are not correlated ($r=0.19$), but these data evidence a moderate positive relationship at the post-test administration ($r=0.44$, $p=0.022$). At the end of Year 1, those who held more cognitively-oriented pedagogical beliefs had stronger mathematics teaching efficacy, while this was not the case at the inception of the professional development project.

Qualitative findings

Analysis of the individual and focus group interview data illuminates a number of ways engagement in the project supported participants as emerging teacher leaders (RQ2, with the interview source and participant ID noted in parenthesis). These findings cluster around four themes: *growing confidence for the uncomfortable*, *creating and finding spaces for stepping up*, *advocating for learned mathematics pedagogy*, and *building teacher capacity through interactions*.

Providing insights into findings of the CSI, participants were experiencing a *growing confidence for the uncomfortable* in their teacher leadership. Some described a profound struggle related to this self-belief, with one sharing: "The only thing is that I'm always like, 'Do people really want to listen to me? I mean, do I have anything interesting to say?'... Maybe I don't like talking in front of adults" (Ind. Int., Part. 18). Another described this internal hurdle as: "I feel like it's not in my personality... Not that I don't like to lead... I don't always like to be any kind of center of attention" (Ind. Int., Part. 1).

Across participants, and especially for those who were less confident in their leadership capabilities, the mathematics content, pedagogy, and coaching strategies they were learning and trying out, as well as support provided via the project's elements, were bolstering their confidence. They were moving beyond their comfortable spaces focused on classroom teaching and shifting into new, unfamiliar spaces of teacher leadership, with one sharing:

Sometimes I'm in my little comfort zone and afraid to reach out and share my expertise and be that teacher leader. But, just the fact that we have to do those things and that there's help. There are different people in the program, who are also teachers and in other schools, and in similar schools. And, we just talk and share ideas in our PLCs, and just the fact that we have to do those things, I mean, get out there. So, it's helped me to really get out of my shell and kind of branch out and really step up to be that leader... I think it shaped my mindset and my confidence level. And, just to

have the knowledge backing with the courses that we've been taking, just all coupled together with putting myself out there. (Ind. Int., Part. 16)

Another described her increased willingness for discussion with others on her grade level team and leadership, linked to a new confidence. This self-belief had emboldened her to challenge the grade level mathematics assessments based on her new understandings about the capabilities of all children to engage in mathematical reasoning and problem solving:

I've talked to the other fourth grade teachers and just have the confidence now to say, "We need to look at this because this is not providing a great assessment"... I feel like [assessments] should allow for the students to go into that deeper thinking, and I think that's something where previously I might have thought that was just something for higher level students... We need to be challenging everyone. (Ind. Int., Part. 27)

Another described this shift in confidence, giving an example of providing feedback to those she already views as efficacious teachers: "It has definitely pushed me out of my comfort zone. I've always been like the helper, but it's been more like one-on-one or informal, or just kind of like on the down-low... [But now] having to observe a colleague, and having to deliver feedback to someone I admire and look up to, it just pushes me as a leader" (Foc. Grp., Part. 15).

A second theme, *creating and finding spaces for stepping up*, illuminates the ways in which participants made or took advantage of spaces for teacher leadership and how the project supported them in this process. Some noted that participation in the project compelled them to seek these responsibilities, which they would not normally do, and held them accountable. These navigations of creating and finding space were described by those who already held strong confidence in their leadership capabilities, as well as those who had lesser confidence. There was also variability in the degree to which the participants had historically taken on leadership responsibilities. One described the newness of creating and finding teacher leader spaces as: "I've had to just take the leader role, which I don't openly always do. So I've had to lead a STEM night... I'm not the one to say, 'Okay, let's do this.' And, like delegate and pick the direction of where this activity is going to go, but I've had to do that" (Ind. Int., Part. 16). Another described this new undertaking as: "I think this [project] has definitely given me the opportunity to explore that [leader] role more. It's things that I've wanted to do but didn't really have an excuse to just do it" (Foc. Grp., Part. 13).

Conceptualizing, planning, and implementing teacher leader activities through a formalized process, including submission of plans to the program director at the beginning of the school year, continuous revisiting during PLCs, ongoing individual mentoring, and completion of the TLR at the end of the school year, were meaningful for participants. One said:

I often have a lot of ideas but when you get into the school year, things start rolling. And, you don't really get to do what you set out to do at the beginning of the year. But this year, working with [program director] and having to write the plan, and revisiting the plan as many times as we did, and even talking to each other about what our goals were for our leadership, I think that plan and sticking to it has really helped me this year to improve on my leadership. Also, one of the components was we had to meet with our assistant principal or principal to go over our plan, and that was something new that I hadn't done before. I had plans, but I hadn't really sat down

and expressed what I wanted to do, how I could do it, and how the school could help me. And so, I think for me, that's been a major change this year. (Foc. Grp., Part. 8)

Another characterized this formalized process as providing incentive and supporting commitment. She shared:

I believe that writing a plan and making it plain [was important]. Those things that don't get written, don't get taken care of. So, having to do that created a different level of accountability. Where, it was like, you can't really drop the ball on this, because it's something that you've kind of put in the place. And it's going to be checked on at some point, so that was really nice to have in a way that perhaps I haven't had in the past. So, I will say that that even made me more motivated. (Foc. Grp., Part. 17)

A third theme, *advocating for learned mathematics pedagogy*, provides insights into the focus of their teacher leadership and how they were sharing the mathematics pedagogy learned through project experiences. They described sharing pedagogical aspects such as: (a) the CGI framework for problem types and solutions strategies, along with principles for instruction, (b) elements of effective instructional tasks, and (c) equity and access for all learners. They also elucidated a growing influence on others. Some described advocacy with fellow teachers, while others provided insights into opportunities with parents. When explaining her work with teachers, one said: "I am math content [lead] for my team... Especially with the [instructional] tasks, I did lead collaborative planning on coming up with performance tasks. And, I did put some of the things that I learned [in the project] into there. And then just always making sure that I advocate for students in our meetings" (Ind. Int., Part. 1). Another described her advocacy within a PLC and other professional learning she leads as, "The information that I've learned in [Number & Operations] class I've been able to push back out to the teachers," with plans for next year including: "My first semester of [professional development] will be on equity and mathematics. And my second semester PD will be on worthwhile tasks and CGI... The biggest pieces I want to do are equity, and going over those instructional practices I think will be very helpful. And, going over the different types of [CGI] strategies that kids use... Just exposing them [teachers] to those different [CGI] terms and things that they may not be familiar with" (Ind. Int., Part. 18). One described advocacy for her newly learned understandings with parents, particularly focusing on CGI:

I've taken on as one of my leader responsibilities teaching the parents how their children are learning. So, I've done a couple [CGI-focused] parent workshops, we're focusing on K-2. The first time I did it, I just did it and showed the parents with the tools. Then, the second time I did it, I had videotaped kids doing it, so they would see how the kids are reacting, and how they are using the different manipulatives, and how they are solving it and that it can be solved in multiple ways. So, I think if I hadn't [learned about CGI], knowing the different ways and what's the hardest problem to solve, which is that unknown beginning part, [I] wouldn't have known to do that, without taking this [Number & Operations] class. We're going to continue it on for next year, adding 3rd grade in as the parents, as the children, are going to the next grade. (Foc. Grp., Part. 3)

When describing their advocacy for learned pedagogy, they also expressed a growing influence on others, both in formal and informal ways, and being sought out by others for expertise. Said one:

Leadership activities I've had to do, people have shown real interest... a [school-wide] newsletter I've been sending with tips and things I learned from the math course. So, people are kind of curious, like, "What is the thing you're doing?" And, they're wanting to know, and they're seeing me as, even in my [grade level] team, they're seeing me as a math person. And, so they just ask me, "How do you teach this with your kids because my kids are not really getting that?" So, that impact is slowly spreading in my team and throughout the school." (Ind. Int., Part. 16)

Another talked about her advocacy and increasing influence, particularly in informal ways ("It's kind of by accident" Foc. Grp., Part. 11), as a push-in support teacher being noticed for what she is doing. She is implementing CGI in her small group instruction and her co-teachers are noticing the benefits for children and wanting to learn themselves. She describes their response as: "'Wait, you're doing something really cool, these kids could do that, and these kids could use that.' I'm like, 'Well, would you like to learn how to do it?' And, she's like... 'You have to teach me.' So, it's pretty cool to see the impact that we have, just when we're trying things out, and people are seeing it and liking it, and knowing that it's good for kids." (Foc. Grp., Part. 11).

A fourth theme, *building teacher capacity through interactions*, illuminates the ways in which participants were relating to other teachers, which aligned with the project's coaching emphasis, and included a shift for some of focus on "self" to "teacher as learner" and the development of interpersonal skills to support such an approach. There was a move from directive approaches to coaching (i.e., telling others what to do) to facilitative approaches to coaching (i.e., promoting self-analysis through active listening and questioning), while focusing on the strengths and needs of the teacher(s). In their descriptions, they alluded to various elements of the Cognitive Coaching Cycle as especially meaningful.

These coaching strategies were evident throughout the data as they described interactions with both practicing teachers at their schools and university teacher candidates, and within group and individual contexts. One described her shift in approach with a group of fellow teachers, aiming to build teacher capacity by centering on the teacher as learner, capitalizing on strengths, and employing facilitative strategies of active listening and questioning:

I think trying to focus more on collaborating and helping to build another teacher's capacity, instead of like: "This is how I do it, and this is how it should be done". So, just trying to build what they know about something because I do have some new teachers on our team. So, just trying to build off of their strengths more... So when we collaborate, I'm asking a lot more questions, and [giving] more feedback. Like, "What do you guys think?" I'm trying not to like steer too much because I want everyone else to have some feedback and to offer what they think, too. So that anything that we make, anything that we talked about, they can use in their classrooms, too. (Ind. Int., Part. 1)

She went on to describe similar strategies, such as asking probing and clarifying questions in a nonjudgmental way, while working one-on-one with a teacher candidate to promote the individual's thinking and reflection:

Coaching that student teacher, having to watch her videos [of her teaching]. And, giving that feedback, and asking her what she thought and what she wanted going in before the lesson with the pre-conference and in the post-conference. And, just trying to collaborate. Just kind of talk things through with her, and see what she was trying to get at versus, “Oh, this is what I would have done.” (Ind. Int., Part. 1)

This new way of supporting and interacting with teachers was embraced and appreciated by participants. For example, one connected it to her learning in the Teacher Leadership & Coaching course, and expressed her enthusiasm for building trust and developing open and collaborative relationships, and her anticipation for using strategies that are non-judgmental and focused on needs important to the mentee:

When we first started, we had an assignment where we had to observe our colleague, and we went through the coaching cycle... We learned that really a teacher or teacher candidate can decide what they want to improve on. And, it takes off a lot of the judgment and the stress and the pressure— having that conversation of we can improve on anything that you want to improve on in your math instruction in your classroom climate. When I went with that to my colleague, she didn’t feel pressured or judged, and she really let me in. I was able to tell her that she’s actually doing a lot better in the thing that she wanted to do better in, which was questioning, during the post-conference. It just brought it full circle, that I could do that with more than one teacher. Having those revelations and conversations with more than one teacher, that makes me excited for the teacher leadership part of this program (Foc. Grp., Part. 23).

Discussion

Increasing advocacy for EMSs has resulted in the creation of preparation programs that evidence significant variability in program features. Understanding differing program models and their effectiveness in supporting EMSs’ development as mathematics teachers and teacher leaders is essential in building research-based understandings of vital program elements. Our project provides an example of a preparation program guided by standards and research, with findings illuminating how the experiences supported participants’ development as EMSs in urban school contexts as well as confirming and extending the extant research literature. Notably, teacher leader development is especially under-studied (Reys et al., 2017; Yopp et al., 2019), yet this competency holds much importance for EMSs contributing to systemic changes in mathematics education. Findings from this study provide important information about EMS program improvement and replication that are essential in scaling-up the use of these professionals.

When collectively considering the quantitative and qualitative findings, the preparation and support provided through the project fostered the EMSs as teacher leaders. The interview and CPS data provide insights into participants’ growth and work as a *more knowledgeable other* for a community of practice within a school, with the interview data illuminating specific emphases of their efforts and influences of the project. They were emphasizing content and practices learned in their preparation experiences, particularly learner-centered, responsive, cognitively-demanding instruction, and equity and access for all learners (NCTM, 2014, 2020). They also focused on building teacher capacity through cognitive coaching and associated productive coaching activities such as centering on

teachers' concerns, teacher self-analysis, and developing trusting relationships (Edwards, 2021; McGatha, 2015, 2017). They especially appreciated the coaching emphasis of valuing teachers' professionalism, judgement, and decision-making. This stands in contrast to top-down teacher evaluation systems and activities in K-12 schools that are *for* teachers rather than *with* teachers, where teachers are not engaged in problems of practice centered on their needs and goals (Bradford & Braaten, 2018). Relatedly, a body of research shows the positive outcomes of the cognitive coaching approach for teachers and school climate (Edwards, 2021).

In the EMSs' coaching, data from the CPS illuminate variability in specific mathematics coaching practices, including those most participants were and were not using. Likely a function of the relative newness of their teacher leader role coupled with it being in an informal capacity at their schools, EMSs reported least descriptive practices related to communicating and collaborating with school administration. Although understandable as these data were collected at the end of the first year of the project, findings provide implications for project experiences and how this aspect could be improved, since the selection and implementation of teacher leader activities are to occur in consultation with school leadership. Given that the understanding and involvement of administration are essential factors in developing school capacity and sustainability of coaching and instructional reforms (Campbell & Griffin, 2017; Hopkins et al., 2017), additional attention on fostering and guiding the EMSs in navigating these professional relationships and on becoming more confident in their role as teacher leaders is important to their effectiveness as EMSs. Considering the timing of this study and that they were developing as EMSs, it will be interesting to see if these findings shift over the 5 years of the project.

Both the CSI and interview data show EMSs' strengthened beliefs in their effectiveness as mathematics coaches. Analysis of the CSI data evidences the largest increase in the sub-scale focused on the subject area of the professional development project: coaching related to mathematics content and mathematics-specific pedagogy. The interview data illuminate these shifts, in that while they were confident in their classroom teaching, they were less confident in their work as teacher leaders. This finding resonates with that of Chval and colleagues (2010) as their study participants were transitioning from experienced teacher to mathematics teacher leader/coach, similarly experiencing uncertainties in the new role. When considering changes in this study, some EMSs described their marked struggle with low confidence, project elements that were important contributors to shoring up this self-belief, such as knowledge backing and the community of practice with other EMSs, and examples of new ways of taking up teacher leadership in light of this new confidence. They described how the project's formalized process and supports for their teacher leader activities contributed to accountability and commitment in this work. Notably, the data provide insights into the profound challenges for some participants with low self-confidence as a teacher leader and the difficulty of change, which is an area needing more exploration over time, coupled with intentional focus on bolstering this self-belief during the project's learning experiences.

When considering the EMSs' beliefs about teaching and learning mathematics, the quantitative results show significant positive changes, including more cognitively-oriented beliefs about teaching and learning the subject and stronger beliefs in their mathematics teaching effectiveness. These findings resonate with and add to those in the extant literature related to shifts in participants' beliefs during EMS preparation programs (Campbell & Malkus, 2014; Kutaka et al., 2017). However, nuance and complexity are evident, for example when it comes to mathematics teaching efficacy. On the MTEBI, the PMTE scores were high for these participants at the pre- and post-test administration, indicating

that they held particularly strong beliefs in their personal capabilities to teach mathematics effectively. This finding is not especially surprising given their participation in the project and identification as successful, experienced teachers of mathematics. However, they were largely uncertain at both the pre- and post-test administration that this effective teaching of mathematics would influence student learning in positive ways (MTOE). With these participants being seasoned teachers, it is not surprising that they recognize the myriad and complex influences upon student learning. The current context of the COVID-19 pandemic and providing instruction to remote learners likely heightened this awareness, with studies showing that while mathematics achievement was lower for all students, Black and Hispanic elementary students in high-poverty schools were disproportionately impacted during this time (Dorn et al., 2021; Lewis et al., 2021).

When examining shifts in their pedagogical beliefs (MBI), the pre-mean scores show they were largely uncertain about cognitively-oriented pedagogy. Learner-centered, cognitively-based instruction differs from the ways in which many elementary mathematics classrooms function in the USA. Though progress has been made with reform efforts (NCTM, 2014, 2020), transmission-based instruction where it is the teacher's responsibility to impart mathematical information with students on the receiving end (Stipek et al., 2001) remains prevalent in mathematics classrooms. In fact, the mathematics instructional model for these participants' school district centers on gradual release, where teachers demonstrate and model procedures and strategies that students emulate and practice. This leans into transmission-based methods of teaching. Though the participants were skeptical at the inception of the project, the experiences provided across Year 1 contributed to significant positive changes in pedagogical beliefs, with the largest increase in mean score on the Learner subscale. During the Number & Operations course, the immersion in children's capabilities with respect to mathematical problem solving and reasoning via video, text, and work samples is a likely contributor, given that the Learner subscale centers on children constructing their own mathematical knowledge. When considering the EMSs' pedagogical beliefs, it is interesting to note that mathematics teaching efficacy was not related to these beliefs at the inception of the project; however, there was a positive correlation at the end of Year 1. As participants shifted toward embracing cognitively-oriented pedagogical beliefs, it appears they became more efficacious in this learner-centered pedagogy.

Finally, and significantly, it is important to note that this project intentionally supports EMSs who are from underrepresented populations and working in schools that serve students who have been historically marginalized and underserved in mathematics education. The school sites serve 91% students of color and selection criteria for the project ensured the EMSs are a diverse group, with 70% identifying as non-White. This is significant as increasing research shows students of color benefit from having teachers of color (Carver-Thomas, 2018; Egalite & Kisida, 2018; Yarnell & Bohrnstedt, 2018). Equity and access within mathematics education are through-threads of this project. Within this context, continued research across the 5 years of the project provides a unique and exciting opportunity to follow the trajectory of the EMSs in their development as agentic advocates for effective and equitable mathematics instruction.

Acknowledgements Support for this work was provided by the National Science Foundation's Robert Noyce Teacher Scholarship Program under Award No. 1950064. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

- Aguilar, E. (2020). *Coaching for equity: Conversations that change practice*. Jossey-Bass.
- Aguirre, J. M., Mayfield-Ingram, K., & Martin, D. B. (2013). *The impact of identity in K-8 mathematics: rethinking equity-based practices*. National Council of Teachers of Mathematics.
- Association of Mathematics Teacher Educators. (2013). *Standards for elementary mathematics specialists: a reference for teacher credentialing and degree programs*. Author.
- Association of Mathematics Teacher Educators. (2017). *Standards for preparing teachers of mathematics*. Retrieved from <https://amte.net/sites/default/files/SPTM.pdf>
- Association of Mathematics Teacher Educators. (2022). *The role of elementary mathematics specialists in the learning and teaching of mathematics*. Retrieved from https://amte.net/sites/amte.net/files/EMS_Pos_Statement_Final.pdf
- Baker, C. K., Saclarides, E. S., Harbour, K. E., Hjalmarson, M. A., Livers, S. D., & Edwards, K. C. (2022). Trends in mathematics specialist literature: Analyzing research spanning four decades. *School Science and Mathematics*, 122, 24–35. <https://doi.org/10.1111/ssm.12507>
- Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: what makes it special? *Journal of Teacher Education*, 59, 389–407.
- Bartell, T. G., Wager, A. A., Edwards, A. R., Battey, D., Foote, M. Q., & Spencer, J. A. (2017). Toward a framework for research linking equitable teaching with the Standards for Mathematical Practice. *Journal for Research in Mathematics Education*, 48, 7–21.
- Bradford, C., & Braaten, M. (2018). Teacher evaluation and the demoralization of teachers. *Teaching and Teacher Education*, 75, 49–59.
- Buehl, M. M., & Fives, H. (2009). Exploring teachers' beliefs about teaching knowledge: Where does it come from? Does it change? *Journal of Experimental Education*, 77, 367–407.
- Campbell, P., & Griffin, M. (2017). Reflections on the promise and complexity of mathematics coaching. *Journal of Mathematical Behavior*, 46, 163–176.
- Campbell, P., & Malkus, H. (2011). The impact of elementary mathematics coaches on student achievement. *Elementary School Journal*, 111(3), 430–454.
- Campbell, P., & Malkus, H. (2014). The mathematical knowledge and beliefs of elementary mathematics specialist-coaches. *ZDM Mathematics Education*, 46, 213–225.
- Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (2015). *Children's mathematics: Cognitively guided instruction* (2nd ed.). Heinemann.
- Carver-Thomas, D. (2018). *Diversifying the teaching profession: How to recruit and retain teachers of color*. Learning Policy Institute.
- Chval, K. B., Arbaugh, F., Lannin, J. K., van Garderen, D., Cummings, L., Estapa, A. T., & Huey, M. E. (2010). The transition from experienced teacher to mathematics coach: Establishing a new identity. *The Elementary School Journal*, 111(1), 191–216.
- Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 255–296). Macmillan.
- Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Sage Publications, Inc.
- Costa, A. L., & Garmston, R. J. (2016). *Cognitive coaching: Developing self-directed leaders and learners* (3rd ed.). Rowman & Littlefield Publishers.
- Dorn, E., Hancock, B., Sarakatsannis, J., & Viruleg, E. (2021). *Covid-19 and education: The lingering effects of unfinished learning*. Retrieved from <https://www.mckinsey.com/industries/education/our-insights/covid-19-and-education-the-lingering-effects-of-unfinished-learning>
- Edwards, J. (2021). *Cognitive coaching: A synthesis of the research* (15th ed.). Thinking Collaborative.
- Egalite, A. J., & Kisida, B. (2018). The effects of teacher match on students' academic perceptions and attitudes. *Educational Evaluation and Policy Analysis*, 40, 59–81.
- Elementary Mathematics Specialist & Teacher Leaders Project. (2022). Retrieved from <http://www.mathspecialists.org/state-certifications.html>
- Enochs, L., Smith, P., & Huinker, D. (2000). Establishing factorial validity of the mathematics teaching efficacy beliefs instrument. *School Science and Mathematics*, 100, 194–202.
- Gibbons, L. K., & Cobb, P. (2017). Focusing on teacher learning opportunities to identify potentially productive coaching activities. *Journal of Teacher Education*, 68(4), 411–425.
- Harbour, K. E., Adelson, J. L., Pittard, C. M., & Karp, K. S. (2018). Examining the relationships among mathematics coaches and specialists, student achievement, and disability status: A multilevel analysis using national assessment of educational progress data. *Elementary School Journal*, 118(4), 654–679.

- Harbour, K. E., & Saclarides, E. S. (2020). Math coaches, specialists, and student achievement: Learning from the data. *Phi Delta Kappan*, 102(3), 42–45.
- Harrington, R., Burton, L., & Beaver, C. (2017). Answering the call by developing an online elementary mathematics specialist program. *Journal of Mathematical Behavior*, 46, 303–312.
- Hjalmarson, M. A., & Baker, C. K. (2020). Mathematics specialists as the hidden players in professional development: Researchable questions and methodological considerations. *International Journal of Science and Mathematics Education*, 18, 51–66. <https://doi.org/10.1007/s10763-020-10077-7>
- Hopkins, M., Ozimek, D., & Sweet, T. M. (2017). Mathematics coaching and instructional reform: Individual and collective change. *Journal of Mathematical Behavior*, 46, 215–230.
- Jacobs, V. R., & Empson, S. B. (2016). Responding to children's mathematical thinking in the moment an emerging framework of teaching moves. *The International Journal on Mathematics Education*, 48(1), 185–197.
- Jacobson, E., & Kilpatrick, J. (2015). Understanding teacher affect, knowledge, and instruction over time: An agenda for research on productive disposition for teaching mathematics. *Journal of Mathematics Teacher Education*, 18, 401–406.
- Kutaka, T. S., Ren, L., Smith, W. M., Beattie, H. L., Edwards, C. P., Green, J. L., Chernyavskiy, P., Stroup, W., Heaton, R. M., & Lewis, W. J. (2018). Examining change in K-3 teachers' mathematical knowledge, attitudes, and beliefs: The case of Primarily Math. *Journal of Mathematics Teacher Education*, 21, 147–177.
- Kutaka, T., Smith, W., Albano, A., Edwards, C., Ren, L., Beattie, H., Lewis, W., Heaton, R., & Stroup, W. (2017). Connecting teacher professional development and student mathematics achievement: A 4-year study of an Elementary Mathematics Specialist program. *Journal of Teacher Education*, 68(2), 140–154.
- Lewis, K., Kuhfeld, M., Ruzek, E., & McEachin, A. (2021). *Learning during COVID-19: Reading and math achievement in the 2020–21 school year*. NWEA. Retrieved from <https://www.nwea.org/content/uploads/2021/07/Learning-during-COVID-19-Reading-and-math-achievement-in-the-2020-2021-school-year.research-brief.pdf>
- Maasepp, B., & Bobis, J. (2015). Prospective primary teachers' beliefs about mathematics. *Mathematics Teacher Education and Development*, 16, 89–107.
- McGatha, M. B., Davis, R., & Stokes, A. (2015). The impacts of mathematics coaching on teachers and students. In M. Fish (Ed.), *NCTM research briefs*. NCTM.
- McGatha, M. B. (2017). Elementary mathematics specialists: Ensuring the intersection of research and practice. In E. Galindo & J. Newton (Eds.). In *Proceedings of the 39th annual meeting of the North American chapter group for the psychology of mathematics Education*. Hoosier Association of Mathematics Teacher Educators.IN
- Meyers, H., & Harris, D. (2008). *Evaluation of the VMI through 2008*. Retrieved from http://www.uvm.edu/~vmi/index_files/2008%20VMI%20Evaluation.pdf.
- Mills, R., Bourke, T., & Siostrom, E. (2020). Complexity and contradiction: disciplinary expert teachers in primary science and mathematics education. *Teaching and Teacher Education*. <https://doi.org/10.1016/j.tate.2019.103010>
- Mudzimiri, R., Burroughs, E. A., Luebeck, J., Sutton, J., & Yopp, D. (2014). A look inside mathematics coaching: Roles, content, and dynamics. *Education Policy Analysis Archives*, 22(53), 53.
- Myers, K. D., Swars Auslander, S., Smith, S. Z., Smith, M. E., & Fuentes, D. S. (2020). Developing the pedagogical capabilities of Elementary Mathematics Specialists during a K-5 Mathematics Endorsement program. *Journal of Teacher Education*, 71, 261–274.
- Myers, K. D., Swars Auslander, S., Smith, S. Z., & Smith, M. E. (2021). Prospective Elementary Mathematics Specialists' developing instructional practices: Support and mentorship during an authentic residency. *Journal of Mathematics Teacher Education*, 24, 309–330.
- National Council of Teachers of Mathematics. (2014). *Principles to actions: ensuring mathematics success for all*. Author.
- National Council of Teachers of Mathematics. (2020). *Catalyzing change in early childhood and elementary mathematics: Initializing critical conversations*. Author.
- National Council of Teachers of Mathematics. (2021). *Continuing the journey: Mathematics learning 2021 and beyond*. Retrieved from https://www.nctm.org/uploadedFiles/Research_and_Advocacy/colle ctions/Continuing_the_Journey/NCTM_NCSM_Continuing_the_Journey_Report-Fnl2.pdf
- Nickerson, S. (2010). Preparing experienced elementary teachers as mathematics specialists. *Investigations in Mathematics Learning*, 2(2), 51–68.
- Orlando-Barak, L., & Wang, J. (2020). Teacher mentoring in service of preservice teachers' learning to teach: Conceptual bases, characteristics, and challenges for teacher education reform. *Journal of Teacher Education*, 72, 86–99.

- Peterson, P. L., Fennema, E., Carpenter, T. P., & Loef, M. (1989). Teachers' pedagogical content beliefs in mathematics. *Cognition and Instruction*, 6, 1–40.
- Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. K. Lester (Ed.), *Second handbook on mathematics teaching and learning* (pp. 1099–1109). Charlotte, NC: Information Age.
- Polly, D., McGee, J. R., Wang, C., Lambert, R. G., Pugalee, D. K., & Johnson, S. (2013). The association between teachers' beliefs, enacted practices, and student learning in mathematics. *The Mathematics Educator*, 22(2), 11–30.
- Reys, B., Webel, C., & de Araujo, Z. (2017). Elementary mathematics specialist preparation: What's next? What's needed? In M. McGatha & N. Riegelman (Eds.), *Elementary mathematics specialists* (pp. 221–234). Association of Mathematics Teacher Educators.
- Romberg, T., & Carpenter, T. (1986). Research on teaching and learning mathematics: Two disciplines of scientific inquiry. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 850–873). Macmillan.
- Schifter, D., Bastable, V., & Russell, S. J. (2018). *Examining features of shape*. National Council of Teachers of Mathematics.
- Schoenfeld, A. H. (2015). What counts, when? Reflection on beliefs, affect, attitude, orientations, habits of mind, grain size, time scale, context, theory, and method. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 395–404). Switzerland: Springer International.
- Skott, J. (2015). Towards a participatory approach to 'beliefs' in mathematics education. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 3–23). Switzerland: Springer International.
- Spangler, D. A., & Orvick, R. L. B. (2017). Models for mathematics specialist program development and delivery. In M. McGatha & N. Riegelman (Eds.), *Elementary mathematics specialists* (pp. 41–52). Association of Mathematics Teacher Educators.
- Stipek, D. J., Givvin, K. B., Salmon, J. M., & MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and Teacher Education*, 17(2), 213–226.
- Swars Auslander, S. (2016). Attending to elementary teachers' affect during university mathematics content courses. In L. C. Hart, S. Oesterle, S. Swars Auslander, & A. Kajander (Eds.), *The mathematics preparation of elementary teachers: Issues and strategies for content courses* (pp. 87–102). Information Age Publishing.
- Swars Auslander, S., Smith, S. Z., Smith, M. E., Carothers, J., & Myers, K. D. (2018). The preparation experiences of Elementary Mathematics Specialists: Examining influences on beliefs, content knowledge, and teaching practices. *Journal of Mathematics Teacher Education*, 21(2), 123–145.
- Swars Auslander, S., Smith, S. Z., & Smith, M. E. (2019). Preparing Elementary Mathematics Specialists: Aspirations for a university endorsement program. In N. P. Gallavan & L. G. Putney (Eds.), *ATE teacher education yearbook XXVI, building upon inspirations and aspirations with hope, courage, and strength* (v.2): *Tomorrow's leaders in classroom and schools* (pp. 223–240). Rowman & Littlefield.
- Swars Auslander, S., & Myers, K. D. (2022). Keep inquiring: A collective examination of Elementary Mathematics Specialist preparation. In T. Bourke, D. Henderson, R. Spooner-Lane, & S. White (Eds.), *Reconstructing the work of teacher educators: Speaking back to policy through agentic approaches* (pp. 51–69). Springer International.
- Tarr, J. E., Reys, R. E., Reys, B. J., Chavez, O., Shih, J., & Osterlind, S. J. (2008). The impact of middle-grades mathematics curricula and the classroom learning environment on student achievement. *Journal for Research in Mathematics Education*, 39, 247–280.
- Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 127–146). Macmillan Library Reference USA; Simon & Schuster and Prentice Hall International.
- Wilkins, J. L. M. (2008). The relationship among elementary teachers' content knowledge, attitudes, beliefs, and practices. *Journal of Mathematics Teacher Education*, 11, 139–164.
- Wilson, M., & Cooney, T. (2002). Mathematics teacher change and development: The role of beliefs. In G. Leder, E. Pehkonen, & G. Toerner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 127–148). Kluwer Academic Press.
- Yarnell, L. M., & Bohrnstedt, G. W. (2018). Student-teacher racial match and its association with black student achievement: An exploration using multilevel structural equation modeling. *American Educational Research Journal*, 55, 287–324.
- Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Sage.
- Yopp, D. A., Burroughs, E. A., Sutton, J. T., & Greenwood, M. C. (2019). Variations in coaching knowledge and practice that explain elementary and middle school mathematics teacher change. *Journal of Mathematics Teacher Education*, 22, 5–36.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.