

Experimental effects of a preschool STEM professional learning model on educators' attitudes, beliefs, confidence, and knowledge

High quality early science, technology, engineering, and math, or STEM experiences can lay a foundation for meaningful, lasting learning for young children (Early Childhood STEM Working Group, 2017; McClure et al., 2017). Although evidence suggests how important and powerful early STEM experiences can be for young children, many teachers have little access to STEM training, and find it challenging to incorporate STEM in their classrooms along with other priorities of early education (Brenneman, Stevenson-Boyd, & Frede, 2009; Clements & Sarama, 2014; Duschl, Schweingruber, & Shouse, 2007). To most effectively support children's learning, teachers need to be exposed to, and supported in, approaches to incorporate developmentally appropriate STEM experiences into their existing curricula in ways that can engage learners from varied linguistic and cultural backgrounds. Limited preparation, lack of exposure, or one's own negative educational experience can influence teachers' attitudes, beliefs, or confidence in teaching STEM subjects. These can, in turn impact the quality of the learning experiences offered to children and subsequently students' learning outcomes (Beilock, Gunderson, Ramirez, & Levine, 2010). This paper presents evidence from an experimental evaluation of the effectiveness of a professional learning (professional development) model, which was co-developed with educators and was designed to build preschool teachers' attitudes, beliefs, confidence, and knowledge, with the ultimate goal of improving STEM teaching practice that will lead to better educational experiences and outcomes for all young children. We use the term professional learning instead of professional development, as we intentionally approach the process as collaborative and recognizing of teachers' own expertise and agency, rather than our work as doing something to teachers (Darling-Hammond, 2017).

The Importance of STEM Education

STEM domains are connected to one another in unique ways that set them apart from other domains; we can use the term “integrated STEM education” for cases in which learning experiences intentionally integrate two or more areas (National Research Council, 2014). For example, engineers design and create new technology, using math and science knowledge and skills. We focused on science and math in our study. We provided teachers with information about engineering and technology within the context of science, and we discussed how to integrate learning experiences across STEM as well as with literacy. See more about definitions and relationships across STEM domains in the Framework for K-12 Science Education (National Research Council, 2012).

Each of the STEM disciplines consists of a rich and distinct content worthy of full attention in classrooms. Increasing attention has been paid to the value and importance of early STEM for young children’s long-lasting growth and development (Early Childhood STEM Working Group, 2017; McClure et al., 2017; Sarama et al., 2018). STEM activities lend themselves to high-quality teacher-child interactions such as open-ended questioning (Cabell, DeCoster, LoCasale-Crouch, Hamre, & Pianta, 2013; McClure et al., 2017). Math (Watts et al., 2014) and science particularly (Morgan et al., 2016) have been shown to be important predictors of later learning, and are increasingly linked to domain specific skills (such as verbal counting), and domain general skills (such as approaches to learning and executive functions: Author, 2013; Bustamante, White, & Greenfield, 2018; Grissmer et al., 2010; Watts et al., 2014). Evidence of the field’s increasing interest in STEM comes in part from the fact that in recent years, there have been efforts to incorporate more STEM content into early childhood programs. For example, in 2010, The Office of Head Start revised its learning standards to include science

knowledge and skills, which is defined by developing scientific skills and methods for inquiry as well as conceptual knowledge of science phenomena (Office of Head Start, 2010). A number of state early learning standards, such as Massachusetts (Massachusetts Department of Elementary and Secondary Education, 2019), incorporated science, engineering, and technology, in a way that parallels the national Next Generation Science Standards for K-12 (NGSS Lead States, 2013).

Teaching STEM in Early Childhood Classrooms

With the increasing presence of STEM in preschool standards and guidelines, it is important to consider how we teach STEM. Developmentally appropriate practice in early childhood generally is based in hands-on experiences and learning through play, and is responsive to children's identities, contexts, and cultures (NAEYC, 2020). Experts in early STEM education also recommend an active, experiential, inquiry-based learning approach to teaching STEM. In this approach, students develop math and science understanding through hands-on and minds-on problem solving, working collaboratively, and communicating their thinking, and this is recommended for children in early years of schooling and as they progress through the upper grades (NGSS Lead States, 2013; NRC, 2012, NSTA, 2014). This is a shift from the way that many of us remember math and science being taught in the United States, which used to place more of an emphasis on rote memorization (e.g., NGSS Lead States, 2013). As we learn more about the benefits of incorporating STEM into early education, it has become increasingly important to create learning environments that bring STEM into early childhood settings in ways that still adhere to the play-based, developmentally appropriate, and culturally-situated pedagogy.

In addition to building deeper and more lasting knowledge, teaching STEM in a more active way with hands-on, minds-on, inquiry-based experiences in science allows for access and inclusion of learners from a range of cultural, linguistic, and socio-economic backgrounds (Clements & Sarama, 2007; Donegan-Ritter, & Zan, 2017; Lee, 2002). Dual language learners (DLLs) making up the fastest growing student population in the U.S. (Banilower et al., 2013), and more young students speaking a language other than English at home (García & Frede, 2010; Friedman-Krauss et al., 2018; Matthews & Ewen, 2005). As such, it is critical that we consider all learners' needs in our increasingly diverse classrooms (Castro, Espinosa, & Páez, 2011) and develop teaching approaches that ensure that all children can engage in, and benefit from, the learning experiences in their classrooms. However, studies have found that educators with large populations of DLLs may not feel properly prepared to meet the needs of these students (Gándara, Maxwell-Jolly, & Driscoll, 2005).

Considering the concurrent needs to engage all children in developing scientific and mathematical thinking and understanding while properly serving children from varied backgrounds, “the integration of ‘discipline-specific’ and ‘diversity-oriented’ approaches to teaching and learning is essential to achieve the goal of science and math for all students” (Lee & Buxton, 2010). Studies with third and fourth grade DLLs found that participating in an inquiry-oriented science educational intervention improved children’s science outcomes in 4th grade (Lee et al., 2005); and recent work has endeavored to foster accessible preschool STEM experiences in informal learning spaces (Moore, Seilstad, Ridley, & Kim, 2019). This project focused on supporting best practice for supporting children in general, attending to accessible and inclusive instruction for children from linguistically, culturally, and socio-economically diverse backgrounds.

Attitudes, Beliefs, Confidence about STEM

The increasing demands on teachers to incorporate more STEM into early learning environments, while also accounting for the needs of children from culturally and linguistically diverse backgrounds pose new challenges. We need to attend to teachers' attitudes and beliefs towards STEM and working with DLLs because the attitudes and beliefs of an educator towards the subject taught influence what is taught and how it is taught (Pajares, 1992; Richardson, 1996; Wilkins, 2008). Some of the beliefs around STEM include that STEM is worthwhile, is important for learning and development, and is appropriate to teach in preschool. Attitudes around the feasibility of teaching STEM using inquiry-based learning are also critical for success. Teachers who have positive attitudes towards teaching STEM in preschool, such as that it is enjoyable, it is feasible in terms of cost, materials, and time, are more likely to incorporate STEM into instruction (Park, Dimitrov, Patterson, & Park, 2017). Teachers' confidence in their own abilities is also critical (e.g., Meier et al., 2013). This includes confidence in content knowledge, ability to teach about STEM (pedagogy), in planning appropriate math and science activities, and confidence in being well prepared to teach in a way that meets needs of DLL students. Confidence in teaching STEM influences teaching quality and teaching practice for early childhood and primary school educators (Gerde, Pierce, Lee, & Van Egeren, 2018; Platas, 2014a; Jamil, Linder, & Stegelman, 2018; Meier et al., 2013; Sarama & DiBiase, 2004)

STEM in early childhood is a more recent focus; research has shown that little time is spent preparing teachers to teach math and science at the early childhood level, or to understand the developmental trajectory of children's understanding of these subjects (Brenneman, Boyd, & Frede, 2009; Isenburg, 2000; Lobman, Ryan, & McLaughlin, 2005; NAEYC & NCTM, 2002; Ryan, Whitebook, & Cassidy, 2014). In addition, teachers may place a higher priority on literacy

or socio-emotional development and therefore report that time is a primary barrier to teaching STEM, and teachers may lack confidence in their own science and math ability, or find STEM hard to teach because they are more comfortable with literacy (Author, 2017; Cho, Kim & Choi, 2003; Gerde, Pierce, Lee, & Van Egeren, 2018; Ginsburg et al., 2008; Greenfield, et al., 2009; Platas, 2014a; Torquanti, Cutler, Gilkerson, & Sarver, 2013). Other studies report that teachers may conceptualize math as a static set of facts to be memorized, instead of an interactive, dynamic field of study (Sarama & DiBiase, 2004). A recent study found that at least for some preschool teachers these beliefs may be shifting (Pendergast, Lieberman-Betz, & Vail, 2017). The results suggested that educators increasingly understand the value of teaching science and are more comfortable teaching science, but they still express anxiety about their science knowledge and ability to scaffold children's scientific learning (Pendergast, Lieberman-Betz, & Vail, 2017).

Attitudes, Beliefs, Confidence About Teaching DLLs

Teachers' beliefs, attitudes, and confidence towards teaching linguistically diverse students may also influence teaching quality and affect the experiences of DLLs in school (Figueras-Daniel, 2016; Lee & Oxelson, 2006). Children's home language and cultural context can be a strength that can be nourished to build bilingualism as well as to effectively engage children in academic domains (Banse, 2019; Lee & Buxton, 2010; Schwartz, 2013).

Unfortunately, some teachers hold negative attitudes and have a deficit bias about children coming from families where English is not the home language (Mellom, Straubhaar, Balderas, Ariail, & Portes, 2018), which are in turn tied to their effectiveness in teaching these students (Pettit, 2011). Further, teachers' attitudes towards home language maintenance may impact

children's attitudes towards maintaining their home language (Lee & Oxelson, 2006). DLL children in classrooms in which teachers support children's home language tend to score better on measures of English and home language (Méndez, Crais, Castro, & Kainz, 2015).

As early childhood classrooms become more diverse, teachers need support in appropriately engaging DLLs. Despite this growing need, support for DLLs is often lacking in teacher preparation curricula, with one study of teaching preparation programs in the U.S. found working with bilingual children was the least likely subject to be covered as part of a practicum (Figueras-Daniel, 2016; Maxwell, Lim, & Early, 2006). Although many early childhood educators understand the importance of supporting children who come from non-English speaking homes, this view is not universal (Freedson, 2010). Some teachers may believe that teaching only in English is best for the dual language learners in their classrooms, even if they do speak the child's home language (Espinosa, 2010, Freedson, 2010, Garcia & Rodriguez, 2000). Many teachers do believe in the importance of supporting DLLs, but find that they are not properly trained and supported in integrating linguistically and culturally responsive pedagogy along with the already demanding loads of meeting children's academic, social, and emotional needs (Gandara, Maxwell-Jolly, & Driscoll, 2005; Ryan, Ackerman, & Song, 2005).

Content and pedagogical knowledge

Teachers' knowledge of content, pedagogy, and understanding of child development as it relates to children's STEM learning and of teaching DLLs impacts their efficacy in translating that knowledge to students. It is important to consider teachers' STEM content and pedagogical content knowledge, since teachers' knowledge of the subject is related to that of their students (Diamond, Maerten-Rivera, Rohrer, & Lee, 2014). Elementary teachers with higher levels of

science knowledge have students with higher science achievement (Diamond, Maerten-Rivera, Rohrer, & Lee, 2014; Heller, Daeler, Wong, Shinohara, & Miratrix, 2012). In mathematics too, the conceptual knowledge and instructional planning skills are shown to shape early childhood teachers' practices in teaching (Borko & Livingston, 1989; Lui & Bonner, 2016; Dunekacke, Jenßen, & Blömeke, 2015). Studies that focus on DLLs have found that students benefit when early childhood teachers know how to support their specific needs (Hendricks, 2014; Méndez, Crais, Castro, & Kains 2015; Zepeda, Castro, & Cronin 2011). Understanding of the stages and mechanisms of language development (Tabors, 2008), as well as the appropriate pedagogy for effectively drawing on children's existing linguistic and cultural capital to connect it to instructional content and providing proper accommodations when necessary (Shanahan & Beck, 2006), are crucial for effective instruction.

Teachers in early childhood – including those in preschool - report a lack of content and pedagogical knowledge needed to effectively implement early education programs in both mathematics (Anthony & Walshaw, 2007; Lui & Bonner, 2016) and science (Roehrig et al., 2011; Wilson, Taylor, Kowalski, & Carlson, 2010). Many early childhood teachers are also not professionally prepared to use effective strategies that invite DLLs to engage with academic content in meaningful ways (Administration for Children and Families and U.S. Department of Health and Human Services 2010; Doran, 2017; Zepeda, Castro, & Cronin, 2011). This is a particular challenge for young DLLs in STEM because they can fall behind in learning academic content related to STEM domains if they are not supported to use their home language as a tool to understand new constructs and terms that have special meaning in math or science, like *table* in math (Francis, Rivera, Lesaux, Kieffer, & Rivera, 2006). This can create a cycle that is hard to

break, insofar as DLLs can fall behind their peers as they get older in both their English language acquisition and in their learning of STEM content.

Professional learning as a solution

Given recent shifts towards STEM in early childhood classrooms and the growing diversity in the student body of early childhood classrooms, teachers need professional learning opportunities that provide guidance in how to support experiential, multimodal STEM teaching, and in strengths-based strategies to support DLLs. Teachers with more professional learning hours focused on science are more likely to enjoy science-related activities, feel comfortable planning and teaching science activities, and agree that science related activities benefit skills in other domains (Penderghast, Lieberman-Betz, & Vail, 2017). The mixed methods study by Jamil, Linder, and Stegeman (2018) suggest that teachers who received training in STEAM (with Arts added into the STEM acronym) demonstrated mixed levels of understanding of how to implement STEM and how to align active STEM experiences with standards. Interventions that integrate the teaching of science with the teaching of language development for English Language Learners (ELLs) have had positive impacts on elementary teachers' science knowledge and instructional practices (Bravo, Mosqueda, Solis, & Stoddard, 2014; Lee & Maerten-Rivera, 2012; Lee, Llosa, Haas, O'Connor, & Van Booven, 2016). These findings hold promise for similar results in preschool.

We need professional learning to support educators to engage all preschoolers, including those from diverse backgrounds in STEM experiences. Preschool professional learning programs focused on science (Gropen, Kook, Hoisington, & Clark-Chiarelli, 2017) or on math and science (Whittaker, Kinzie, Williford, & DeCoster, 2016) that have found positive impacts on teachers,

tend to be tied to a particular curriculum. Although this can be a powerful way to deliver professional learning supports, there is also a need for professional learning that is not tied to a curriculum. This is because a center's or district's chosen curriculum can and does change. Our approach is to provide strategies for teaching STEM that can be used with almost any curriculum, which we term "curriculum-agnostic." There are programs to improve early childhood STEM teaching (Jamil, Linder & Stegelman, 2018; Whittaker, Kinzie, Williford, & DeCoster, 2016) and those that focus on DLLs (Buysse, Castro, & Peisner-Feinberg, 2010; Gardner-Neblett, Franco, Mincemoyer, & Morgan-Lopez, 2020), but we could not find any that address issues for early childhood educators focused on STEM, that are curriculum-agnostic, and that also provide supports for DLLs. This paper reports on our approach, which was meant to address all of these needs.

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Our Professional Learning Approach

Our curriculum-agnostic professional learning model, SciMath-DLL, was co-developed with educators in line with best practice in professional learning (Author, 2018). Our evidence-based model supported teachers working in diverse classrooms by engaging with interactive, hands-on learning opportunities in workshops tied to classroom practice (National Research Council, 2000; Tout, Zaslow & Berry 2006), individual coaching (Costa & Garmston 2002; Kraft, Blazar, & Hogan, 2018; Riley-Ayers & Frede 2009), and professional communities of practice (Ball & Cohen, 1999; Easton, 2002; Kiggins, 2016; Vescio, Ross, & Adams, 2008). The goals of the program were to improve attitudes, beliefs, and confidence, increase knowledge directly and indirectly, and to improve the quality of STEM teaching.

Our logic model is shown in Figure 1. We believe that in order to impact teaching practice, teachers first need the following: to build confidence in their knowledge and ability to teach the material, to build content and pedagogical content knowledge, to believe that STEM is important and appropriate for preschool, and to know about best practice in supporting DLLs, such as the importance of supporting home language (Banse, 2019). Our logic model shows the model's inputs and shows that we must address these factors first, with the goal of influencing teaching practice in the intermediate term, and ultimately student outcomes in the longer term. Following this logic, this paper focuses on the effects of participation on educators' attitudes, beliefs, confidence, and knowledge. The logic model is represented in Figure 1.

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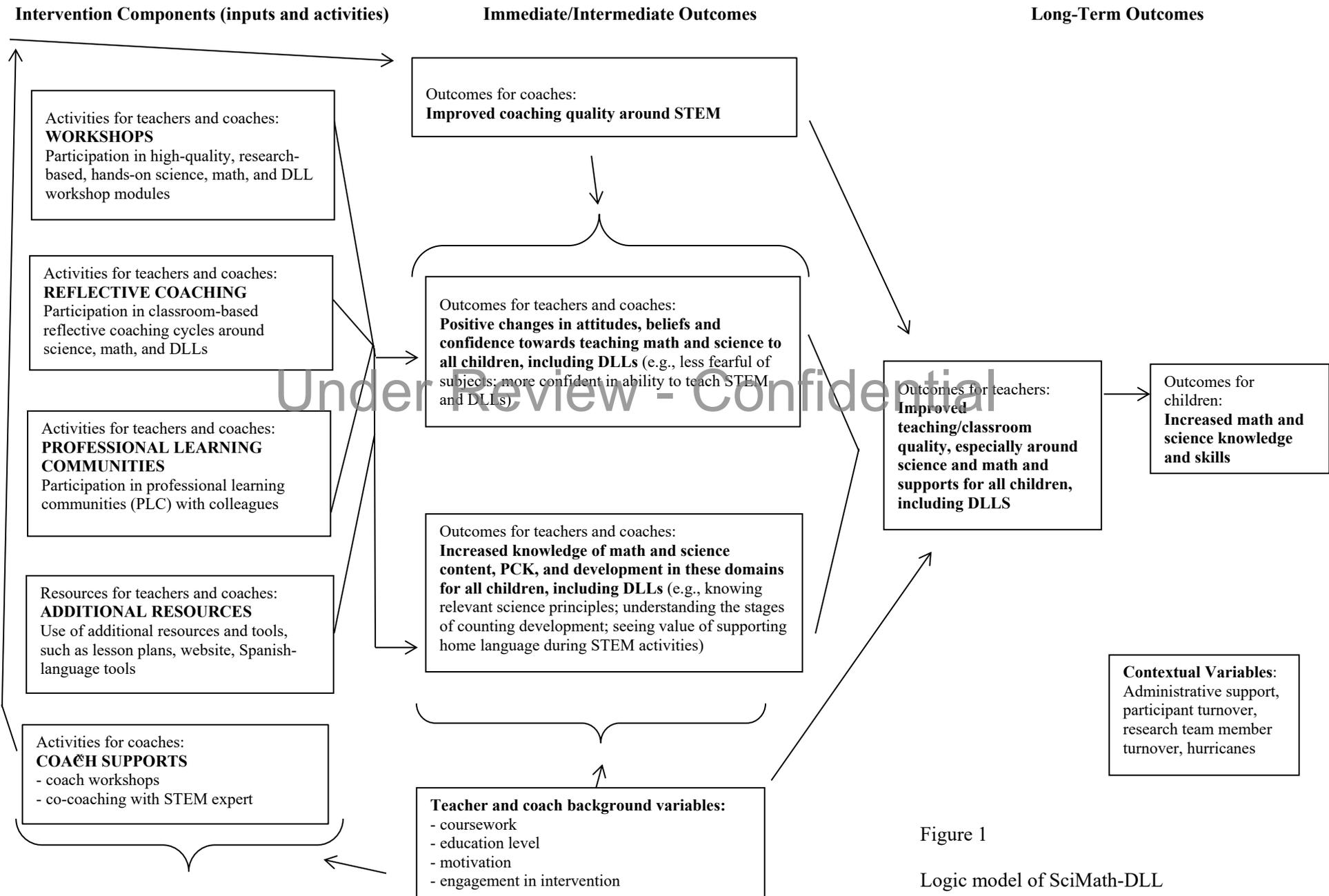


Figure 1

Logic model of SciMath-DLL

Research Questions

1. What are preschool teachers' attitudes, beliefs, confidence, and knowledge of STEM and teaching DLLs prior to intervention?
2. What are the effects of participation in this professional learning experience on attitudes, beliefs, confidence, and knowledge about STEM and teaching DLLs?

Materials and Methods

We used a randomized trial experimental design to evaluate the impacts of the professional learning model on teachers' attitudes, beliefs, confidence, and knowledge. Classrooms were randomly assigned to treatment or control conditions within centers.

Participants Under Review - Confidential

The study was conducted in an urban public-school district in the northeast United States with a predominantly Hispanic population (71%), approximately 89% of preschoolers eligible for free- or reduced-school lunch, and 133 full day mixed age group (3- and 4-year-old) preschool classrooms that use the High Scope curriculum. Fifty female preschool lead teachers who volunteered to participate in the study were randomly assigned to the treatment or control condition. All classrooms of participating teachers were located at 8 different centers affiliated with the public school district (5 elementary schools, 3 community providers).

Two treatment teachers left the study; one voluntarily, and one due to reassignments, resulting in an attrition of 8% of treatment group. One teacher in the control group did not complete the post-intervention surveys for unknown reasons (4% attrition), which was an overall sample attrition level of 6%. The teachers who left the sample did not significantly differ on any

outcomes from those in the analysis sample. The final sample included 23 treatment and 24 control teachers. Table 1 shows the demographic characteristics of teachers in each group. All teachers were certified public school teachers in the state, with a minimum of a Bachelor's degree. Fifty-one percent of teachers had a Master's degree and 56% had more than ten years of teaching experience. The majority (67%) of teachers were bilingual (primarily Spanish).

All analyses were run with the final analysis sample: 23 treatment and 24 control. The treatment and control group teachers were equivalent on pre-intervention measures, except for the child benefit subscale of the P-TABS (Maier, Greenfield, & Bulotsky-Shearer, 2013) science attitudes and beliefs instrument: treatment mean = 4.8 (.26); control group mean = 4.5 (.52), indicating that the treatment group had slightly higher agreement with statements about the benefits of early science for preschool children at pre-intervention. Pre-intervention scores on all available tools were included in the models to account for any group differences prior to intervention.

Professional Learning Model

A total of 64 hours of professional learning were offered over two years to the treatment teachers (48 workshop hours, 8 individual coaching hours and 8 professional learning community [PLC] hours). These hours were in addition to the regular professional learning received by all teachers in the district, none of which focused on STEM. The mean number of hours of professional learning for treatment teachers was 56 (7.5), with a range of 36 - 64. The majority of the lower dosage numbers were due to four teachers being out on maternity leave.

The professional learning model was created to reflect topics and practices most pertinent to early childhood science and math education, based on existing research and standards for

those early years (Greenfield et al. 2009; National Research Council 2012; NCTM 2006; NRC 2006). The professional learning included 3 components: in-person, interactive workshops, individual reflective coaching sessions, and professional learning communities. STEM topics were introduced in four full-day workshops, consisting of two half-day modules, during each year. A list of modules is included in Appendix A. Each module included an overview of the research related to each focal topic as well as relevant content knowledge, and concrete implementation strategies. During the workshops, participants rotated through a set of small group learning experiences, with the guidance of a STEM specialist (SciMath-DLL project personnel). These were concrete ways to explore the topic covered, along with discussion of how to implement the activities in the classroom. The activities were intentionally designed to use materials already present in a preschool classroom, easily found at home, or inexpensively purchased. Teachers received annotated activity plans for the small group learning experiences, which provided detailed suggestions for questioning, information about differentiation, and supports for DLLs (See Appendix B). Note that these intentionally included suggestions about language, questioning, and setup. They were NOT, however, intended to be delivered verbatim. Rather, we encouraged teachers to leave room for inquiry and students' ideas, and for teachers to make the activities their own, while maintaining the learning objectives. At the conclusion of each workshop, we assigned teachers one of the small group activities to be the focus for the individual reflective coaching.

Teachers then planned a teaching experience in the month following the workshop that engaged their students in the assigned small group learning experience. A district master teacher along with a STEM coach from the SciMath-DLL project observed, videotaped, and then met with the teacher to reflect on this activity as part of a reflective coaching cycle. District coaches

and STEM experts co-coached in order to support professional learning and particularly early STEM knowledge of the coaches, as well as to build capacity within the district. In a reflective coaching cycle, teachers receive feedback on practice, and plan a revised activity for the future. After all teachers had their individual coaching sessions, they attended a professional learning community meeting, typically including 6-8 teachers from the same center or from centers that were located nearby. One teacher led the PLC by sharing her experience in implementing the small group experience for that cycle. Peers provided input and feedback following a set protocol (Easton, 2002) and shared their experiences. There were 8 total workshops, reflective coaching cycles, and PLCs held over the course of the 2-year intervention (4 each per school year). Further detail about the content, approach, and model can be found in Author (2018).

Each professional learning component included specific methods and strategies for addressing the immediate target outcomes related to attitudes, beliefs, confidence, and knowledge. For example, during workshops, we pointed out ways in which educators might already be doing science without realizing it, and we reflected together about confidence regarding math and science skills and knowledge. We also shared research showing the benefits and strategies of incorporating a young DLLs' home language into instruction and leveraging it as a strength (Castro, Paez, Dickinson and Frede 2011; Cheatham, Jimenez-Silva and Park 2015; Tabors 2008). Teachers gained experience building knowledge of pedagogy, and confidence as they brought the STEM to life in their own practice, while they got feedback from peers, their district coach, and a STEM expert during coaching cycles and professional learning communities.

Measures

Educator attitudes and beliefs surveys. Educator attitudes and beliefs surveys were collected for all teachers and master teachers who participated in the study using four instruments before and after the intervention. The four educator surveys were:

Mathematical Development Beliefs Survey (MDBS). The Mathematical Development Beliefs Survey (MDBS; Platas, 2014a) examined teacher beliefs and attitudes towards teaching math in preschool. The MDBS involves a six-point Likert scale survey format (item scores ranging from 1-6), consisting of 40 statements that are designed to measure beliefs related to four subscales concerning: (a) age-appropriateness of mathematics instruction, (b) classroom locus of the generation of mathematical knowledge (i.e. teacher vs child), (c) socio-emotional versus academic (specifically mathematics) development as primary goals of preschool education, and (d) teacher confidence in mathematics instruction. Each subscale and the total score are coded as a mean between 1-6. Evidence of reliability and validity was collected by the author, such as a Chronbach's alpha of .84 or higher for the reliability of the dimensions, and multiple stages of development and revision, factor analysis, and concurrent validity (Platas, 2014a).

Preschool Teacher Attitudes and Beliefs Survey (P-TABS). The Preschool Teacher Attitudes and Beliefs survey (P-TABS; Maier, Greenfield, & Bulotsky-Shearer, 2013) measured preschool educators' attitudes and beliefs about science. The instrument was used to evaluate the ideas teachers have about science teaching and to assess the effects of our professional learning on these ideas. P-TABS includes 35 items, both positively and negatively worded, rated on a five-point Likert scale ranging from "strongly disagree" to "strongly agree". Items were designed to address several aspects of teachers' attitudes and beliefs toward science teaching: confidence, cognitive aspects, affective aspects, behavioral aspects, and contextual aspects. The 35 items fell

into three subscales: “Teacher Comfort” consists of 14 items measuring teachers’ comfort with planning and demonstrating different science activities; “Child Benefit” includes 10 items assessing teachers’ attitudes and beliefs toward how preschool science fosters children’s interest in science and improves their school readiness skills; “Challenges” consists of seven items reflecting teachers’ negative attitudes and beliefs toward teaching science. Strong evidence for reliability and validity of the measure has been established with excellent overall internal consistency (Cronbach’s alpha = .91) and evidence of concurrent and predictive validity, including a Confirmatory Factor Analysis which confirmed three-factor structure identified by an Exploratory Factor Analysis (Maier et al., 2013).

Educator Questionnaire on Dual Language Learners (DLLs)/English Language Learners (ELLs) The Educator Questionnaire on Dual Language Learners (DLLs)/English Language Learners (Cuellar-Klitzke, 2009) was developed to assess preschool teacher attitudes and beliefs around home language (in particular, Spanish) practices in school and at home. The self-administered questionnaire includes 16 items that are scored on a 5-point Likert scale where a score of 1 on an item indicates strong disagreement and 5 indicates strong agreement. Questions on fall into one of two subscales; 1) the use of Spanish for instruction in the classroom; and 2) the idea that home language maintenance is important for children’s learning. A subscale extraction was conducted through a maximum likelihood analysis, which confirmed the two subscales above (Figueras-Daniel, 2016).

Knowledge of STEM content and pedagogy. Teachers’ content knowledge, and knowledge of teaching practices related to teaching STEM, and teaching DLLs were assessed using the two measures as described below. The Knowledge of Math Development (KMD) instrument was given before and after the intervention, while the SciMath-dll Instrument for

teacher Learning (SMILE) was given after the intervention for both groups, and before and after each workshop for the treatment group only.

Knowledge of Math Development (KMD). This instrument consists of 20 items that address six content knowledge categories within numbers and operations: verbal counting sequence; counting/numerosity; ordinal number words describing position; addition and subtraction; division of sets (fair/equal sharing); written number symbols/word recognition and production. For each item on the KMD Survey, respondents indicated whether Task #1 or Task #2 represented the easier of the two mathematical tasks for young children or marked “Same” or “Do not know.” Each item is scored as 1 point for correct or 0 points for incorrect or “Do not know.” The total raw correct is the total score. Platas (2014b) found examination of reliability showed adequate internal consistency with a Cronbach’s alpha of .81, and evidence of content and concurrent validity.

SciMath-DLL instrument for teacher learning (SMILE). As part of the project, the SciMath-dll Instrument for teacher Learning (SMILE) assessment tool was developed to measure teacher’s knowledge of key content and concepts covered in each workshop (Author, 2016). Items relevant to each workshop were modeled after the format of a common licensure test, with items intended to assess participants’ understanding of content, developmental learning trajectory of the concepts covered, and application of the content and developmental trajectory to classroom practice. SMILE items were based on workshop content, which was derived from pre-K state and national standards and the latest research, supporting content validity (e.g., NCTM; NGSS). As an example, one item was, “An activity in which children suck water through a straw gives children real-life experience of which property of water? a. Water will change direction if acted on by a force; b. Whether an object sinks depends on its density; c. Water takes the same

shape as its container; d. Water sticks to itself and other objects; e. Water fills the shape of its container.”

Teachers answered 5 SMILE items relevant to each workshop right before (pretest), and then right after (posttest) each of the 15 half-day module workshops (excluding the Intro to STEM module). At the end of the study, two items per module were taken to create a 30-item final SMILE assessment. The 30 item SMILE instrument was given to both treatment and control groups at the end of the 2-year intervention. Evidence of concurrent validity for the SMILE was found as the posttest scores were correlated with the KMD posttest scores (Platas, 2014b), a validated measure of teacher knowledge (math), $r = .54$. Internal consistency ($\alpha = .79$), inter-item correlation ($r = .41$), and pre- to post-workshop correlations ($r = .70$) provide reliability evidence for the SMILE

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Procedure

Attitude and beliefs surveys for science (P-TABS), math (MDBS), and DLLs (DLL survey) and measures of knowledge of math development (KMD) for treatment and control (50 teachers) were administered pre-intervention in fall of 2015 and post-intervention (47 teachers) in spring of 2017. The SMILE measure was administered pre- and post-workshop for treatment teachers and post-intervention.

To assess teachers' learning directly before and after each professional learning module, teachers completed the SMILE questionnaire pertaining to the specific concepts covered before and after each workshop module. Fifteen pairs of pre and post SMILE tests were collected for the treatment teachers over the course of two years. To assess the knowledge retainment of the

treatment teachers, and to compare it with the control teachers, a cumulative posttest was administered in the spring of 2017 to all 47 teachers.

Analysis plan

Data from educator surveys were analyzed using descriptive statistics to answer research question one (RQ1). We used an OLS regression with treatment group and teacher education level (MA=1; lower than MA=0) as predictors, and survey subscale and total scores at the pretest as covariates, and at the posttest as outcomes for research question two (RQ2). We used this analysis approach in order to account for more variance in outcomes, that is, to increase the precision of our estimates. Due to the limited sample size, we could not include additional predictors. Effect sizes were calculated using Cohen's f^2 . Cohen's (1988) guidelines suggest the following values for this coefficient that correspond (generally speaking) with small, medium, and large effect sizes, respectively: $f^2 \geq 0.02$, $f^2 \geq 0.15$, and $f^2 \geq 0.35$. Paired samples t-tests were used to evaluate changes in the SMILE from before to after the workshops for the treatment group only. Pearson product moment correlations were used to evaluate the relation between dosage (number of hours of participation) and the posttest outcomes. Descriptive results are displayed in Table 2.

Results

RQ1: What are preschool teachers' attitudes, beliefs, and knowledge of STEM and DLLs prior to intervention?

We examined attitudes and beliefs of educators towards, and knowledge of STEM and teaching DLLs prior to the professional learning project. These data served as pre-intervention measures in the randomized control trial to assess effects of the professional learning model.

Pre-intervention Teacher Attitudes and Beliefs.

Preschool teachers' average overall score on the math attitudes and beliefs survey, the MDDBS (Platas, 2014a) prior to intervention was 4.8 out of 6 (.37). Total scores ranged from 3.9 – 5.3. This corresponds roughly to a rating of “Agree” on the Likert scale with positive statements about teachers' self-perceptions, such as their confidence in their math teaching ability. The mean ratings for teacher comfort of 5.4 (.58), beliefs about the age appropriateness of math for preschoolers of 5.5 (.48), and math as primary developmental goal of 5.4 (.52) were relatively positive. The mean for the locus of generation of math knowledge, as child versus teacher were lower, with a mean of 3.4 (.63). These numbers are similar to those reported by Platas (2014a), in which preservice teachers' with two or more years of experience, enrollment in a Master's course, and exposure to an early math development course ratings were 5.2 (teacher comfort), 5.6 (appropriateness), 5.2 (math as primary goal), and 2.75 (locus).

Similarly, teachers scored on the positive end of the scale for the science attitudes and beliefs, P-TABS (Maier, Greenfield, & Bulotsky-Shearer, 2013). Prior to intervention, teachers scored an average of 4.3 out of 5 (.43) on the overall assessment, with a range of means scores between 2.3-4.89. This corresponds to roughly “Agree” on the Likert scale with statements about teachers' perceptions. The average score on the Teacher Comfort factor was 4.42, with a range of means between 4.04 and 4.85. The average score on the Child Benefit factor was 4.66, with a range of means between 4.36 and 4.89. The average score on the Challenges factor was

3.42, with a range of means between 2.3 and 4.1. about teaching science. These findings reveal beliefs and attitudes that are more positive than those reported by Maier et al (2013), in which 507 teachers' P-TABS results found a range of means between 3.86 and 4.62 on the Teacher Comfort factor ($M = 4.35$), 3.54 and 4.87 on the Child Benefit factor, and 1.79 and 2.93 on the Challenges factor ($M = 2.43$), which were not reverse-coded as they were in our study. In that study, 51% of teachers completed a CDA (Child Development Associate) or other associate's degree, 38% a bachelor's degree, and 10% a master's or doctoral degree. Given the findings that teachers' education level is associated with their beliefs and attitudes (Platas, 2014a), the fact that all teachers in our sample held at least a bachelor's degree and 51% held a master's, as well as the growing focus on STEM education even in the last few years, may account for some of the differences.

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Teachers' views of teaching DLLs were also positive, but more mixed. Subscale 1 (use of home language in instruction) was 4.3 (.45), and subscale 2 (value of supporting home language) was 3.9 (.66), both out of 5, corresponding to a rating of slightly above and slightly below a rating of "Agree". These were similar to results reported elsewhere, at 4.0-4.2 and 3.9-4.1, respectively (Figueras-Daniel, 2017).

Teacher Knowledge.

At pre-intervention, teachers scored 13.88 (3.85) on the KMD instrument (Platas, 2014b), or 69.4% correct. The findings align with previous findings with teacher cohorts with comparable education and years of teaching experience (Platas, 2014b). On the SMILE, teachers (treatment group only) scored an average of 53.4% on the pretest questions given prior to each workshop. The SMILE was developed as part of this project to assess the content of the

SciMath-DLL workshops and therefore no comparison cohorts exist. The scores reveal that the content covered was not overly familiar to the teachers and supported the need for this training.

RQ2: What are the effects of professional learning on attitudes, beliefs, and knowledge about STEM with DLLs?

Attitudes and Beliefs about Math

Regression model estimates of teachers' math attitudes and beliefs on the MDBS instrument (Platas 2014a) revealed that teachers who participated in the professional learning project (treatment group) scored higher than control group teachers at the end of the intervention for the confidence teaching math, $b = .35, p < .05$, belief in appropriateness of teaching math in preschool subscales, $b = .25, p < .01$, and on the overall measure, $b = .16, p = .01$, (see Table 3). Mean gain from the beginning to the end of the intervention in the treatment group teachers' confidence and comfort with teaching math scores was 0.4 (0.61) compared to control group teachers' gain of 0.02 (0.49). Treatment teachers' gain in their belief that math is appropriate and beneficial for preschoolers scores was 0.3 (.50) compared to the control group teachers gain scores of .004 (0.40), and treatment teachers' overall total gain score at post-intervention was 0.2 (.37) compared to the control group, at 0.08 (.30). The possible scores ranged from 1-6.

Attitudes and Beliefs about Science

Regression model estimates revealed that treatment teachers showed a significantly higher score on post-intervention science teaching attitudes and beliefs across all 3 subscales and in the total score. Compared to control group teachers, treatment teachers had higher confidence and comfort with teaching science ($b = .35, p < .01$), lower agreement that teaching science is challenging (reverse coded), $b = .99, p < .001$, stronger beliefs that science is appropriate and

beneficial for preschoolers, $b = .21$, $p < .001$, and higher scores on the overall instrument, $b = .45$, $p < .001$ (see Table 4). Mean gain from the beginning to the end of the intervention in the treatment group teachers' confidence and comfort with teaching science scores was 0.3 (0.46) compared to control group teachers' gain of -0.02 (0.46). Treatment teachers' gain in their belief that science is beneficial for preschoolers scores was 0.1 (0.32) compared to the control group teachers gain scores of 0.1 (0.58). Treatment teachers increase in scores from pre- to post-intervention on their view of science as challenging to teach (reverse scored) was 0.7 (0.96), compared to control teachers' gain scores of 0.1 (0.92), and on treatment teachers' overall total score at post-intervention was 0.2 (.37) compared to the control group, at 0.07 (.50).

Attitudes and Beliefs about Teaching DLLs

The regression analysis revealed a significant effect of the intervention in favor of treatment teachers on both subscales of the DLL survey – use of Spanish for instruction, $b = 0.30$; $p < .01$, and the value of home language maintenance, $b = 0.42$, $p < .05$ – as well as on the total scale, $b = 0.37$; $p < .05$ (see Table 5). Treatment teachers' total scores increased from 4.2 (.34) to 4.4 (.33), while control group teachers' scores on the measure decreased from 4.1 (.48) to 4.0 (.46) from pre-to post-intervention.

Knowledge

Treatment teachers' knowledge of content and pedagogy as measured by the SMILE immediately before and after each workshop on related content, increased significantly from 53% (16.0) before the workshops, to 74% (11.8) right after the workshops, $t(22) = 9.52$, $p < .01$. Teachers in both groups were administered the full, 30-item SMILE assessment at the end of the intervention. The OLS regression analysis that examined effects of treatment on STEM content

and pedagogical knowledge, with pretest KMD scores as a covariate and teachers' education level included in the model revealed a significant treatment effect in favor of the treatment group, $b = 11.6$ (3.59), $p = .01$. Teachers in the control group scored 54% (14.5) compared to an average of 65% (15.6) for the treatment group at the end of the intervention.

While treatment groups' performance at 65% correct is a decrease from their average score directly after the workshops, this score is a significant increase from the pre-workshop scores, indicating a degree of long term retention of STEM knowledge as a result of participation in the program, $t(22) = 6.25$, $p < .01$. There was no significant group difference on the measure of knowledge of math development (KMD). However, the treatment group's score increased from pre- to posttest (mean gain score of .39) while the control group's score decreased from pre-to posttest (mean gain score of -1.38), which would be an effect size of $d = .45$.

Dosage

The dosage of the intervention for the treatment group was measured in hours of STEM professional learning received. Each workshop was 6 hours (3 hours per half-day module, 2 per workshop day), reflective coaching was 1 hour (on average), and PLCs were 1 hour (on average) in duration. The mean hours were 56 (7.6). Dosage was correlated positively SMILE ($r = 0.5$). In other words, teachers who participated in more total hours of professional learning tended to have higher scores at the end of the intervention period on the test of content covered in the training. Dosage was not correlated with other outcomes.

Discussion

The SciMath-DLL project aimed to improve STEM teaching in preschool classrooms by creating a multi-pronged, high-quality, research-based professional learning model that delivers content knowledge, addresses teachers' attitudes and beliefs towards math and science, and highlights evidence-based practices for teaching DLLs and all children. This paper adds to and expands the body of research around preschool teachers' beliefs and attitudes towards teaching math and science, and provides evidence of an effective approach to professional learning aimed at supporting early educators in STEM instruction in their classrooms that serve culturally and linguistically diverse students and those from low socio-economic backgrounds.

Improved Attitudes, Beliefs, Confidence

The findings of the pretest analyses add to recent findings that early childhood teachers may be becoming more open to, and confident in, teaching STEM in their classrooms (Pendergast, Lieberman-Betz, & Vail, 2017). Even before the intervention, most teachers' attitudes, beliefs, and confidence started out relatively high in favor of teaching science and math and working with DLLs. Most teachers across study groups agreed or strongly agreed with positive statements about math, science, and DLLs, such as related to their confidence in teaching math or their beliefs that preschoolers could learn science. This finding may be related to the fact that teachers in this sample were highly educated, with all teachers having a BA and about 50% having a Master's degree; a finding that builds evidence that teachers with more experience and higher education levels report more positive attitudes, beliefs, and confidence (Platas, 2014a). This parallels the Pendergast et al. study related to science, in which 32% of the teachers had a Master's degree, and about 63% had a BA. That said, there was still a range in

ratings across teachers in the present study, with some teachers' ratings closer to "disagree" than "agree." These findings are encouraging given the importance of positive beliefs and attitudes for teachers to engage in high quality instruction and to effectively support students from all backgrounds. It is important to note that teachers may vary in the degree to which their beliefs and attitudes translate into practice. Future analyses will examine effects on teacher practice.

Given the relatively high starting point, it is notable that teachers in the treatment group showed significantly improved attitudes on most subscales compared to the control group. The effect sizes were quite large in some cases (e.g., $d = 1.47$ for the degree to which teachers perceived challenges to teaching preschool science). This is in line with our hypotheses that through workshops and coaching that focused on developmentally appropriate STEM instruction, its benefits, and teaching strategies, we could shift teachers' beliefs, attitudes, and confidence in teaching math and science, and teaching DLLs.

Gains in Content and Pedagogical Knowledge

The SMILE assessment was developed as part of this project to measure teacher's content knowledge and pedagogy directly relevant to the content of the modules. Scores on this instrument revealed that teachers had limited content knowledge prior to the intervention. STEM knowledge scores on the SMILE instrument for teachers who participated in the intervention significantly improved from before to immediately after participation in the workshops, and a gain persisted over time. This lends support to existing findings that long-term, multi-pronged professional learning are more effective than short-term efforts in areas of STEM (e.g., Whittaker, Kinzie, Williford, & DeCoster, 2016; and in working with DLLs (Buysse, Castro, & Peisner-Feinberg, 2010).

Given the post-workshop average score of 74%, we posit that some of the content may not have been adequately emphasized or understood during workshops. It is also possible that the wording of the items may have been challenging for some teachers. This is an important finding that calls for examination of both teachers' content knowledge in STEM, as well as for further development of instruments that capture content and pedagogical content knowledge in these areas. It is promising that research efforts are beginning to appear related to measuring content and pedagogical content knowledge in preschool science (Barenthien, Lindner, Ziegler, & Steffensky, 2018).

Compared to control group teachers, teachers in the intervention group had higher scores on this STEM content knowledge measure at the end of the two years. Although group differences did not reach significance on the Knowledge of Math Development, there was a trend toward an effect that should be explored further, with an effect size of $d = .45$. Those teachers who scored higher on the delayed SMILE content test than their immediate pre and post-workshop tests may have taken the concepts to heart and deeply incorporated them into their practice. Indeed, those who have worked in professional learning or adult learning might recognize that the effect such programs have differ by individuals in ways not fully captured by assessment of outcomes.

Mechanisms of Change

Our findings support our theorized logic model; the intervention significantly impacted the components on which we expected to have an immediate effect: attitudes, beliefs, confidence, and knowledge (content and pedagogical content knowledge) of STEM and of teaching DLLs. As we unpacked these findings further, we pondered the direct and indirect

mechanisms through which these attitudes, beliefs, confidence, and knowledge constructs would be influenced by our model. Based on existing research on components of effective professional learning experiences for educators (Blank et al., 2007; Wei et al., 2009; Zaslow et al., 2010), we theorize that the chance to reflect with peers, to see STEM and supporting DLLs as accessible, to have access to ongoing coaching and support, and to learn about the importance of early STEM for children's trajectories played a role in improving how teachers feel about teaching STEM, increasing knowledge about the topics, and strategies of teaching these to their students.

Further, participants engaged in these components, including teaching and reflecting, alongside supportive STEM experts and district coaches over the course of 2 years, which allowed them to experience success as a STEM instructor, likely adding to their perception of their competence. The collaborative opportunities across teachers were highlighted in feedback forms as a strength of the workshops, and we noticed changes in teachers' through anecdotal reports, such as in external evaluator survey comments such as, "I feel that I approach the topic of science differently in that I do not let it overwhelm me...I always felt that I had to learn science first, but after this experience I feel more comfortable." (Teacher, external evaluation: Open Minds, 2016). We also noticed how critical relational trust (Byrk & Schneider, 2003) was in building the relationships with teachers and coaches in order for any of the transfer of knowledge to occur. Although we cannot statistically unpack impacts of specific professional learning components to identify which was most influential to which outcome because they were combined, this is a topic for future research.

Limitations

The SMILE assessment tool was developed as part of this project to measure the impact of each workshop on teachers' content and pedagogical knowledge. Although we found evidence of construct validity for SMILE, the tool is still under development. In addition, the sample size of 47 teachers was reasonable considering the expensive and intensive nature of this type of intensive professional learning. However, the sample may not have been large enough to detect effects that may have been present (e.g., in the KMD).

The attitudes, beliefs, and confidence measures were self-report. These come with the limitations inherent in measures that rely on people's ability to reliably assess and honestly report on their own perceptions. Other limitations include limited or unknown generalizability to teachers with different levels of formal education and to those without the supports and benefits associated with teaching in a state-funded preschool program with funding for supports such as coaches. Finally, the research team was directly involved and external funds supported this intensive, ongoing professional learning. Future directions involve translation of the key features of this model into more cost-effective model to ensure sustainability.

Conclusion

These results hold promise for answering the call for more professional learning support for early childhood teachers to teach STEM, and to do so effectively in classrooms serving linguistically, culturally, and socio-economically diverse students (McClure et al., 2017). Our findings add to recent literature that has found teachers' to hold more positive beliefs, attitudes, and confidence about teaching STEM and about supporting DLLs in their preschool classrooms, and that these can be even further improved through professional learning. Additionally, our

findings suggest that preschool teachers need more support in content and pedagogical knowledge about teaching STEM, and suggest that sustained training and coaching can improve teachers' skills in these areas. It is our hope that this work can inform researchers and practitioners working to build effective models of professional learning around STEM-based instruction and support for teaching STEM in classrooms that serve dual language learners, and young children from all backgrounds.

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Tables

Table 1. Demographic characteristics of the sample.

		Control (N = 24)		Treatment (N = 23)		Total (N = 47)	
Education	BA	12	50%	11	48%	23	49%
	MA	12	50%	12	52%	24	51%
Experiences	1-5 Years	4	17%	7	30%	11	23%
	6-10 Years	4	17%	5	22%	9	19%
	10+ Years	16	67%	11	48%	27	57%
Bilingual	Yes	13	54%	18	78%	31	66%
	No	11	46%	5	22%	16	34%
Race	Black	3	13%	3	13%	6	13%
	White	16	67%	11	48%	27	57%
	Other	5	21%	9	39%	14	30%
Ethnicity	Hispanic	8	33%	13	57%	21	45%
	Not Hispanic	16	67%	10	43%	26	55%
Age	39 or younger	9	38%	15	65%	24	51%
	40 or older	15	63%	8	35%	23	23

Table 2. Descriptive statistics for all outcomes

	Control		Treatment		Total	
	M	SD	M	SD	M	SD
Total Dosage (hours)			56	7.47		
Knowledge of Content and Pedagogy						
KMD total correct: pre	14	3.3	13.7	4.46	13.9	3.88
KMD total correct: post	13	5.3	14.0	3.86	13.4	4.64
SMILE total % correct: pre-workshop			53	16.0		
SMILE total % correct: post-workshop			74	11.8		
SMILE total % correct: post-study	54	14.5	65	15.6	59	15.9
<h2>Under Review - Confidential</h2>						
Attitudes, Beliefs, Confidence						
DLLs subscale 1 Spanish use in instruction: pre	4.3	0.46	4.3	0.47	4.3	0.46
DLLs subscale 2 home language maintenance: pre	3.8	0.72	4.0	0.56	3.9	0.65
DLLs total: pre	4.1	0.48	4.2	0.34	4.1	0.41
DLLs subscale 1 Spanish use in instruction: post	4.1	0.44	4.4	0.44	4.3	0.46
DLLs subscale 2 home language maintenance: post	3.8	0.84	4.3	0.63	4.1	0.79
DLLs total: post	4.0	0.46	4.4	0.34	4.2	0.45
PTABS						
PTABS subscale 1: teacher comfort, pre	4.4	0.45	4.5	0.52	4.4	0.48
PTABS subscale 2 child benefit: pre	4.5	0.50	4.8	0.26	4.7	0.42
PTABS subscale 3 challenges (reverse coded): pre	3.2	0.66	3.6	0.92	3.4	0.82
PTABS total: pre	4.2	0.38	4.4	0.47	4.3	0.43
PTABS subscale 1 teacher comfort, post	4.4	0.46	4.7	0.29	4.5	0.43

	Control		Treatment		Total	
	M	SD	M	SD	M	SD
PTABS subscale 2 child benefit: post	4.7	0.34	4.9	0.19	4.8	0.29
PTABS subscale 3 challenges (reverse coded): post	3.3	0.64	4.3	0.4	3.8	0.74
PTABS total: post	4.2	0.36	4.7	0.21	4.5	0.38
MDBS subscale 1: locus of math knowledge: pre	3.4	0.65	3.5	0.65	3.4	0.64
MDBS subscale 2: age-appropriateness pre	5.5	0.42	5.4	0.48	5.5	0.45
MDBS subscale 3 primary goal: pre	5.4	0.47	5.5	0.52	5.4	0.49
MDBS subscale 4 confidence: pre	5.4	0.48	5.3	0.58	5.4	0.53
MDBS total: pre	4.8	0.32	4.8	0.38	4.8	0.35
MDBS subscale 1 locus of math knowledge: post	3.5	0.73	3.5	0.73	3.5	0.72
MDBS subscale 2: age-appropriateness post	5.5	0.45	5.7	0.28	5.6	0.39
MDBS subscale 3 primary goal: post	5.5	0.44	5.7	0.26	5.6	0.38
MDBS subscale 4 confidence: post	5.4	0.48	5.7	0.37	5.6	0.46
MDBS total: post	4.9	0.34	5.1	0.28	5.0	0.32

Note. N for control = 24; treatment = 23; total = 47, except for the DLL survey, for which the treatment N = 22. KMD (Platas, 2014b); SMILE (Author, 2016); DLLs (Cuellar-Klitzke, 2009); PTABS (Maier et al., 2013); MDBS (Platas, 2014a)

Table 3. Results of OLS regression models for impact of treatment group on attitudes and beliefs about teaching math (MDBS)

	(1)	(2)	(3)	(4)	(5)
	locus of control	math as age appropriate	math as primary goal	comfort teaching math	total
	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>
pretest	0.71*** (0.14)	0.34* (0.12)	0.26* (0.09)	0.32** (0.09)	0.49** (0.11)
treatment	-0.10 (0.15)	0.25** (0.08)	0.19 (0.09)	0.35* (0.13)	0.16** (0.04)
teacher education (masters=1)	0.23 (0.11)	0.10 (0.07)	0.13 (0.08)	0.12 (0.14)	0.16* (0.05)
constant	1.02 (0.54)	3.58*** (0.71)	4.04*** (0.52)	3.62*** (0.52)	2.43** (0.56)
R^2	.40	.25	.22	.27	.37
Cohen's f^2	.67	.33	.28	.37	.59
N	47	47	47	47	47

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.

Table 4. Results of OLS regression models for impact of treatment group on attitudes and beliefs about teaching science (P-TABS)

	(1)	(2)	(3)	(4)
	comfort teaching science	child benefit	challenges (reverse coded)	total
	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>	<i>b</i> / <i>se</i>
pretest	0.37** (0.11)	0.06 (0.13)	0.05 (0.08)	0.13 (0.11)
treatment	0.35** (0.08)	0.21*** (0.04)	0.99*** (0.13)	0.45*** (0.07)
teacher education (masters=1)	-0.09 (0.14)	0.04 (0.07)	-0.31* (0.11)	-0.10 (0.09)
constant	2.78*** (0.53)	4.37*** (0.59)	3.33*** (0.23)	3.74*** (0.45)
R^2	.38	.15	.52	.43
Cohen's f^2	.61	.18	1.08	.75
N	47	47	47	47

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.

Table 5. Results of OLS regression models for impact of treatment group on attitudes and beliefs about teaching dual language learners (DLL survey)

	(1)	(2)	(3)
	use of Spanish for instruction	home language maintenance	total
	<i>b/se</i>	<i>b/se</i>	<i>b/se</i>
pretest	0.33*	0.62**	0.45*
	(0.12)	(0.22)	(0.16)
teacher education (masters=1)	0.24*	-0.27	0.07
	(0.08)	(0.21)	(0.09)
treatment	0.30**	0.42*	0.37*
	(0.13)	(0.19)	(0.13)
constant	2.58***	1.52	2.10**
	(0.47)	(0.85)	(0.65)
R^2	.31	.39	.39

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Cohen's f^2	.45	.64	.64
N	46	46	46

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.

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Appendix A

Workshop modules by content and day of delivery

Day	Module Name	Module Content Focus
1	Introduction to STEM	STEM overview; Project overview
	Senses are Tools for Observation	Science: Life, Physical, Technology
2	Introduction to Number	Math: Number sense; Counting
	Introduction to Geometry	Math: 2D Geometry; Spatial
3	DLLs, Language Strategies, and Change	Science: Physical; DLLs: Language development
	Exploring Science Journals	Science: Life, Earth and Space, Physical, Technology
4	Form and Function in the Garden	Science: Life, Earth and Space, Physical, Technology
	Measurement in the Garden	Math: Measurement; Science: Life, Technology
5	Exploring Water	Science: Physical
	Exploring Movement	Science: Physical, Engineering
6	Beyond the Weather Chart	Science: Earth and Space, Technology
	DLLs and Sorting	Math: Sorting, Data Analysis
7	Operations/arithmetic/composition	Math: Operations
	Comparing/ordering/estimating	Math: Comparing, ordering, estimating
8	Animal Adaptations	Science: Life
	Patterns	Math: Patterns

Appendix B

SciMath-DLL Annotated Lesson Plan: Exploring Water Module

WATER FLOWS (*Properties of Water*)

The following describes a set of related activities around water movement. These should be done over multiple days and weeks – not in one day.

Description

Children will engage in activities to explore and think about how water moves and what makes water move in different directions.

Learning Objective(s)

- Children will understand that water tends to move down.
- Children will learn that the path of water movement can be changed by putting something in its way or by pushing or pulling it (applying force).

Vocabulary

- water (*agua*)
- flow (*fluye*)
- movement (*movimiento*)
- down (*abajo*)
- up (*arriba*)
- push (*empujar*)
- pull (
- squeeze (*exprimir*)

Tips for DLL

Strong supports of vocabulary introduction incorporate use of words that are not only associated to the topic of study, but also words that relate well to each other. Use of the words must be weaved through other activities and routines as often as possible. Also important is to intentionally use specific words to both name and describe materials as they are used (e.g., “Please make sure you are wearing a smock. It will protect your clothes from getting wet.” or, “This is called a funnel. It has a large cone-shaped opening that leads to a narrow pipe. Funnels helps us pour liquids into containers with small openings without making a mess!”).

Literature

For Children

- *Splish Splash*, by Joan Bransfield Graham
 - *I Get Wet*, by Vicki Cobb
 - *Follow the Water From Brook to Ocean*, by Arthur Dorros
 - *Dot & Jabber and the Mystery of the Missing Stream*, by Ellen Stoll Walsh
- For Teachers
- *Exploring Water with Young Children*, by Ingrid Chalufour and Karen Worth

Websites for Teachers

- PEEP and the Big Wide World - Explore Water:
<http://www.peepandthebigwideworld.com/guide/water.html>
- *Marvelous Explorations Through Science and Stories (MESS)*
<http://eclkc.ohs.acf.hhs.gov/hslc/tta-system/teaching/eecd/domains%20of%20child%20development/science/investigatingwater>

Materials

- Small cups
- Funnels (enough for one per pair of students)
- Eye dropper(s) turkey basters
- A clear plastic hose (one per pair of students)
- A plastic crate to hold the tubes and serve as an elevation
- Pipes/tubes (or show pipes under sink)
- A water table or dishpans
- Water smocks
- *Splish Splash*, by Joan Bransfield Graham
- *I Get Wet*, by Vicki Cobb
- Pictures of sprinkler, water fountain, waterfall or river (where water is clearly flowing down), and sink pip

Preparation

1. Allow children to explore water and the materials that will be used in the related lessons (e.g., see “What is Water?” lesson from MESS Teacher’s Guide:
<http://eclkc.ohs.acf.hhs.gov/hslc/tta-system/teaching/eeed/domains%20of%20child%20development/science/investigatingwat.htm>).
2. Encourage children to try to make water move in different ways using different tools (e.g., eye dropper, tube, cups, funnel).
3. Read the books or parts of the books such as *Splish Splash* and talk about how water is moving on some of those pages (e.g., waterfall and sprinkler pages).

Tips for DLL

If possible, make copies of books available for a lending library. This can be an important home link as it allows children to review stories and concepts at home. For DLLs, sending home books in the home language (when available), can encourage families to continue to use and nurture the home language.

Exploration 1 – Water Flow**Procedure**

Note: This will work best with small numbers of children to allow for hands-on exploration in the water table or in a clear dishpan.

1. Gather children in a small group around a water table, sink, or plastic dishpan(s). Tell them that they will be exploring how water moves. Ask them to think about how water moved when they explored water before.
2. Show children that you are holding a cup of water over a water table or dishpan. Ask children to tell you where they think the water

Tips for DLL

The teacher should adjust her talk to each DLL child's level of English ability especially when asking questions. “Point to where the water will go when I pour it in here.” Does not require a verbal response; “Is the water moving?” requires just a yes or no; “What is the water doing?” or “What is happening to the water?” are questions for more verbal children.

will go if you tip over the cup. Which direction will the water go? Up? Sideways? Down? Pour some out to check.

3. Have each child (or a few children) try it with a cup of their own. They'll observe that it goes down each time. Show pictures or actual water coming out of faucet – it is flowing down too. Outside, water flows downstream or downhill or down a waterfall too (show picture of waterfall or river flowing down). Ask children, "So where does water usually go?" Down!
4. Ask children to think about whether water ALWAYS goes down. Can they think of examples when water does not go down?
5. Have a child put his/her hand out (or hold out a spoon) and pour some water from the cup on it. Where does the water go when it hits the hand or spoon? It stops, splashes in many directions, or goes sideways. So now we know we can make water go another way if we put something in its way.
6. What about sprinklers, fountains, or pipes under the sink? Show images of actual items. Water in these goes UP or to the SIDE! How? We can make water go another way if we push or pull it (if we apply force)
7. Let's explore! Let children explore how to make water move in another direction other than down using the tools provided (tube, cups, eye dropper, funnel, others you want to include). Remind children to try making water go another way by putting something in the way, or by pushing or pulling it.
 - Remind children of the rules of the water table and how they can explore making water move another way, but the water should stay in the water table.
 - Using the eyedropper, pipette or turkey baster, we can make water go another way. What are we doing to make this work? Squeezing the bulb and PUSHING the water out.
 - Try pouring just a little water in one end of the tube while holding the other end up at least as high. What happens? It does not come up the other end. If we pour lots of water quickly or if we use something to PUSH the water through, it will come up the other end.
 - Prompt putting the funnel in the tube, and pouring lots of water in at once.
8. The objectives of this lesson are for children to understand that water usually goes down unless, a) we put something in its way, or b) it is pushed (i.e., force is applied). Water can also be pulled (another kind of force). If there is time, you could introduce the idea of pulling water up through a straw by sucking, and continue it during snack time. See *Moving Water by Pulling* extension below.

Tips for DLL

The teacher can model his or her own thinking process while using the materials by using self talk. The teacher might say the following while demonstrating the process: "I am going to pour just a little water into one end of this tube while holding the other end up equally high. You see the water does not come up the other end. If we pour lots of water quickly though, or use something to push the water, it does come up the end." Aside from providing vocabulary, this allows children to see a model for developing inquiries.

Exploration 2 - Water Flows - Solve a Problem!

Children will use what they learned in the Water Flows lesson to solve a problem. (Note: This will be another lesson or set of lessons at another time. Building these systems could take quite a bit of time. The garden irrigation system could be a terrific long-term project.) Tell children that you have a problem you want them to help you solve. The two possibilities given below are just examples. You might think of something else that allows children to apply their understandings about water flow.

- One problem might be that we need to fill up or empty the water table, but we have no cups. What can we use to get the water in the table? For example, you could attach a hose to the faucet. Alternatively, you could use some piping to build a pipe system from the faucet to the water table. You might look at books related to irrigation or water systems to see how these kinds of structures were built. Children might test out such a system with a little water first to fix any leaks.
- Another problem to be solved could be that we want to set up a system to water plants in the garden quickly. What would this look like? Could we use pipes or tubes with holes? Will the pipes or tubes have to be going down?

Lesson Extensions

1. **Science:** Moving Water by Pulling (another kind of force). Try drinking water or another drink at snack with a straw. See that water can go UP by pulling too - not just pushing. Use different shaped straws (silly straws) to see the different, fun ways water will travel as it is going up.
2. **Science:** Explore WHY Water Flows. Read *I Get Wet*, by Vicki Cobb. Do explorations described in the book to see that water sticks to itself. Try pouring sand down a tube at a slight incline, and it will not flow down. Try it with water. Compare the movement. Sand does not stick to itself like water does! Sticking to itself helps water flow!
3. **Science:** Explore *Another Way Water Moves!* (capillary action). Water sticks to itself (cohesion) and to other things (adhesion). Water can travel UP all by itself (without force) if it likes to stick to something that goes up. Try putting a strip of paper towel in a glass of colored water. Does it travel up? Check out *I Get Wet*, by Vicki Cobb for more ideas.
4. **Science:** Water Movement in the Environment (Note: This would be its own series of lessons that occur over multiple days and maybe weeks – not in one day.)
 - Read about water movement in the environment. Show a few pages from *Follow the Water From Brook to Ocean* starting at page 10. Discuss how when it rains on mountains and other high places, water goes/flows DOWNHILL. When water gets into rivers, the water flows DOWNSTREAM. Water then flows out to oceans. Water is flowing down, and it is also taking the shape of its container - the space in the ground where the river flows!

Tips for DLL

A project-based curriculum (or a unit of study) offers all children, including DLLs, opportunities to explore a topic using skills from various learning domains. Offering children the chance to explore concepts and use language related to the topic of study in independent play centers allows them to use new vocabulary in context and to exhibit the mastery of skills, knowledge, and words.

- Exploring Rivers and Lakes (adapted from: <http://www.homemade-preschool.com/preschool-science.html>) *Materials:* a long, flat plastic container, dirt/soil, spoon, water, wooden block. Place a thick layer of dirt or soil in the bottom of the container. Using a spoon or fingers, have children make rivers and lakes in the dirt. When it is ready, slowly pour water in. Ask children to watch the water flow into the lakes. What happens to the rivers if you prop up one side of the container?
5. Art: Water Movement and Art. See how water moves with art. Suggest that children explore art and water movement at the art center with paint, paper and an easel. Children can put globs of paint at the top of the paper clipped to an easel. Then, they should put a few drops of water above the paint using an eye dropper. Where will the paint go? You can also have students paint by blowing on colored drops using straws instead of brushes. What happens to the water droplets when you blow on them from different angles?

Check ✓ for Understanding – Tell Me, Show Me!

- Do children understand that water tends to move down? TO CHECK – Say: “If I pour water out of the cup and into a cup below, will it go up or down?”
- Do children understand that water can go up when a force is applied? TO CHECK – Say: “Show me where the water will go when we use straws to drink the water.”

Teacher Reflection Questions

1. Why is it valuable for children to learn about water movement?
(Possible responses: Understanding properties of water helps children better understand and interact with the world around them. It also provides a foundation for understanding environmental issues such as storm drains and runoff from fields leading to oceans. Once children understand the properties of water, they can also use this information to solve problems.)
2. Can you think of other “challenges” or problems to solve that you could do in your classroom that allow children to apply what they learn about water movement from these activities?
(Possible responses: How could you create something to give water to a class pet, such as a gerbil, if you don’t have a bottle with the spout?)