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Powering Up Preschool Science: A Home–School–Community Partnership to Support Science Learning with a Focus on Emergent Multilingual Learners

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Abstract: All children, including emergent multilingual learners (EMLs), are primed to engage with science from an early age. Yet preschool educators traditionally have not been offered in-depth professional learning (PL) in science, how to teach it effectively to young EMLs, and how to communicate its importance to families. This quasi-experimental study investigated a partnership model designed to engage early educators, children's families, informal science educators, and STEM role models at an informal science learning environment (ISLE)in collaboratively supporting high-quality science experiences for young EML children at school, at home, and in the community. The study examined the effects of a multi-faceted PL program on educators' beliefs and attitudes toward science and their classroom instructional practices. Caregivers were surveyed and interviewed to assess their beliefs and attitudes around early science learning. Results indicated that educators in the treatment condition gained confidence in supporting science with EMLs and showed significant increases in instructional quality relative to comparison classrooms. Caregivers rated themselves as more confident in supporting science with their children. Promoting partnerships between preschools and ISLEs can be an effective way to power up educators' and families' capacities to activate young EMLs' science inquiry, learning, and language development across multiple contexts.

Keywords: early childhood science education; preschool education; children's learning; teacher professional learning; emergent multilingual learners (EMLs); family engagement

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1. Introduction

Young children are naturally curious. In their efforts to make sense of the world they live in, they engage with their surroundings in scientific ways: by exploring, asking questions, investigating, and making observations. Indeed, all children—including emergent multilingual learners (EMLs)—are primed to engage with science. Critically, in the early years, high-quality science experiences build a sturdy foundation for children's later learning [1,2]. When children's exploratory play and inquiry is guided by nurturing, engaged adults, it can promote the development of science, technology, engineering, and mathematics (STEM) habits of mind, including persistence, motivation, and flexible thinking [3], while also fostering children's self-efficacy and positive attitudes toward doing and learning science [4]. Moreover, high-quality science experiences provide rich, cognitively challenging content for children to engage with [5]. Yet, one of the key problems facing early childhood science education is that preschool teachers traditionally have not been offered in-depth professional preparation to support their science teaching practice [6,7] or to enact science experiences that incorporate the language-learning approaches that support young EMLs [8].

1.1. Support for Science in the Early Years

While young children are capable of engaging in scientific practices, including making inferences, drawing conclusions, and reasoning about probability, they cannot do it alone [2,9]. When children's science experiences are guided by knowledgeable and engaged adults, including their early childhood teachers and primary caregivers, they build their emerging understanding of science concepts and encourage children's positive attitudes toward doing and learning science, while fostering their collaboration, communication, and creative problem-solving skills [10]. High-quality science experiences in the early years have been linked to children's developing science identity and interests. Research indicates that as early as ages 3 and 4, children develop their STEM interests which, if supported, may persist over time—and even influence their STEM learning trajectories in school and beyond [11–14].

In particular, families have the potential to be powerful facilitators of their children's science learning, inquiry, and interests [15–17]. A growing body of research points to the importance of parent–child conversations—at home and in informal settings—for sparking children's science dispositions and supporting their problem-solving skills and conceptual reasoning [18,19].

1.2. Challenges for Educators and Primary Caregivers in Supporting Early Science Learning

Many teachers of young children lack the knowledge and support they need to promote children's science learning in ways that are aligned with the current vision of a high-quality science education that promotes inquiry, talk, and collaboration [15,20]. In early childhood classrooms, an emphasis on reading and writing can also limit time for these kinds of in-depth science experiences, despite the fact that science can be leveraged as an excellent vehicle for supporting children's early literacy learning [21,22]. EMLs may be further disconnected from the science that does happen in classrooms because many teachers struggle with including these students in ways that connect to the social and academic life of the classroom [23].

For families, even the term *science*—often interpreted as a specific body of knowledge—can be a barrier for caregivers who would otherwise engage their children in inquiry and exploration [24] because they believe they lack the necessary knowledge of science content and how to support learning it with their young children [15,20]. For caregivers with limited economic resources, feelings of inadequacy can be particularly strong; despite valuing learning, their self-efficacy for participating in science may be low [24,25]. Yet, families want to know more about what science their children should be learning, how to best support them, and home activities they can do with simple materials [15]. Families often look to their child's teacher to provide them with support in science and mathematics and have reported a desire to learn from their child's teacher, particularly in STEM content areas [26]. Implicit biases about who does science and who can access the 21st century STEM workforce pipeline may lead families and teachers to steer Black, Latinx, and EML children of all ethnicities away from science and STEM opportunities [27,28]. Teachers may undervalue the potential influence of families on their children's science learning, and families of EMLs especially may feel unwelcome or intimidated in the school environment for any number of reasons [29]. Families experiencing economic hardship, especially those whose home language is not English, often encounter unequal access to culturally sustaining, concrete, and specific information about learning and development in their home languages [30–32]. Despite the clear need for teachers to appropriately engage EMLs in instruction, teacher preparation programs rarely support teachers to work with these learners [33], and educators with more EMLs in their classroom often feel underprepared to meet these students' needs [34]. These factors create an insufficient support system for EMLs that may negatively impact their science and literacy learning, their overall academic achievement, and their enthusiasm for and interest in science [35]. But it does not have to be this way.

1.3. Science and Language: A Natural Fit

Access to concrete science materials and phenomena—a central feature of inquiry—provides a particularly rich context for talk in children's home languages as well as in English [36,37]. Supporting children to engage in inquiry-based science experiences with hands-on materials allows for the inclusion of a diverse range of learners, particularly EMLs. Learning that focuses on *doing* science facilitates language development, particularly when engaged adults encourage children to talk about what they are noticing, describe their observations, and make sense of their findings [3,8]. Research suggests that integrating instructional supports for language learning in the context of children's science experiences promotes language and literacy development in both English and science [36–38]. Science motivates children to use oral language—a precursor to literacy—as they ask questions, talk about their findings, and explain their thinking [36,37]. Promoting strong oral language skills and robust vocabulary knowledge can support children's participation in early science learning by providing them with the words they need to think critically about science concepts and begin to build their understanding of foundational concepts [38–42].

1.4. Forging Strong Partnerships among EMLs' Families and Educators

As a way to power up teachers and families and create a school community that effectively supports all students, including EMLs [43,44], schools must be committed to initiating and supporting culturally and linguistically sustaining, asset-based home–school partnerships. The Dual Capacity-Building Framework for Family–School Partnerships [44] prioritizes building families' and educators' capacities in four key areas: capabilities (skills and knowledge), connections (networks), cognition (shifts in beliefs and values), and confidence (self-efficacy). The Framework addresses common barriers to creating robust home–school partnerships, including families' feelings of being unwelcome or intimidated in the school environment and educators not necessarily viewing family engagement as an essential part of their practice. Teachers can create a welcoming classroom culture and connect families to children's school learning by providing specific ideas for supporting learning at home that are culturally and linguistically responsive and respectful. This enables families to more fully support, encourage, and monitor their children's school learning, to cocreate learning opportunities at home, and to advocate for their children's science learning at school [44].

Much research has been carried out on early childhood learning that links culturally and linguistically responsive teaching and support for children's home language development to child outcomes, including in schools and programs where teachers do not speak the primary home languages of the children in their care [39]. These studies show that when teacher PL incorporates knowledge of effective language teaching strategies for EMLs that include support for the home language, it can improve EMLs' language and literacy outcomes [45,46]. For example, the Personalized Oral Language Learning [47] approach employs a variety of practical strategies for teaching young EMLs that can be applied across content-learning areas [48]. These strategies include focusing on Big Ideas, using intentional messages, asking productive questions, facilitating talk with books and children's work, grouping children intentionally, and partnering with families [48].

1.5. Creating Home–School–Community Partnerships

Connecting children's learning experiences across home, school, and community settings can promote children's science inquiry by enabling them to investigate and talk about related phenomena from different perspectives and with different people [48,49]. For EMLs, these opportunities promote transfer of their conceptual and vocabulary knowledge from one language to another and support bilingualism, self-efficacy, and identity development [50–52]. Extensive research has been carried out on building STEM career interest in middle school and beyond, but far less is known about how to promote the foundational dispositions that will prepare young children for full engagement in the 21st century STEM workforce. We do know, however, that children's informal science experiences at home and in their communities are as important, if not more important, as school is in sparking interest in science, with families playing a critical role in fostering children's early STEM identities [16,53,54]. We also know that high-quality curriculum guidance can be a valuable tool for teachers, especially when it provides suggestions for bridging children's experiences across home and school. SISTEM utilizes the *PEEP and the Big Wide World* digital guide as a way to do this. It includes parallel school and home activities across the three focal topics. Tips for teachers and families on supporting inquiry, and authentic videos of home and school experiences, and all of the other *PEEP* resources are publicly accessible and available in English and Spanish.

1.6. Partnering with Informal Science Learning Environments (ISLEs)

Research shows that ISLE staff and other STEM professionals who reflect children's and families' ethnicities and languages can be powerful role models [55]. Opportunities to interact with "STEM Community Helpers" in different careers who "look like me and speak like me" may have the potential to spark EMLs' STEM interests, promote their confidence, and encourage them to view themselves in similar roles [56]. STEM Community Helpers can also counter some of the biases that families and teachers may hold about who is capable of doing and learning science and promote a shared vision of science inquiry as a vehicle for supporting EMLs' future access to the STEM pipeline [56–58].

Likewise, ISLEs, such as science museums and science centers, provide opportunities for self-directed exploration and inquiry. Families' ISLE experiences and interactions in these settings have been linked to children's early STEM passions for specific objects, topics, and phenomena [16,59]. When families engage in STEM learning with their children in ISLEs—become actively involved; respond to their goals, interests, and wonderings (e.g., *What does this do? How does this work? Why does this happen?*); make connections between STEM phenomena and children's everyday lives; and engage in reciprocal family "science talk"—they can fuel formation of their children's STEM identities [60–63]. Early childhood education staff, who already have strong, trusting relationships with families, can act as a bridge, helping families initiate and sustain relationships with ISLEs, ISLE educators, and local STEM professionals in the community [64–66].

1.7. Theoretical Underpinnings

Our theory of change is grounded in Bronfenbrenner's Ecological Systems Theory [67], which posits that children simultaneously grow and develop within different ecosystems, from the most intimate family and home ecological system, moving outward to educational systems, and then to the larger community. Each system inevitably interacts with and influences the others in every aspect of the child's life. We hypothesize that creating a home–school–community partnership that infuses each level of the learning ecosystem with positive attitudes toward science and opportunities for children to engage with high-quality science practices will shift educators' and families' beliefs and attitudes about science and the value of their own presence in science learning. Taking a sociocultural approach to science, we honor alternative ways of knowing, learning, and interacting around science, and emphasize science identity as a multifaceted construct shaped largely by the implicit and explicit messages children receive from their families, educators, respected community members, and society at large [68–71].

1.8. Overview of Current Study

To address the needs described above, EDC and the Connecticut Science Center (CSC) joined forces with five community-based early childhood programs to develop a program for home-school-community partnership that supports science learning for young EMLs: *Supporting Science Inquiry, Interest, and STEM Thinking for Young Dual Language Learners* (SISTEM). In this paper, we describe a quasi-experimental pilot study of the SISTEM program for home–school–community partnerships to support science learning for young EMLs that uses a mixed-methods approach to address the following research questions:

RQ1. Is SISTEM participation associated with preschool educators' self-efficacy in science teaching and in engaging EMLs and their families in science?

RQ2. Is SISTEM participation associated with increased quality of preschool educators' science teaching?

RQ3. Is SISTEM participation associated with preschool caregivers' positive beliefs and attitudes about supporting their children's science learning and interest in STEM?

2. Materials and Methods

2.1. Setting

This study took place in Hartford, Connecticut, in partnership with CSC and five community preschool programs, all of which serve a diverse population of children and families that includes EMLs. The city has the lowest median income and the highest poverty rate in the state [72] in the areas in which the programs are located, and community members deal with high rates of unemployment, violent crime, and food insecurity [73] with 49% of residents living below the federal poverty line and only 38% earning high school degrees. Yet, this community is rich in cultural funds of knowledge, skills, abilities, resources, strengths, and aspirational, navigational, social, linguistic, and familial capital [74–76].

The CSC was an ideal project partner and central setting for this project as its aim is to bring to life its mission statement, "to develop the minds of future thinkers and inventors who will compete in the global marketplace for technology and innovation", for all the city's children, including its very youngest. To do so, CSC recruits local STEM organizations and professionals who facilitate science and engineering activities for families and act as community STEM role models.

2.2. Post-Pandemic Challenges

This study occurred during the 2022–2023 school year. While we were able to meet in person for the PL sessions and the "I Love Science!" events held at CSC, many programs were operating fewer classrooms than they had pre-COVID-19 due to staff shortages. Many families were on waitlists to enroll, but programs were struggling to hire staff. Additionally, some programs had continued their COVID-19-related restrictions on allowing outside guests and families into schools. Given these limitations and the continued uncertainty of visitor policies, we held some components of the program virtually.

2.3. Program: The SISTEM Model

The full SISTEM model was organized around three topics of study: Water in the fall, Ramps in the winter, and Shadows in the spring. It included three PL instructional sessions for educators and program staff, collectively referred to as the Inquiry Institute; six virtual professional learning community (PLC) meetings customized to meet the needs of educators and staff at individual programs; three PE collaborative workshops, mainly held remotely but with two programs opting to independently organize and facilitate the third one onsite; and three "I Love Science!" events held at CSC in fall, winter, and spring. These all-inclusive events, held at the beginning, middle, and end of the program year, were designed to bring all project participants and teams together with their own families to experience and engage with the exhibits and a variety of activities facilitated by ISLE educators and local STEM Community Helpers. Resources included three classroom science kits for participating classrooms, one for each topic of study, and three smaller topic-specific kits for each participating family. Educators and families also received information and guidance for using digital resources to support children's home, school, and community explorations of each topic.

The most central digital resource was the *PEEP and the Big Wide World* suite of online materials, which included guidance for facilitating Water, Ramps, and Shadows experiences with young children at home and school; tips for teachers and families on supporting inquiry; and a wealth of short videos illustrating authentic classroom and family explorations of these topics. All *PEEP* resources are publicly accessible on computers, tablets, and smartphones and available in English and Spanish. We also created digital resources, such as "unboxing" videos for families, providing suggestions for how families might use the materials in the home science kits to support topical explorations with their children (see Table 1 for the program components). All of these events and resources worked toward advancing six program objectives, described in Section 2.4.

Table 1. SISTEM program components.

	Water	Ramps	Shadows
Inquiry Institute	PL Session 1 (6.5 h). Tools for language-rich inquiry during a Water study. Immersive experiences.	PL Session 2 (6.5 h) Tools for language-rich inquiry during a Ramps study. Immersive experiences.	PL Session 3 (6.5 h). Tools for language-rich inquiry during a Shadows study. Immersive experiences.
Professional Learning Communities (PLCs)	Two Zoom meetings: 1. Classroom practice and *PEEP* resources. 2. Family engagement.	Two Zoom meetings: 1. Classroom practice and *PEEP* resources. 2. Family engagement.	Two Zoom meetings: 1. Classroom practice and *PEEP* resources. 2. Family engagement.
Parent–Educator (PE) workshops	One virtual session. Home science kit. Spanish and English.	One virtual session. Unboxing video. Home science kit. Spanish and English.	Three virtual sessions and two onsite sessions. Unboxing video. Home science kit. Spanish and English.
CSC "I Love Science!" events	Focus Families, educators, program staff and their families. STEM Community Helpers.	Focus Families, educators, program staff and their families. STEM Community Helpers.	Focus Families, educators, program staff and their families. STEM Community Helpers.

2.4. Program Objectives

All program objectives were focused on building adults' capacity to support early science inquiry and to forge relationships across home, school, and community, thus creating a web of supports for promoting all children's (with a focus on EMLs) science and language learning across contexts.

2.4.1. Objective 1: Provide Educators with Guidance, Resources, and Support for Engaging Children in Rich Science Inquiry and Learning around Three Compelling Topics (Water, Ramps, and Shadows) That Can Be Explored across Contexts

A team of early science and teacher educators from EDC and CSC implemented and facilitated three robust full-day PL sessions—the Inquiry Institute—that allowed for a gradual, integrated introduction of pedagogical content and strategies for promoting children's inquiry, talk, and vocabulary through direct experiences (Session 1), interactive books and readings (Session 2), and supporting documentation and children's representations (Session 3). Based on our ecological systems approach and the goal to infuse each level of the learning ecosystem with positive attitudes toward science, it was important to offer this PL to *all* educators working in each participating classroom, including lead teachers, assistant teachers, support staff, and curriculum specialists. To make it possible for full teaching teams to participate, sessions were held on Saturdays.

Each session included the following elements: a reflection discussion on how educators had applied learning from the previous session (Sessions 2 and 3); an introduction to the science content relevant to the topic; adult immersive experiences of inquiry into the topic; strategies for facilitating talk about the topic across the inquiry cycle; representations of the topic from authentic classrooms, including children's work, educator documentation, and *PEEP* videos; an overview of the *PEEP and the Big Wide World* teacher and family resources available for that topic; and time for collaborative planning, using a planning form we developed that was aligned to the teachers' current planning form and emphasized integration across the Early Learning and Development Standards [77] (see Figure 1). At PL sessions 2 and 3, we shifted the adult immersive experiences to incorporate five or six investigation stations that educators rotated through to more effectively scaffold their use of the *PEEP* resources. During Sessions 2 and 3 we also moved the planning section to earlier in the day and then revisited planning at the end of the session to devote more time to planning for classroom implementation. Assessment of children's learning was emphasized in Session 3; as part of the reflection discussion, we assisted educators in creating documentation panels to help make children's science learning visible to families.

SISTEM Planning Form
Planning for Shadows

Teacher(s)		
Big Idea (aligned ELDS)		
Intentional Message		
Target Vocabulary	English	Home Language
Learning Goals	Cognition	
	Language Literacy	
	Math	
	Soc/Emotional	
	Physical Health	
	Creative Art	
Family Engagement Plan		
Identify the POLL Strategies that are supported	Big Idea and Intentional Message	Songs and chants
	Targeted Vocabulary	Documentation of explorations
	Small group supports	Anchor Text

Describe the Experience	**How will the Teacher support inquiry? What will they say/do?**
Materials or changes to the environment	
Describe the Experience	**How will the Teacher support inquiry? What will they say/do?**

Figure 1. SISTEM planning form for Shadows explorations.

2.4.2. Objective 2: Support Educators' Classroom Pedagogy and Family Engagement Practices with Individualized Scaffolding Based on Each Program's Goals, Strengths, Needs, and Interests

Educators at each of the five programs, including lead teachers and assistant teachers, were invited to engage in six collaborative program-specific PLC meetings across the school year (two after each Inquiry Institute session) to support their transition from theory to practice and their capacity and confidence in applying the science pedagogy (PLC meeting 1) and family partnership practices (PLC meeting 2) introduced at the PL sessions. These meetings were designed to be program-specific in order to meet the needs of each of the five programs, which varied broadly across multiple indicators (e.g., diversity of educators, staff, and families; educators' prior experiences with science teaching; degree of current family partnership commitments). A highly experienced EDC coach facilitated the meetings, offering two options for attendance to each program to be responsive to individual program schedules, increase educator participation, and address the specific needs of program staff in dealing with post-COVID-19 stressors.

PLC meetings focused on classroom implementation prioritized opportunities for educators to share "roses and thorns" as they implemented new science and language support strategies with children in their classrooms. The family-engagement-focused PLC meetings provided opportunities for educators to discuss their current interactions with families, share ways of deepening reciprocal relationships around science and language with a focus on EMLs' families, and supported planning the upcoming PE workshop. For example, the initial family-engagement-focused meeting laid the groundwork for reaching out to and engaging families in the project and begin the process of learning about families' routines, typical family activities, and primary home languages. In subsequent meetings, the coach introduced a concept map of potential topics educators might discuss with families and helped them select ones they identified as relevant to their own families' strengths, needs, and interests. At the final PLC meeting, the EDC coach organized educators into separate meetings according to the degree to which they felt comfortable taking ownership of the event and facilitating the final PE workshop, either independently and in person at their program, virtually with support from the EDC coach, or virtually with the EDC coach facilitating most of the meeting.

2.4.3. Objective 3: Bring Families and Educators Together for Collaborative Inquiry-Based Learning, Discussions about the Science Children Are Doing at School, and Joint Planning for Aligned Home and Family Experiences

Educators were asked to invite up to four multilingual families (referred to as "Focus Families") to participate in a series of three collaborative Parent/Educator (PE) Workshops (one per topic). The PE workshops were designed to strengthen educators' capacity to engage, educate, and power up EMLs' families around early science and language and to provide a venue in which EMLs' primary caregivers would feel confident and comfortable about engaging with educators around science, language, and their child's learning. All PE meetings were held in English and Spanish with simultaneous interpretation. EDC staff facilitated discussions that incorporated the *what*, *how*, and *why* of early science learning, introduced concept and inquiry-support practices that adults could apply across settings, and offered an overview of books and *PEEP* digital resources specific to the topic at hand.

Educators and parents also interacted directly in breakout rooms, including significant time for educators and primary caregivers to share photos, videos, and stories of children's home and school explorations with one another. The time allotted for these conversations increased at each subsequent meeting as educators became more comfortable guiding the discussions. All PE meetings were scheduled with input from program directors and educators to ensure that they were responsive to both educators' and parents' availability.

2.4.4. Objective 4: Facilitate Innovative Adult Learning Experiences That Bring All Participating Adults (Educators and Parents) Together with Their Families for Informal Science Experiences

EDC and CSC staff hosted three "I Love Science!" events, held at the CSC, that were the backbone of the SISTEM model and brought together Focus Families, program educators and staff, EDC and CSC staff, and all of their families for science exploration and learning. At each event, Focus Families and program staff received "passports" in English and Spanish to orient them to the science center and exhibits specifically designed for young children; despite the CSC's close proximity to the five programs, only a small percentage of educators and families had previously visited the center. Program staff and families collaboratively explored the center's exhibits, including those related to the topics being explored at school and at home. Supported by ISLE educators, staff and families interacted at a giant stream table and water play area (Event 1), activities to build their own roller coaster and race cars down ramps (Event 2), and a weather broadcasting simulation and shadow puppets experience (Event 3).

The third "I Love Science!" event was a culminating SISTEM celebration. Participating staff and families were encouraged to explore the entirety of CSC with their families. A special event space was set up for Focus Families and program staff to enjoy a slideshow of photos taken across the year and to view and discuss the documentation panels educators had created of Ramps and Shadows explorations. Everyone shared a celebratory lunch hosted by the CSC.

2.4.5. Objective 5: Activate a STEM Community Helper Model with CSC's Hispanic STEM Career Professionals Who Can Broaden Families' and Educators' Awareness of STEM Careers

The CSC "I Love Science!" events provided a context for activating the STEM Community Helpers model and broadening children's and adults' awareness of STEM careers and the people who have them. At each event, a diverse group of local STEM professionals who hold STEM-related positions at several local companies facilitated investigations compelling to preschoolers, including engineering straw rockets and sink-and-float explorations (Event 1), a Junior Fire Marshall demonstration to learn more about how STEM Community Helpers' roles connect to STEM (Event 2), and space-related programs and activities as part of CSC's Space Day (Event 3).

2.4.6. Objective 6: Employ Innovative Digital Technologies and Resources in English and Spanish to Support Initiating, Strengthening, and Sustaining Home–School–Community STEM Connections

For this objective, we created several digital resources, including Google sites specific to educators and families, unboxing videos, and a digital newsletter. A teacher-facing Google site and a companion family site (in English and Spanish) were designed and developed to be active, with evolving resources where educators and families could easily access all the Water, Ramps, and Shadows resources as they were added throughout the year. After the launch of each new topic, the sites were updated with supporting materials, including photos, videos, tip sheets, and links to resources. The unboxing videos were created to support families' engagement with the home science ramps and shadows kits. Each video featured a CSC informal science educator who previewed and described the home science kit materials (in English and Spanish) and demonstrated multiple ways of using them to support children's inquiry. The home science kits and the digital newsletter included QR-coded links to the unboxing videos, making them easily accessible to families. We also developed a bilingual digital newsletter aimed at both educators and families that provided reminders of program events, additional information related to each topic of study, links to resources, photos from homes and classrooms, and further guidance for facilitating children's inquiry. The joint newsletter enabled parents and educators to see the direct connections between the home and school resources. The newsletter was distributed to educators, who then delivered digital or hard copies to families. The newsletters were also added to the educator and family Google sites. Finally, we created bilingual family-friendly flyers to notify families of the CSC "I Love Science!" events.

2.5. Research Design

2.5.1. Recruitment

To support successful implementation and buy-in, we met with program administrators and support staff the spring before implementation to explain the project in detail and describe program and educator expectations and project components. We asked participating directors to sign a commitment form specifying that they will attend monthly check-in meetings with the SISTEM team and designate a "SISTEM liaison" (e.g., curriculum specialist, family engagement coordinator) to participate in the program.

After directors signed the commitment form, the research team met with educators to explain the project, answer questions, and invite participation. The team recruited 22 classrooms; 11 were asked to be in the treatment condition (Group 1) and 11 in the comparison, education-as-usual condition (Group 2). Treatment classrooms engaged in SISTEM PL in the 2022–2023 school year, and comparison classrooms engaged in SISTEM PL the following school year. Note: We did not randomly assign classrooms to treatment or comparison groups, as this was a quasi-experimental study, and directors often requested the classroom's condition (e.g., one teacher was scheduled for maternity leave and could not attend all PL sessions, so she was assigned to the comparison group). All educators from participating classrooms (lead teachers and assistant teachers) were invited to participate and were asked to complete a consent form. Among treatment classrooms (henceforth referred to as *SISTEM classrooms*), 23 educators consented to participate in the first year of the SISTEM PL.

Throughout the year, participation was significantly impacted by teacher turnover and program restructuring. In late fall, one comparison classroom was redesignated as an infant–toddler classroom and so could no longer participate; we recruited another comparison classroom to replace it, but the educators from this classroom also ultimately left the program. Midyear, an SISTEM classroom was also redesignated as an infant–toddler classroom and could no longer participate, and an additional teacher from an SISTEM classroom and a comparison classroom left their programs and could no longer participate. The SISTEM PL was well under way at this point; therefore, these classrooms could not be replaced. In addition, two assistant teachers from SISTEM classrooms and two assistant teachers from comparison classrooms left their positions midyear, although the lead teachers from these classrooms continued their participation.

2.5.2. Participants

After the attrition described above, there were a total of 9 SISTEM classrooms with 16 participating educators, and 11 comparison classrooms with 13 participating educators. Of these 29 total educators, 27 provided information about their years of experience, education, and demographics. Average years of experience in early childhood education was similar across groups: 6.85 years (SD = 6.78) for SISTEM educators, and 7.92 years (SD = 7.93) for comparison educators. In both groups, about half the educators reported that they were able to communicate in a language other than English (most often Spanish): 58% of SISTEM classroom educators and 54% of comparison classroom educators. A total of 42% of SISTEM classroom educators had bachelor's degrees, 24% had associate's degrees, 17% had some college experience, and 17% had a high school diploma or GED. Comparison classroom educators had a roughly similar distribution of education: 7% had graduate degrees, 42% had bachelor's degrees, 22% had associate's degrees, and 29% had some college experience. Three SISTEM educators and one comparison classroom educator were male; the rest were female.

Once all educators were recruited, SISTEM classrooms invited up to four multilingual families to serve as Focus Families. Across the nine SISTEM classrooms, educators recruited a total of 24 Focus Families. A majority of Focus Families spoke either Spanish or a mix of Spanish and English at home; one family spoke French and Togo.

2.6. Instruments and Analysis

2.6.1. Surveys

To assess participants' perceptions of program impacts after completion of the program, we developed survey scales for Focus Families and SISTEM educators to rate their beliefs and attitudes related to science before and after participating in SISTEM. Educators were asked to rate nine items related to their beliefs about the importance and value of early science learning and their comfort, confidence, and excitement about teaching science and engaging EMLs and their families in science. Parents rated two items related to their beliefs about the value of science for their child and their awareness of STEM careers, and five items related to their comfort, confidence, and excitement about engaging in science learning with their child. All items were rated on a six-point scale (from "very low" to "very high"). Participants were asked to rate each item twice: retrospectively reporting on their beliefs and attitudes *before* participating in SISTEM, and their current beliefs and attitudes *after* having participated in SISTEM.

2.6.2. Classroom Observations

To evaluate the quality of science teaching practices, we used a modified version of an observation protocol called the Science Teaching and Environment Rating Scale (STERS) [78]. The STERS is a classroom observation tool designed to measure the quality of teacher–child interactions, the environment, and teachers' planning and assessment practices related to science teaching and learning in the preschool classroom. Teachers are asked to lead a science activity or exploration of their choosing. Observers code eight items on a four-point scale (1 = deficient, 2 = inadequate, 3 = adequate, and 4 = exemplary) based on the extent to which teachers do the following: (1) create a physical environment for inquiry and learning, (2) facilitate direct experiences to promote conceptual learning,

(3) promote use of scientific inquiry, (4) create a collaborative climate that promotes exploration and understanding, (5) engage in extended conversations, (6) build children's vocabulary, (7) plan in-depth investigations, and (8) assess children's learning (for more information about these items, see [79]). The original observation protocol was intended to be conducted in person and to include interviews with teachers before and after the observation to evaluate their thinking about planning and assessment. We modified the protocol to be used for video observations, eliminating both these interviews and two items that would have been assessed during an interview ("*Plan in-depth investigations*" and "*Assess children's learning*"). Additionally, for the item "*Create a physical environment for inquiry and learning*", we did not include indicators related to aspects of the classroom environment that could not be observed on camera (e.g., availability of science books related to the topic, use of displays), instead focusing on observable use of materials.

2.6.3. Research Team Informal Observations

Research staff attended and observed all program meetings and events. Staff convened weekly research meetings to review and discuss field notes, observations, interviews from SISTEM events, discussions with educators and Focus Families, photos and videos shared by educators and families, and educator reflections of SISTEM's impact on their practices shared at the last PLC.

2.7. Procedures

In the 2022–2023 school year, some early childhood programs in the study continued to have COVID-19- and illness-related concerns (such as flu and RSV), particularly around outside visitors in classrooms. For this reason, classrooms were provided with iPads and tripods, and educators were asked to video-record their classroom science instruction in lieu of in-person observations. In the fall, before the start of the PL sessions, we asked both SISTEM and comparison classrooms to record a video of any science activity or experience, on any science topic, aiming for 10–20 min of footage. In the spring, after the completion of SISTEM PL activities, we asked both SISTEM and comparison classrooms to record a video of a science activity focusing on the topic of Shadows, again aiming for 10–20 min of footage. Educators uploaded and shared their video recordings via secure sharing, and we stored the recordings on a secure storage site. We received complete fall and spring recordings for 12 classrooms (6 SISTEM and 6 comparison). Although some videos included assistant teachers, all observed activities were led by lead teachers. A member of the research team, who is an STERS master coder, trained an external evaluator on the modified STERS protocol. The trainer and the external evaluator independently coded three observation videos to ensure that the external evaluator was reliably scoring according to the STERS training guidelines. The evaluator then scored all video observations.

We asked SISTEM educators and Focus Families to complete surveys in the spring after the completion of SISTEM activities. A total of 11 SISTEM educators and 9 Focus Family caregivers completed the survey. We asked all SISTEM educators to participate in one of several reflective conversations over Zoom after the completion of SISTEM PL activities. Finally, we conducted four interviews with Focus Family caregivers to gain greater insight into their experiences.

Attrition and Fidelity

Of the 23 educators who originally signed on to participate in SISTEM, seven left their programs or were moved to different positions and could no longer participate. The remaining 16 had the opportunity to participate in three PL sessions, six PLC meetings, three PE meetings, and three CSC events. Eighty-one percent attended two or three PL sessions, all attended at least four PLC meetings, 88% attended at least one PE meeting, and 88% attended at least one CSC event.

2.8. Analysis Plan

To address our research questions, we conducted quantitative analyses and synthesized reflective conversations with educators and informal observations. Quantitative methods are described here. To address RQ1, we conducted paired *t*-tests on SISTEM educators' ratings of their beliefs and attitudes before and after participation in SISTEM. Using data from both SISTEM and comparison classrooms, we conducted a series of regression analyses on each science teaching practice, regressing the quality of spring science teaching quality on fall science teaching quality and participation in SISTEM. To further explore changes in teaching practice, we also conducted paired *t*-tests on each science teaching practice for SISTEM and comparison teachers. To address RQ2 and RQ3, we conducted paired *t*-tests on caregivers' ratings of their beliefs and attitudes before and after participating in SISTEM.

3. Results

3.1. Impact on Educators' Self-Efficacy

To understand changes in educators' sense of self-efficacy related to their science teaching practice and engaging with EMLs and their families around science learning, we conducted paired *t*-tests comparing educators' retrospective ratings of their feelings before SISTEM participation with their ratings of their current feelings (See Table 2). Eleven educators completed "before" and "after" ratings. All ratings significantly increased except for one ("*Belief that science is important for children's future careers*"), which had only a marginally significant effect, $t(10) = 2.19$, $p = .054$.

Table 2. Educators' science beliefs and attitudes.

Science Beliefs and Attitudes	Before SISTEM M (SD)	After SISTEM M (SD)	Difference (After–Before)	SE Mean	t (df = 10)
Confidence in planning science experiences for children	3.09 (1.14)	5.00 (0.78)	1.91	0.32	6.06 ***
Belief that science is important for children's future careers	4.27 (0.79)	5.00 (1.10)	0.73	0.33	2.19 †
Belief in the importance of giving children opportunities to see people who look like them in science careers	3.55 (1.37)	4.64 (1.29)	1.09	0.32	3.46 **
Excitement to do science in the classroom	3.64 (1.21)	5.18 (0.98)	1.55	0.34	4.54 **
Confidence in supporting children's language development through science	3.73 (0.65)	4.91 (0.70)	1.18	0.18	6.50 ***
Confidence in supporting EMLs during science experiences	3.64 (1.12)	4.82 (0.75)	1.18	0.18	6.50 ***
Comfort in asking productive questions during science experiences	3.36 (1.21)	4.82 (0.60)	1.46	0.34	4.28 **
Interest in engaging all families in science learning	3.27 (1.42)	4.91 (1.04)	1.64	0.31	5.29 ***
Confidence in engaging EML families in science learning	3.09 (1.45)	4.82 (0.98)	1.73	0.41	4.25 **

† $p < .10$, ** $p < .01$, *** $p < .001$.

3.2. Impact on Educators' Science Instructional Practice

To understand how SISTEM impacted educators' science teaching practice, we compared the quality of SISTEM and comparison educators' science teaching practice, as measured by six items of the STERS, in fall and spring. In the fall, educators were free to lead a science activity on a topic of their choosing. Among the 12 classrooms with complete fall and spring observation data, eight educators led activities related to mixing and reactions (e.g., mixing paints of different colors, mixing oil and water, mixing baking soda and vinegar), two led activities about pumpkins (cutting it open and looking at its parts), one led an activity about magnets, and one led an activity about capillary action on a paper towel. In the spring, all educators were asked to lead an activity related to or an exploration of shadows. Descriptive statistics are presented in Table 3.

Table 3. STERS descriptives for SISTEM and comparison classrooms.

	SISTEM Classrooms (n = 6)		**Comparison Classrooms (n = 6)**	
Science Teaching Practice	**Fall M (SD)**	**Spring M (SD)**	**Fall M (SD)**	**Spring M (SD)**
Create a physical environment for inquiry and learning	3.17 (1.33)	2.83 (0.41)	2.83 (0.98)	2.67 (1.51)
Facilitate direct experiences to promote conceptual learning	2.33 (1.21)	3.17 (0.75)	2.50 (1.23)	3.00 (1.55)
Promote use of scientific inquiry	2.00 (0.89)	3.00 (0.00)	2.33 (1.03)	2.17 (0.98)
Create a collaborative climate that promotes exploration and understanding	2.00 (0.89)	2.33 (0.52)	2.33 (1.03)	2.17 (0.98)
Engage in extended conversations	2.00 (0.89)	2.50 (0.84)	2.33 (1.03)	2.50 (1.23)
Build children's vocabulary	1.33 (0.52)	2.00 (0.00)	1.67 (0.82)	1.83 (0.41)

Regression analyses indicated that SISTEM (Treatment) was significantly associated with spring scores related to educators' ability to *"Promote use of scientific inquiry"* (See Table 4). The estimated coefficient for this effect indicates that, on average, SISTEM was associated with a one-point increase in spring STERS scores relative to comparison classrooms, controlling for fall scores. No other science teaching practices were significantly associated with SISTEM participation.

Table 4. STERS regression analyses.

Dependent Variable	**Independent Variable**	**B (SE)**	**β**	***t***	***p***
Create a physical environment for inquiry and learning	Fall Score Treatment	0.65 (0.23) –0.05 (0.50)	0.69 –0.02	2.82 –0.10	.020 .924
Facilitate direct experiences to promote conceptual learning	Fall Score Treatment	0.65 (0.25) 0.28 (0.56)	0.65 0.12	2.58 0.49	.030 .637
Promote use of scientific inquiry	Fall Score Treatment	0.50 (0.17) 1.00 (0.31)	0.59 0.66	2.90 3.23	.018 .010
Create a collaborative climate that promotes exploration and understanding	Fall Score Treatment	0.61 (0.18) 0.37 (0.32)	0.76 0.26	3.37 1.14	.008 .283
Engage in extended conversations	Fall Score Treatment	0.86 (0.22) 0.29 (0.40)	0.80 0.15	3.86 0.72	.004 .492
Build children's vocabulary	Fall Score Treatment	0.36 (0.23) 0.29 (0.30)	0.47 0.29	1.55 0.96	.156 .363

To further explore changes in science teaching practices, we conducted paired t-tests, comparing fall and spring scores for SISTEM educators and comparison educators. Paired t-tests revealed that comparison educators did not significantly increase in any teaching practices from fall to spring, although they did marginally increase in scores related to "*Facilitate direct experiences to promote conceptual learning*", $t(5) = 2.24$, $p = .076$. SISTEM educators, however, significantly increased their scores in both "*Promote use of scientific inquiry*", $t(5) = 2.74$, $p = .041$, and "*Build children's vocabulary*", $t(5) = 3.16$, $p = .025$.

Educators Learned and Applied Strategies for Supporting Children's Science Inquiry and Gained Confidence in Supporting Science with Children in Classrooms

During reflective conversations, all educators shared that they had shifted their pedagogy directly related to science teaching and learning. One of the biggest changes mentioned was the use of the Big Idea/Intentional Message to drive the classroom curriculum and to motivate more extended investigations. One educator said, "Science used to just be in the science area, but we have learned how to make it come alive in the classroom. The children are so excited, the interest just explodes. Letting them investigate topics over time really helps them think and learn". Educators noted a shift from more didactic practices, such as providing facts and demonstrating or leading experiments, to a more scaffolded approach that supported children to think, wonder, and form new ideas through intentionally planned materials, experiences, and interactions. As one educator said, "It made me take a step back and allow the children to take the lead instead of me just giving directions; now I know how to encourage them to explore and investigate".

As Science Big Ideas moved to the forefront of educators' planning, learning goals needed to be aligned to all domains of the state's Early Learning and Development Standards. SISTEM created and provided educators with crosswalks and supportive documents to strengthen their curriculum planning. This immersive approach was embraced by educators as they planned and implemented experiences that provided rich, connected learning. Educators identified learning goals, such as "*measurement and data*" as children checked the changing size of shadows and recorded their results, "*use of rich, expressive language*" and "*use of new vocabulary*" as children talked about what they were doing and how they created a shadow to look like an object and changed its size, and "*approaches to learning*" such as pride in their accomplishments, persistence, problem-solving skills, creativity, and fine motor skills.

Educators also reflected on meeting the needs of the EMLs in their classrooms. One teacher noted, "This approach has allowed me to meet the needs of all of the children in my classroom. Most of the learning goals in math, cognition, language/literacy, fine motor development, and even the creative arts can be supported in a dynamic and interactive way. The children are so engaged, and seeing them apply their skills as they investigate these topics has been so exciting".

3.3. Impact on Caregivers' Understanding of the Importance of Science Learning and Awareness of STEM Careers

After participating in SISTEM, caregivers rated their understanding of how science can help their child develop language skills and their awareness of potential STEM careers before and after participation. Responses indicated that both increased significantly. On average, parents' ratings of their understanding and awareness of STEM careers changed from "Somewhat low" (a rating of 3 on the 6-point scale) to "High" (a rating of 5 on the 6-point scale; See Table 5).

Table 5. Caregivers' science beliefs and attitudes.

Science Beliefs and Attitudes	Before SISTEM M (SD)	After SISTEM M (SD)	Difference (After–Before)	SE Mean	t (df = 9)
Understanding of how science can help my child develop language skills	2.80 (1.48)	4.90 (0.74)	2.10	0.50	4.16 *
Awareness of STEM careers that my child might be interested in someday	3.10 (1.52)	5.00 (0.82)	1.90	0.43	4.39 *

* $p < .01$.

3.4. Impact on Caregivers' Confidence in Engaging Their Children in Science and Working with Their Child's Teacher to Support Their Child's Learning

Following the SISTEM program, caregivers rated their comfort and confidence in supporting their child's science learning as having significantly increased from before their participation in the project (See Table 6). The biggest change as rated by caregivers was in their confidence around working with their child's teacher to support their child's science learning. Individual interviews confirmed this sentiment; as one parent noted, "I love how the teacher shared about the science children were doing at school, because then I could explore some of the same things with him at home and send [the teacher] pictures too". Another caregiver said, "I am closer to the teacher just because of all those workshops and the times where I would go to the science center and [my child's] teacher would be there as well".

Table 6. Caregivers' confidence engaging children in science.

Science Beliefs and Attitudes	Before SISTEM M (SD)	After SISTEM M (SD)	Difference (After–Before)	SE Mean	t (df = 9)
Interest in exploring science with my child	3.30 (1.16)	5.00 (0.94)	1.70	0.34	5.08 **
Belief that exploring science is a fun way to spend time with my child	3.60 (1.17)	5.20 (1.14)	1.60	0.45	3.54 **
Confidence that I play an important role in supporting my child's science learning	3.40 (1.27)	5.20 (0.63)	1.80	0.39	4.63 **
Confidence in working together with my child's teacher to support my child's learning	3.20 (1.23)	5.30 (0.68)	2.10	0.41	5.16 **
Comfort in visiting the Connecticut Science Center with my child	3.50 (1.58)	5.40 (0.84)	1.90	0.57	3.24 *

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

3.4.1. Families Interacted with Their Children around Science at Home and in the Community and Were Empowered to Share Their Explorations with Their Children's Teachers and Others

The documentation obtained of families interacting during their home explorations and data from the PE meetings indicated that small moments of family connection have the potential to be valuable learning opportunities for children and their parents. In some cases, parents described how they had observed a child's knowledge and skills in action that they had not noticed before and became notably excited at seeing what curious and capable young scientists and problem-solvers their children were becoming. During the first virtual PE meeting, one parent was so delighted by her child's engagement in water explorations that she spontaneously shared her screen to show and describe a video of her daughter at the kitchen sink exploring water with the cups, baster, clear tubing, and funnel from the home science (Water) kit. During a breakout session at the second PE meeting, a parent who appeared hesitant to speak up in the full group shared during a breakout session with her child's teacher (in Spanish): "At home [my child] rolls his cars and his balls down everything. He thinks the bigger balls and cars with bigger wheels go faster. I use vocabulary with him too. What happened with this ball? How much more does it weigh? Which one is the smallest? And yesterday we talked about how the one that has more weight goes farther than the other ones".

The videos families shared that included interactions between and among family members were particularly revealing. After the third PE meeting (focused on Shadows), a parent shared a video of her and her daughter discussing their own shadows outdoors as they headed to their car for the trip to school. In the video, the child moves excitedly around her mom in an effort to find a position that allows both of their shadows to appear distinctly ("Mama, get off my shadow!"). The mother then encourages her child to stand next to her so that both of their shadows can be seen distinctly. This prompts a conversation about their "bigger" and "smaller" shadows and how the relative sizes of their shadows change when they move in relation to one another. Mom then playfully encourages the child to try to escape from her shadow, and the child excitedly runs toward their car, simultaneously observing her shadow.

3.4.2. Families, Educators, and School Staff Gained Familiarity with CSC and Its Exhibits, Offerings, and Resources, and Explored Connections to STEM Careers

The three "I Love Science!" events brought a substantial number of SISTEM Focus Families, SISTEM educators and program staff, and educators' families to CSC. Extended families attending the events included grandparents, aunts, uncles, and cousins; one program director was accompanied by three generations of her own family, including her infant great-granddaughter. The "passports" in English and Spanish distributed at Events 1 and 2 and the map of CSC exhibits and activities provided at Event 3 (all in English and Spanish) empowered families to navigate CSC independently and to focus on exhibits and activities related to the SISTEM topics and relevant career connections (e.g., the Build a Roller Coaster exhibit for Ramps, the Forecast the Weather station for Shadows). In addition, CSC had added signage in Spanish and English to two exhibit galleries in 2023, along with general Spanish-language building signage for navigating the center, which allowed for even more family agency in interacting with the exhibits and experiences. Being able to navigate CSC in self-selected groups of families and educators also enabled participants to engage with other exhibits of interest to them that may not have been directly connected to the topics being explored at school and at home, piquing their curiosity and motivating them to return for another visit.

After the first CSC event, families began asking about the benefits of membership, attending special CSC events, and making return visits. Educators also made return visits with their own families, and one partner preschool program brought all their students on their first ever schoolwide field trip to CSC.

Having STEM Community Helpers at the events facilitating additional preK-level activities added value to participants' experiences. For children, families, and educators alike, it was inspiring to interact with adults in STEM roles who represented their own ethnicity, culture, and language. Several SISTEM parents reported that normally they would just walk by activities facilitated by science center staff because they could not understand the activity guidance provided. The presence of STEM Community Helpers who were native Spanish speakers enabled these families to participate in the activities and interact in their home language, fostering their feeling of belongingness in the science center.

4. Discussion

Results from educator survey data indicated that SISTEM educators grew in their sense of self-efficacy in science teaching—and specifically in science teaching for EMLs. While these results are correlational in nature, based on existing research on effective PL experiences for educators, we theorize that engaging educators with interactive, hands-on learning opportunities in workshops tied to classroom practice [80–82] and providing educators with chances to reflect on their practice that included opportunities for ongoing support through a virtual PL community [8] helped to foster educators' feelings of comfort, thus facilitating high-quality science experiences for EMLs.

To ensure that our instruction was responsive to educators' needs, we employed an ongoing process of formative assessment during the PL sessions. For example, in our first PL session, we engaged educators in two adult immersive explorations of water—one open and one focused—with the goal of building their content knowledge related to the topic. However, we learned from subsequent PLCs that educators were not fully leveraging the *PEEP* resources as they planned Water explorations for their own classrooms. To help them do so for Ramps and Shadows, we changed our approach; in PL Sessions 2 and 3, we invited educators to engage with five or six topical stations drawn directly from *PEEP* rather than in one open and one-focused immersive experience.

Based on observations of educators' science teaching, contrasting SISTEM classrooms with comparison classrooms, and assessing changes from before and after program implementation, results indicate that SISTEM was associated with increased quality in educators' science teaching. Given that our sample of classrooms was quite modest, we were pleasantly surprised to see a significant change in teaching practice related to promoting children's use of scientific inquiry, which was a major emphasis of the PL. The magnitude of this effect—a one-point difference between SISTEM and comparison classrooms on the STERS coding rubric (i.e., a change from "inadequate" to "adequate" support for children's science inquiry)—represents a meaningful difference. Based on indicators for these scores in the STERS codebook [78], this could be described as a shift from talking about science experiences "*as a way of providing information or giving instructions*" to encouraging "*discussions and/or reporting on science experiences*", or a shift from providing children with science experiences that afford "*isolated opportunities for inquiry*" to supporting children to use "*specific scientific inquiry skills, such as exploration, observation, and sharing*". This shift aligns with educators' self-reflections that they had moved from one-time science activities to long-term investigations, and from a didactic approach of imparting science knowledge to a scaffolded approach to supporting children's genuine use of inquiry. These are meaningful changes in teaching practice that have the potential to shape children's ability to use inquiry skills.

Interestingly, comparison teachers showed a slight improvement in their spring scores on a specific STERS item: "*Facilitate direct experiences to promote conceptual learning*". This may have been related to the topic of Shadows. Although teachers were free to choose any science topic for their fall observation, all teachers led an activity related to Shadows in the spring. For this item, teachers were evaluated based on the degree to which they structured "*science experiences that provide a high level of engagement, allowing children to directly experience scientific phenomena*". Asking teachers to explore a physical science topic that is conducive to direct exploration may have naturally increased this aspect of quality in science instruction. It is also possible that for programs that included both SISTEM and comparison classrooms, SISTEM educators may have shared some of what they learned with comparison classrooms over the course of the year.

An important part of supporting children's use of scientific inquiry is asking productive questions. This is a sophisticated skill that involves not only knowing the kinds of questions that can support inquiry, but also knowing when and how to ask such questions, based on a teacher's specific learning goals for the children and on children's cues, responses, and unique language skills. Analysis of classroom observations and educators' self-report survey data indicated that educators improved in their ability to construct and use questions to elicit student thinking and then move it forward. Central to supporting teachers to carry out this work was to have an emphasis in the PL on integrating science inquiry and language development and leveraging children's home language to support their engagement in science. We supported monolingual and bilingual educators in using strategies to foster both children's home language skills and their English language skills in the context of rich explorations of science phenomena. For some participating teachers, especially those who had been trained to conduct instruction in English only, thinking about EMLs' home language as an asset to learning required a paradigm shift. However, as educators moved to an asset-based approach to multilingualism, they were supported to engage with families in a way that allowed for reciprocal sharing and learning.

Caregivers who participated in SISTEM reported increased positive beliefs and attitudes about supporting their children's science learning and interest in STEM. Based on caregivers' reflections, these shifts in thinking may have been supported by shifts in their relationships with their children's teachers; feeling connected to the teacher and the learning happening in the classroom gave caregivers confidence to explore science at home and at the science center. Once families started exploring science together in these contexts, their positive experiences of having fun together as a family were self-reinforcing. Interestingly, families reported a substantial increase in their understanding of the importance of science for their child's future career and their awareness of the types of STEM careers their child could have later in life. This is an important marker, as particular parent behaviors—such as being actively involved in their children's science learning, initiating and sustaining science talk, and making connections between science and their children's daily lives—are associated with sustaining children's engagement in science [13,18,83,84]. Additionally, ISLE experiences have been shown to build parents' confidence and agency in supporting their children's science inquiry [15,85]. This study provides further support for linking formal and informal learning environments in science.

Assessing child outcomes was not within the scope of this study; we suspect, however, that supporting educators and primary caregivers to engage together in reciprocal sharing and learning and to plan rich and connected science experiences for EMLs across contexts may be especially powerful for supporting children's learning, particularly for EMLs [45,46,67,68]. Future research should investigate how this approach can support changes in child outcomes, including interest in STEM, ability to engage in science inquiry, and language skills. Importantly for EMLs, this approach has the potential to build children's oral language skills in both English and their home language, while simultaneously building conceptual learning in science.

While ISLEs have not historically acknowledged the sociocultural aspects of science and science learning, this project showed that a partnership between families, schools, and the community can shift the power dynamics of an institution from one that typically reflects broad historical and systemic inequities [66] to one that promotes and values alternative ways of knowing and learning science, and highlights the critical role of language in science sensemaking [86,87]. Additionally, a unique component of this project was to leverage the science center's connections in broadening the local community's awareness of STEM by engaging diverse employees from local STEM industries to serve as powerful STEM role models—specifically engaging role models who reflected children's and families' ethnicities and languages. Introducing Spanish-speaking STEM professionals as role models may have helped to broaden families' understanding of what STEM careers look like; in addition, it supported families in seeing their children as capable of doing, learning, and pursuing STEM opportunities.

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