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Family Learning Opportunities in Engineering and Science

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Abstract

Students who are of low socio-economic status or English language learners do not have the same opportunities to learn science, technology, engineering and math (STEM). These students are the future citizenry and need the tools a good STEM education can provide to, not only make decisions for themselves and their families, but for their communities and our world. Our study in the United States examined how working with English- and Spanish-speaking kindergarteners and their parents in science and engineering sessions provided the opportunity for these low-income families to do science and engineering activities together. We found the experiences helped students learn more about science, scientific practices, and developed science self-efficacy in parents, who changed the way they talked about everyday science with their children. The model of educating children and parents together, using their home languages, to promote STEM learning, builds upon the important work in this field.

Key Words: science education; family learning; emergent bilinguals; language learning in STEM; elementary education; self-efficacy

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Introduction

As our everyday world becomes more technologically advanced, we, as educators and researchers of diverse student populations, are concerned with methods to provide access and support for all members of our community to science. Finding ways to bring science and engineering into the lives and vernacular of young students and their families is a challenge for schools and society. We present this research study as an example of one approach that successfully altered families' view and practice of science outside of school.

Social Justice Impetus for This Work

Students of low socioeconomic status (SES) have a reduced opportunity to learn science, technology, engineering, and math (STEM) in the classroom and the community, with consequences for their ability to be part of an informed future citizenry (Tate, Jones, Thorne-Wallington & Hogrebe, 2012). A report put forth by the National Assessment of Educational Progress (NAEP) identified an existing gap in science achievement for English Language Learners (ELLs) (National Center for Education Statistics, 2012): “At a time when the need for more support for STEM education is critical, many state and district STEM teams are being down-sized or eliminated” (PCAST, 2010, p.19). Harvard’s Saguaro Seminar reports concerning trends in societal data spanning the past 30 years: compared to children of the 1970s, future success of today’s youth is in jeopardy because of growing income inequality and changes in family structures, creating an increasing “class gap” of opportunity, social capital, and civic engagement (Putnam, Fredrick and Snellman, 2012). Putnam et al.’s research highlights parents’ time spent with children as a predictor of future success.

The present study aimed to explore parental interaction with kindergarteners from linguistically diverse, low-SES backgrounds in STEM learning contexts to increase interest and self-efficacy in these areas. Rather than identify the children as “English Language Learners,” we choose the term “emergent bilinguals (EBs)[1], to emphasize their capacity to learn about and describe their learning in two languages.

The broader goal of this model is to educate parents and children together, for the betterment of their communities and personal futures through increasing STEM literacy. Scientific illiteracy leads to poor reasoning strategies and argumentation; skills critical to our increasingly technological society (Sadler & Zeidler, 2004). The Nation’s Report Card for 8th Grade Science in 2011 revealed gaps in achievement for African-American and Hispanic students (NCES, 2012) as compared with Caucasian students. Similar disparities exist for achievement in mathematics. However, gaps in knowledge and skills form long before 8th grade testing. According to the Northwest Evaluation Association, “almost 70 percent of the gap in math achievement is created before the beginning of second grade…” (Fielding, 2006, pp. 32). One study found inequities in science, between white males and other groups, in third grade (Kohlhaas, Lin, & Chu, 2010). These statistics and research provide an impetus to study STEM interest and learning at the kindergarten level, the focus of this project.

Student achievement in the STEM disciplines has been attributed to a complex interrelationship of factors, including student ability and attitude, teacher preparation and quality, socioeconomic factors, home influences, and home-school relationships (Singh, Granville, & Dika, 2002). As Epstein (2011) notes, “Partnerships recognize the shared responsibilities of home, school, and community for children’s learning and development. Students are central to successful partnerships. They are active learners in all three contexts – at home, at school, and in the community” (p. 4). Quality early childhood education is characterized by high levels of engagement and participation among children’s parents and families (NAEYC, 2009; Henderson & Mapp, 2002), so models targeting young children necessarily require their parents’ involvement. Parents from underrepresented groups have been shown to be less involved with their children’s schools than White parents, even in kindergarten (Nzinga-Johnson, Baker, & Aupperlee, 2009).

Examining parental involvement was critical in this study to uncover the nature of its possible relationship to student STEM interest and learning.

Young Student Engagement and Self-efficacy in Science Learning

Student interest in STEM subjects is influenced by attitudes of their parents in the same subjects (Singh, et al., 2002). Student engagement has shown to be an important factor in learning; more significantly, *disengagement* is a barrier to learning (Carini, Kuh, & Klein, 2006; Marks, 2000; Steinberg, 1996). Student interest and engagement in U.S. schools has been problematic, and therefore improving it is a challenge (Steinberg, 1996). Engagement in school is important to cognitive development; engaged students are more likely to pursue higher education (Carini, et al., 2006). For instance, studies show that students' experiences in mathematics strongly affect interest in the domain and that "interest is a significant predictor of student achievement in mathematics" (Singh, et al., 2002, p. 324). Not only are American children falling behind in achievement in STEM, but there is also a pervasive lack of interest in these disciplines (PCAST, 2010). Thus, it is important to give young children positive experiences in the STEM areas, sparking and maintaining their interest in these disciplines. As Heilbronner (2013) states, "Many scientists who achieve prominence in their fields discuss how they knew from a very young age, often as early as 6 or 7, that they were interested in science" (p. 115). A meta-analysis of science education strategies revealed that making topics relevant to students can result in increased engagement in science (Schroeder, Scott, Tolson, Huang, & Lee, 2007). Bringing in family members and science work in the home are ways to draw upon student capital to promote culturally-relevant science teaching to increase engagement (Paris, 2012; Weiland, 2015).

Among young children, learning in science is individualized, active, and exploratory. A willingness or desire to explore one's environment is also fostered through early experiences at home where initiative and self-confidence is actively encouraged. Thus, Mantzicopoulos, Patrick & Samarapungavan (2008) found that children "engaged in integrated science inquiry and literacy activities for a longer time reported higher overall motivational beliefs for science than those who experienced the activities for a shorter time (p. 389)." High-quality science experiences build a critical foundation to support future science knowledge and interest (Gerde, Schachter, & Wasik, 2013). As a result of these extended, and perhaps more satisfying experiences, young children exhibit a greater sense of self-efficacy with regards to science learning. This concurs with studies showing in-depth, gratifying, science experiences as contributing to lifelong learning (DeJarnette, 2012) in science for adults. Bagiati, Yoon, Evangelou and Ngambeki (2010) highlight the importance of STEM activities for our youngest students as a way to build interest and proficiency before content becomes unfamiliar and overwhelming in later grades. Further, incorporating engineering design with elementary students, for instance, can improve student enthusiasm for learning, self-confidence, and process skills (Rogers & Portsmore, 2004). The role of parental encouragement in these pursuits and time experiencing STEM has a direct impact on students' self-efficacy beliefs (Mantzicopoulos, et al., 2008). This study engaged researchers in supporting parents' STEM interactions with their kindergarteners in an informal setting to foster children's early STEM understandings, specifically in regards to the ways the children use science and engineering practices at home.

Parental Involvement and Self-efficacy

Communities and families possess funds of knowledge in science that can be untapped resources to help connect school science to existing historical and cultural knowledge of science by a family (Moll, Amanti, Neff & Gonzalez, 2001). By utilizing knowledge and experiences that families bring with them, STEM connections can be more meaningful and productive. Civil, Bratton, and Quintos (2005) conducted a comprehensive out-of-school math program with Latino parents that emphasized the role of parents as teachers, parents, learners and ultimately facilitators, leading others in the community. Their research illustrated the role parents can take in their children's learning when participating in a community-based program led by researchers. Another math education study including parents as observers of fifth-grade tutoring sessions illustrated how parents' involvement influenced their attitudes and support provided to children (Westenskow, Boyer-Thurgood & Moyer-Packenham, 2015). Although these programs differ from this study, the power of parent involvement is salient across contexts. Providing "space" for varied forms of parental engagement in schools is one avenue to draw in parents as learners and advocates for their children.

Research on parental engagement and negotiation of school and space illustrates how dynamic the school learning community can be. Parents call upon their own funds of knowledge and social capital to create a place for themselves within the school, finding ways to be present and have a voice in their child's learning and education (Barton, Drake, Perez, St. Louis, & George, 2004). According to the framework of Hoover-Dempsey, et al. (2005), parents who clearly understand what they can do to encourage and support learning in STEM disciplines for their young children will be able to convey a sense of confidence that builds self-efficacy in their children. Epstein (2011) notes that the most significant type of at-home parental involvement is supervising any learning activities at home. Early preparation is inextricably linked to later achievement; increasingly, research is focused on providing supports to parents to facilitate their involvement that may accelerate achievement or mitigate risk factors that threaten it (Henderson & Mapp, 2002).

Creating a supportive home environment, attending school events, or monitoring progress in learning are all examples of strategies of parental involvement which contribute to student achievement (Hoover-Dempsey, et. al., 2005). In addition, parental involvement has been linked to students' motivation and sense of personal efficacy (Bandura, Barbaranelli, Caprara, Pastorelli, 1996); these reinforce outcomes in the manner of a positive feedback loop. The belief that education is important and that one can and will succeed in school is a powerful contributor to achievement (Grolnick & Slowiaczek, 1994) and is largely instilled by parents. In fact, increasing parental involvement in the earliest grades can produce long-lasting benefits, such as decreased grade retention, higher graduation rates, and higher rates of participation in advanced placement courses (Barnard, 2004).

Because parents are influential vectors for signaling the significance of STEM education, it is important to understand parents' existing STEM experiences and understandings. Adult learners are best motivated by the desire to enrich their own experience in ways relevant to and able to be integrated into daily life (Knowles, Holton, Swanson, 2011).

Importance of Language

To support involvement and comprehension, this project was offered in both English and Spanish. While use of the home language is essential to communicate with parents who do not speak English, it also presents advantages for the children's learning. Young EBs benefit academically from robust vocabulary in their home language (Kieffer, 2012; Rinaldi & Páez, 2008). There is growing evidence of cross-language transfer of emergent literacy skills from the home language to English (Cummins, 1994; Lopez & Greenfield, 2004; Oller & Eilers, 2002). As the activities modeled scientific vocabulary in Spanish as well as English, all children in the study were exposed to new academic language and vocabulary, which enhances literacy skills. Further, "when students, especially ELLs, are adequately supported to 'do' specific things with language, both science learning and language learning are promoted" (Lee, Quinn & Valdés, 2013, p. 224). Authentic learning experiences, paired with opportunities to share thinking and learn new vocabulary, are critical for the cognitive development in EBs (Huerta & Jackson, 2010). Further, as part of the activities, children were encouraged to draw their observations to support science learning; ". . . children use drawing to communicate with others, while they often combine it with other ways of meaning making so as to improve communication" (Papandreou, 2014, p. 97).

Spanish-speaking children also need introductory school experiences in the native language in order to support cognitive development (Gándara & Contreras, 2009). Bilingual approaches which utilize English and the students' home language for instruction demonstrate significant gains for EBs which potentially neutralize some of the effects of poverty (Barnett, Hustedt, Hawkinson & Robin, 2006; Collier & Thomas, 2009). In addition, bilingual instruction is associated with greater rates of school readiness in the domain of Language and Cognitive Development which includes skills similar to scientific inquiry, such as describing similarities and differences, remembering details about objects, and recognizing numbers and shapes (Tazi, 2014).

Parent Self Efficacy

A parent's sense of his or her own capacity to support their children's learning is a factor in their involvement in schools; stressors due to poverty, overwork or parent demoralization are associated with low persistence in supporting learning (Hoover-Dempsey & Sandler, 1997). Increased self-efficacy among parents is meaningfully related to school readiness and adjustment (Okado, Bierman & Welsh, 2014).

According to Bandura (1997), participation in four kinds of interactions may enhance perceived self-efficacy; i.e., mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states. First, the most influential mode that self-efficacy may be developed is through *mastery experiences*; these provide opportunities for the individual to engage in, and to preserve in, building mastery status. "A resilient sense of efficacy requires experience in overcoming obstacles through perseverant effort" (p. 80). Overcoming obstacles to achieve provides a lasting sense of ability to succeed in the given task. Mastery experiences are complete when they involve some form of "social validation" (p. 81). Social validation provides a context for others to affirm the individual's success.

Vicarious experiences are powerful when the individual witnesses firsthand, or through another recounting the situation, a peer being successful at the task at hand. Knowing that another person, similar to oneself, can be successful in the situation helps to bolster feelings of ability and increase perceived self-efficacy. When an individual is exposed to vicarious experiences, it helps to develop self-efficacy through witnessing another person successfully perform the task at hand. This is even more powerful when that other is a peer.

Others can be influential in terms of supporting self-efficacy development through verbal persuasion, as well. Bandura (1997) explains that a trusted advisor or colleague who encourages an individual that he or she will be successful can positively impact the individual's development of self-efficacy towards a given goal. This effect is even greater when the individual has some belief they will be successful already.

The last method of developing self-efficacy beliefs is physiological and affective states, which is of utmost importance for those performing a physical tasks, but does plays a role for any individual. Physiological and affective states can influence an individual's perceived self-efficacy whether the task at hand is a completing marathon or making observations of an organism. Feelings of stress, anxiety, illness, etc. can all negatively influence a person's belief in their effectiveness to complete a task and can detract from self-efficacy development.

Focus on Scientific and Engineering Practices

To support science learning in this project, the Next Generation Science Standards (NGSS) (Lead States, 2013) were used as a framework for designing learning activities. This new set of standards provides age-appropriate, rigorous benchmarks for young children to *do* science, laying the foundation for scientific thinking and future science work. When students employ the practices, not only is it an engaging way to learn science concepts, but students are developing a deeper understanding of content and learning to think critically (Minner, Levy, & Century, 2010; Sadler & Zeidler, 2004). Additionally, engaging in the science and engineering practices requires the use of language, for communication and sense-making (Lee, et al, 2013). The importance of language in the investigations performed by families in this study was purposeful, as it was meant to promote family learning and engagement for science for all participants; for this reason all activities were conducted bilingually, in English and Spanish.

A Science Framework for K-12 Science Education (NRC, 2012) provides the basis for the NGSS practices. The NGSS delineates developmentally-appropriate benchmarks for students to reach by certain grade bands. This study employed two science and engineering practices for the focus of the learning activities:

> *Practice 4: Analyzing and Interpreting Data - Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.*
> *Practice 6: Constructing Explanations and Designing Solutions - Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.* (NGSS Lead States, 2013)

From these two practices, specific capabilities were addressed:

> *Practice 4: Record information (observations, thoughts, and ideas);* and *Use and share pictures, drawings, and/or writings of observations; Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.*

> *Practice 6: Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena;* and *Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem.*

These capabilities were selected because they are accessible as foundational pieces of doing science for young children and readily can be built upon by families in out-of-school contexts.

Program Description

The model of family learning described in this paper (Family Learning Opportunities in Engineering and Science - FLORES) consisted of kindergarteners and their parents attending two interactive events during the fall semester. These events were family learning sessions and dinner at the school designed to scaffold parents' STEM involvement with their children. Dinner was provided as an added incentive to support working parents, and as a way to foster conversation among the families. At each family session, the group of parents and students (15 students plus their parent(s) or guardian(s)) were split into two classrooms, each with one or two researchers, a school staff member who was bilingual and was assisting with the program, and two high school student helpers. One of these classrooms conducted all activities primarily in Spanish, with some English, and the other classroom exclusively English. The first evening began with researchers leading focus groups with children, while parents completed open-ended surveys. Next, parents and children were brought together to discuss their prior conceptions and experiences with a scientific topic – stimulus and response. A song connecting the terms and meanings was taught and sung by each group in either English or Spanish. Modeling included the use of scientific procedures and targeted science vocabulary to enrich learning. The families engaged in an inquiry activity focused on stimulus and response using earthworms to develop the use of NGSS science practices. The investigation was supported by researcher questions and facilitation. This guided inquiry activity was followed up with a whole group discussion. This sequence of events took place concurrently in English and Spanish, in separate rooms, each room led by principal members of the research team and supported by others, as listed above. Finally, the two groups were brought together for dinner and bilingual discussion. Between sessions, families completed home investigations of their choosing, related to the theme of stimulus-response, utilizing the science notebook and science tools provided during the first session in their take-home 'science bag.' The academic activity, paired with the social activity of eating together, was designed to engender a relationship among researchers, children, and parents.

The following session progressed similarly, with the addition of parent coaching. Due to their heavy involvement during the first session, parents were instructed briefly on the role of questioning and the goal of having the children do the activities independently, with their support and participation, rather than parents controlling the investigation. The at-home science activity was discussed at the start of this meeting and the children's science notebooks were shared. This session included a physical science exploration of sound waves through observing children's musical instruments and culminated with an engineering design activity of creating a cup telephone. Again, the science explorations were followed by discussion and then dinner with the both Spanish- and English-speaking groups. During the family sessions cycle, participant researchers made observations and notes throughout all parts of the evening, even switching roles and/or rooms.

The at-home science activities were extensions of the family sessions. This type of 'homework' has proven effective in other schools (Ashbrook, 2012) and provides an opportunity to continue STEM discussions at home. The home environment and behavior of parents contribute directly to what children demonstrate in STEM skills. The foundation for these skills is laid in the home, as those skills are highly dependent on linguistic inputs such as conversing and describing, as typically occurs between parents and young children (Kleemans, Peeters, Segers, Verhoeven, & 2012). The goal of the at-home science activities was to sustain and develop at home STEM talk that first occurred in the family sessions. As Epstein (2011, p. 126-127) notes, "home assignments that ensure responsibilities and goals of stakeholders are clear and attainable," suggesting a great need for more research on methods for advancing that successful path to improved STEM education.

The family sessions were intended to provide a space where parents could develop self-efficacy in STEM interactions with their child through mastery experiences, verbal persuasion, and vicarious experiences, as described in Bandura's self-efficacy framework (1997). These modalities help develop an individual's self-efficacy in the given task, which help predict the individual's future behavior. The goal of building parents' self-efficacy is to then effect change in their behaviors with their children to support STEM learning.

This study's model views the role of the parent as a critical element in STEM learning and achievement for young children, particularly those living in poverty conditions. The model identified key approaches to engage parents and children:

- If we are to expect parents to assume a role of first teacher to their children, it is imperative to use the home language for all activities.
- STEM activities for young children do not need to feel foreign or difficult, everyone learns from observation and discovery;
- Exploration of naturally occurring conditions can engage children and enrich STEM learning;
- By guiding and satisfying children's curiosity about their environment, parents can increase STEM learning for young children;
- STEM activities can be part of the routine parent-child interactions; they do not require special materials or training;
- Children respond to authentic, self-directed tasks to stimulate their learning.

Research Framework

This study's goal was to examine ways in which student learning and interest in science and engineering may be supported through parental involvement. Researchers led parent-student science-related activities at a partner school to develop productive parent-student interactions and student engagement and learning of science and engineering practices in informal science settings.

Research Questions:

1) How does parental involvement in two family sessions relate to students' use of Next Generation Science Standards science and engineering practices in diverse, low SES families in both English and Spanish?
2) What happens to parents' self-efficacy in interacting with their children on STEM topics when addressing their science understandings and attitudes and by providing bilingual, guided opportunities for parents and children to spend time together on targeted STEM conversation and activities?

Methodology

Participants

Participants were two diverse groups of 7-8 kindergartners and their families. One group was composed of primarily English-speaking families, the other of Spanish-speaking families. Parents of kindergarteners who qualify for the federal, free and reduced-price lunch program were invited by a school staff member to be part of the project by volunteering to attend with their children two family science and engineering sessions and dinner conducted in English or Spanish. Parents who decided to participate committed to participation with their children to two evenings and data collection.

Setting

The Rivertown School (all names are pseudonyms), offers comprehensive early childhood education and services to about 370 kindergarten children throughout the neighboring community. The school is racially and ethnically diverse and serves an economically disadvantaged student population. The school has robust parental involvement and was enthusiastic about the project, being willing to commit resources (space and technology access) with their participation. One of the researchers had worked in the school previously and maintained an excellent rapport with the principal and personnel. This connection paved the way for this program to be implemented. The two family sessions and follow-up focus groups were held in the kindergarten classrooms of this school, with the meal portion of the evenings held in a school cafeteria.

Data Collection, Analysis, and Rigor

Focus groups were held with the children at the start of each family session, while parents completed open-ended questionnaires in English and Spanish. Follow-up focus groups with children were held at the end of the last session, while parents again completed questionnaires. A follow-up parent focus group was held a year later to discuss science activities and learning, as well as parent-child behaviors. The focus groups were semi-structured and conversational; an interview protocol was used but parents and children were encouraged to respond to one another and engage in conversation about their experiences. Using interviews is a valuable way to learn about respondents' changing and emerging ideas (Merriam, 1998). The interviews were transcribed, and researchers recorded observational notes during the focus groups. All activities were observed and by the researchers and extensive field notes recorded for observational data and triangulation. Other data sources included families' written work, such as activity sheets and take-home notebooks. The family worksheets became an important documentary data source for triangulation. Merriam (1998) points out that "one of the greatest advantages in using documentary material is its stability. Unlike interviewing and observation, the presence of the investigator does not alter what is being studied. Documents are 'objective' sources of data compared to other forms" (p. 126).

These qualitative data were compiled, summarized and interpreted on an ongoing basis. Researchers had frequent meetings to discuss data and analysis. Data were analyzed and coded for themes during several passes and then by sifting these codes through the conceptual framework of self-efficacy and the lens of scientific and engineering practices. Miles and Huberman (1994) describe this type of coding - using many separate examinations of the data along with grouping themes that are revealed - as "pattern coding:" "Pattern codes are explanatory or inferential codes, ones that identify an emergent theme, configuration, or explanation. They pull together a lot of material into more meaningful and parsimonious units of analysis" (p. 69). During the successive layers of coding, we used the process of "memoing" to write down ideas and emergent themes to aid the process of coding (Creswell, 2003; Miles & Huberman, 1994).

The variety of data and the time spent in the field are characteristic of a rigorous qualitative study (Creswell, 2003). These facets of the study also allow for triangulation by using different types of data collection (focus groups, observations, written work from activities and surveys), which may be drawn upon to increase rigor and assure validity (Denzin, 1970, 1978). Another element of rigor employed by this study included "participatory modes of research" in which the researchers were present during all activities (Merriam, 1998, pp. 204-205). Using multiple layers of coding and many passes through the data are also elements of rigorous qualitative research (Creswell, 2003).

Findings

(All responses in Spanish have been translated.)

Our data analysis revealed three themes – two relating to students' learning as supported by parental involvement and one relating to parental development. These findings were supported by varied data sources and relate directly to the theory underpinning our research framework. Students learned about science and how to ask as scientists through the study's activities, while parents developed their own self-efficacy for supporting their children's science learning in everyday life.

Children's Initial Ideas About Science

In both the English and Spanish-speaking groups, we found that initially students could not articulate what science was, much less, how to do science. When asked how the children did science at home and at school, student responses included:

- Child 1: We learned [to] count and do smart stuff."
- Child 2: "I do counting."
- Child 3: "When you learn to play new games."
- Child 4: "You need to have a lab to be a real scientist."
- Child 5: "You have to listen and learn to figure out what you can do."

Several students seemed to believe that science was like math—related to numbers and counting. In response, we re-directed our line of inquiry and asked: "What is science?" Responses included:

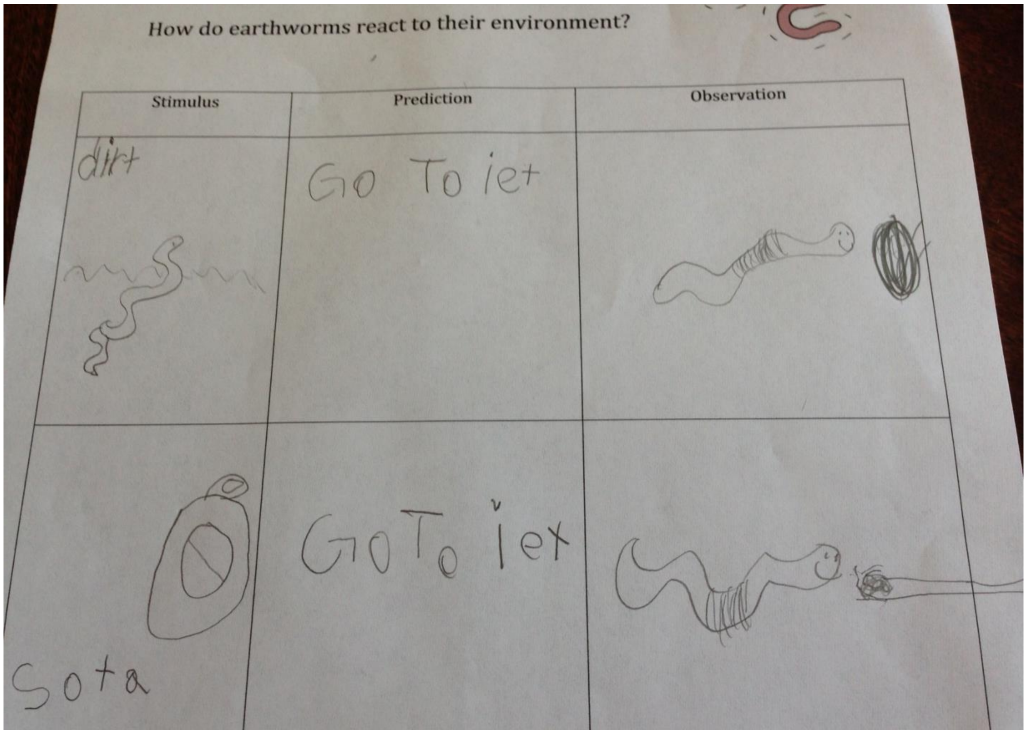
- "Science is important because we need it. Sometimes we learn things that are science. You learn about science so you can be grown up like a grown up.
- Child 2, similar to her previous statement, said, "I think science is like numbers."
- "Scientists look at things."

In both rooms, children struggled with describing what science is and what activities they do that are science. Not one child in either room could provide a correct explanation to their peers. This finding was evidenced in transcripts in each of the researcher-child interactions and all researcher notes. This finding was also discussed with parents during dinner: One of the parents came up to the researchers during the dinner portion of the night and noted that she was concerned that her daughter could not articulate what a scientist was. The students' lack of familiarity with science is even more intriguing and concerning since nearly all parents indicated in their initial questionnaires that they sought out science experiences for their children. However, the experiences cited by parents was limited to: taking walks, visiting museums, zoos and aquariums and watching programming such as: *Law and Order*, *CSI*, *Discovery channel*, *National Geographic*, *Animal Planet* and *PBS Kids*. These experiences also may not have been specifically labeled as science by parents when speaking to their children. Further, this study was conducted in the fall, perhaps these kindergarteners did not have the opportunity to have many/any science classes in school yet.

Learning to Use Science Practices

During the first session, we emphasized NGSS Science and Engineering Practice Four: *Analyzing and Interpreting Data*, and encouraged students to focus on observing skills and recording data in the form of drawing or text written by parents. Both parents and students exhibited a high level of engagement during this activity, which explored stimulus and response with earthworms (Marrero, Gunning & Tazi, 2014). Families explored varied stimuli with the worms and recorded the data, which was shared with their same-language group after the investigation. Students readily made observations and recorded their findings. After the exploration, both groups shared their excitement. Children noted: "Worms were the best part of the investigation" and they liked "watching the worm do twirls after tasting the lemons." Although several mothers noted they did not like touching the worms, parents in general liked the activity and said it was "impressive and interesting to do it with family" and "Important to have good observations otherwise you don't know what you found" and general excitement over the reaction of the worms to the stimuli.

Figure 1: A data sheet from the worm exploration



Similarly, during the second session, the family sessions focused on observations but geared toward NGSS Science and Engineering Practice Six: *Constructing Explanations (for science) and Designing Solutions (for engineering).* Students explored and observed varied children's musical instruments to learn about sound. After sharing observations and using evidence to illustrate that sound originates from vibration, families were charged with the problem of transmitting a message across the room. They used what they learned about sound waves to design a cup telephone. Some children and parents found out through design and experimentation that the string must be taut for the 'phone' to work and that if you are touching the string, it does not work. These observations and their modifications to the cup phone design/use showed they were creating a device to solve the problem posed to them. Several families had multiple designs, as they went from slack string to taut and then to larger cups.

Between the two family sessions, we challenged families to engage in science practices at home – to look for examples of stimulus and response in animals in their community and record them in their science notebooks. Children gained even more experience on *Analyzing and Interpreting Data* through this family activity, as evidenced through their notes and responses in both children's and parents' focus groups. Science notebooks and researchers' field notes both indicate that the concepts of scientific observation and stimulus and response were retained and practiced, providing evidence of students analyzing and interpreting data out of school. For instance, families were asked to observe examples of "stimulus and response" out in the community and record their findings in their science notebooks before the next meeting. One family went to a pet store to make observations, and noted: "The python curled into a ball when we touched the glass cage." Another family observed ducks and squirrels at a local park. A kindergartener recorded that his presence caused the ducks to swim and squirrels to run away, an example of stimulus and response. Another also visited a pet store and drew images of the fish she observed.

Figure 2: A student's depiction of the sound wave moving across the string.

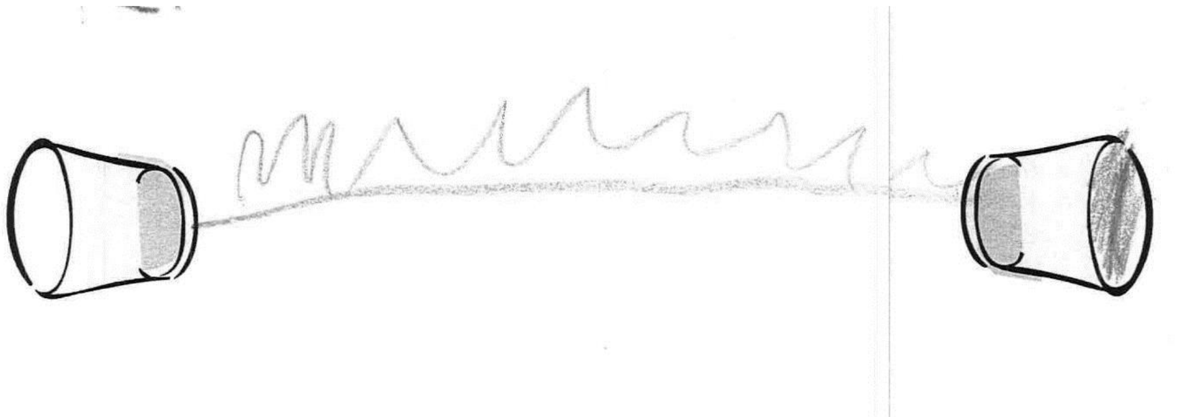
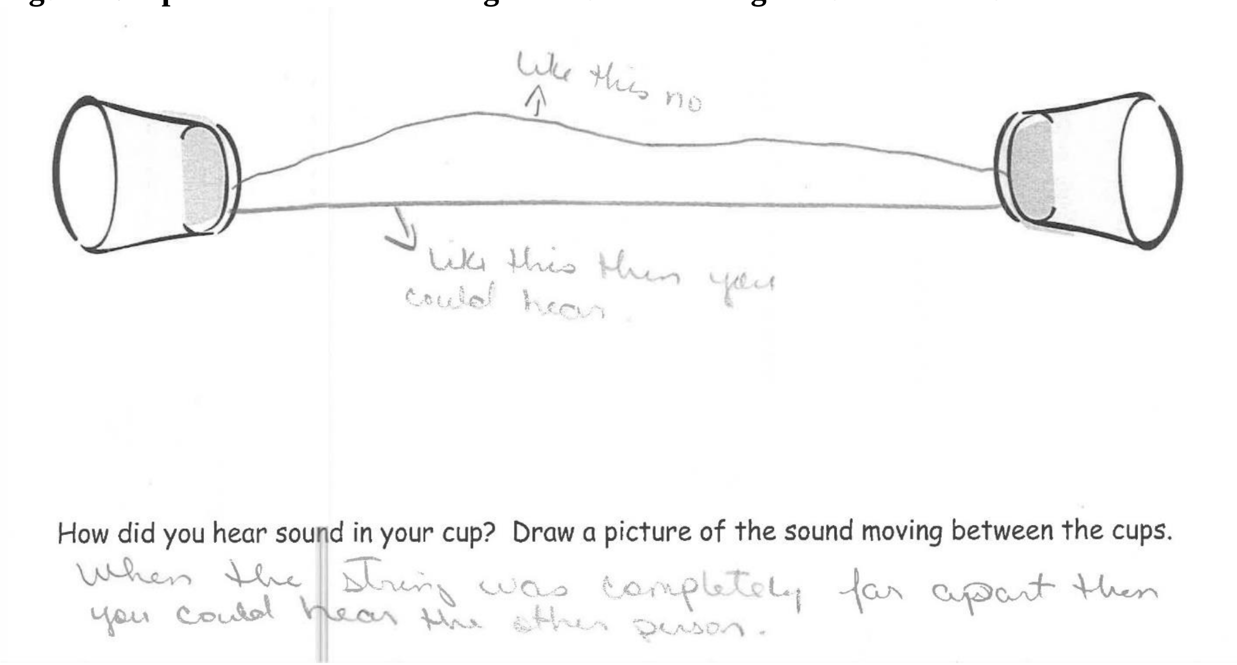
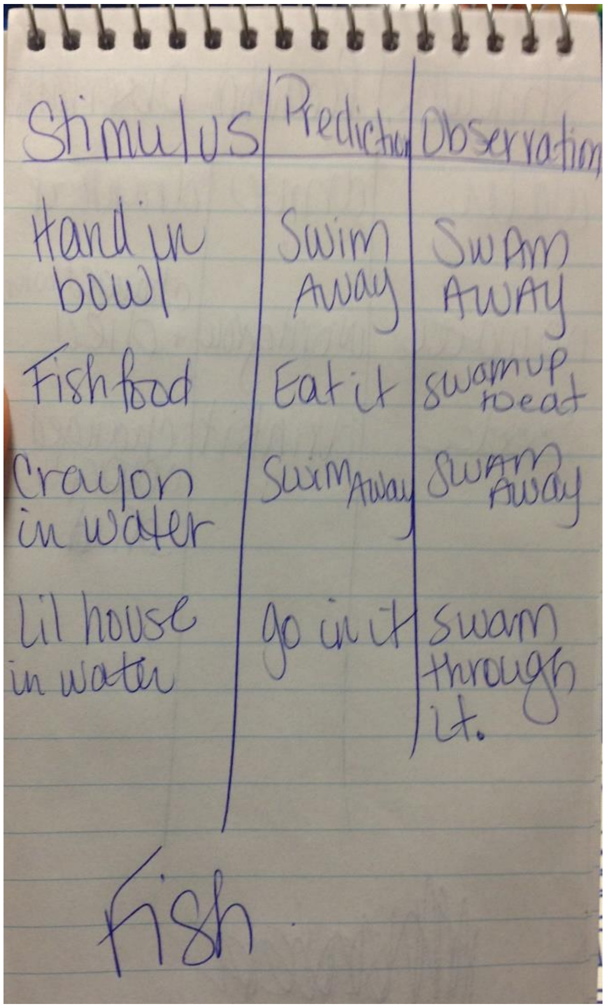


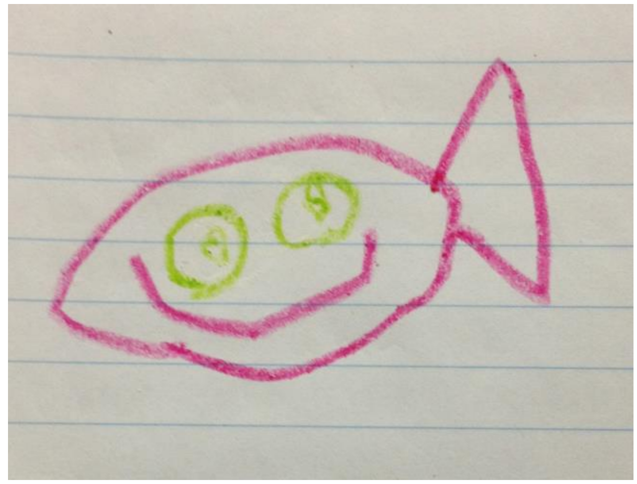
Figure 3: A parent describes needing to ensure the string is taut for the sound wave to travel.



Employing practice four in the context of observation of animal stimulus and response were the targeted concepts during the first family session; the data indicate that students, with support from their families, were able to apply the practice and identify the concept beyond the classroom. Through working with parents, children were able to record their "observations, thoughts and ideas;" "builds on prior experiences and progresses to collecting, recording, and sharing observations;" and in our next session "share pictures, drawings, and/or writings of observations." (NGSS, 2013, Appendix F, p. 9).

Figure 4: Examples of at-home science observations

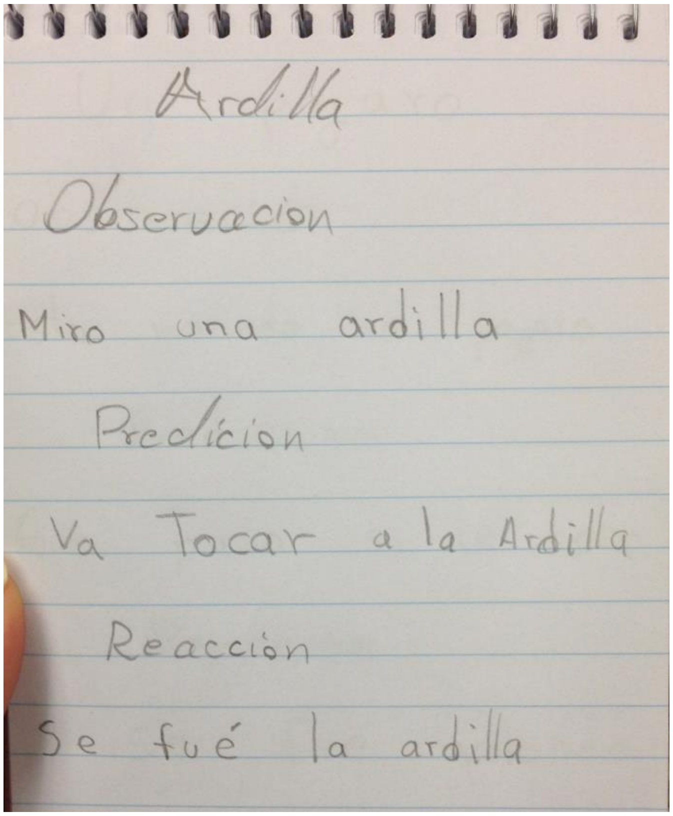


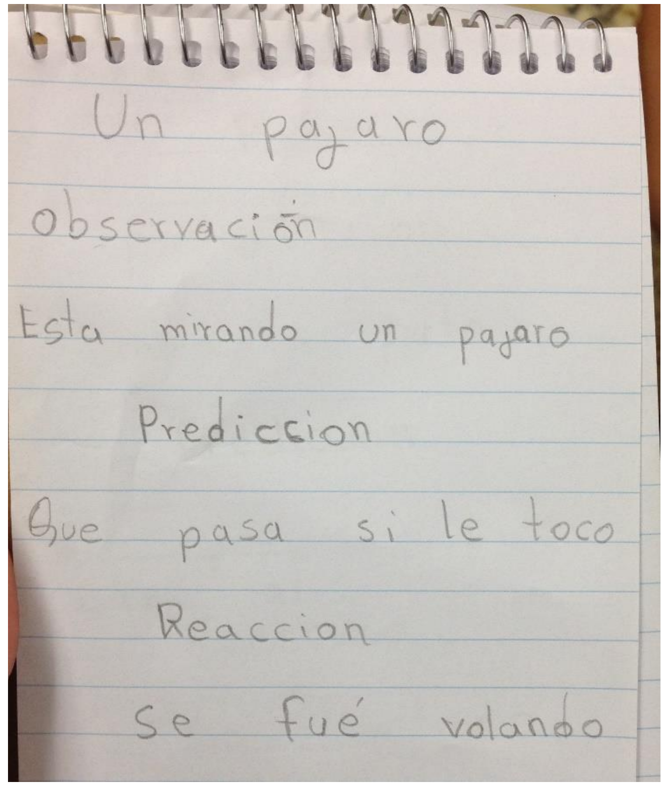


In the follow-up focus groups, conducted a year after the sessions in both English and Spanish, parents provided evidence of children's capability to use practices four and six. Parents reported many examples of children making observations, recording information, sharing it and using their scientific work to make sense of natural phenomena. Parents reported that students still use their science bags and tools, and are enthusiastic about science, relating the FLORES experience to new science experiences.

Several parents mentioned an increased use of STEM vocabulary, which was a focus during the family science and engineering sessions. Some examples of parents' accounts of student behavior are listed in Table 2. Although there were many examples of students and parents exploring animals and nature, fewer examples related to physical science were evident. Although the second family session focused on waves and sound paired with an engineering design activity, these topics were not mentioned in the follow-up focus group conducted a year later.

Figure 5: More at-home observations





Development of Parents' Self-efficacy

As mentioned above, parents initially reported interest in science, citing such activities as watching science-related television shows and taking their children to centers for informal science education, such as zoos and aquariums. Although the latter activity is more in-line with traditional views on science experiences, the connection parents made to their TV viewing, can be interpreted as at least an interest in science. These parents may have been particularly interested since they were willing to attend the family sessions.

During the first family session, parents exhibited enthusiasm for the worms activity, getting very involved, recording observations, reporting findings, and generally having fun. During dinner, there was much talk about the activity and a general positive feeling from the experience. This positive beginning to parents' participation set the stage for the development of self-efficacy for doing science with their children by providing a mastery experience, showing parents real science was accessible, and also assuaged reluctance by making it enjoyable, addressing their psychological and affective state. In the follow-up focus group, mothers described how the learning sessions made doing science with their children "fun;" and how after the mastery experiences, doing science "comes naturally now." These two modes of self-efficacy development are important, according to Bandura (1997).

Table 2: Parent responses describing student use of practices

	Evidence of Analyzing and Interpreting Data	Evidence of Constructing Explanations and Designing Solutions
Parent Reported Evidence	"[My daughter] likes to get the pad out to compare things."	"When the leaves were down, she brought a bunch of leaves and laid them out to see how long it took them to dry out."
	We went to the Hudson river and collected various rocks. My son was helping his sister classify them. "	"My daughter decided to grow lima beans at home. She put them all in a jar. The first time she watered them too much and they spoiled. She tried again and again. I knew she had done it in school but she wanted to do it at home. Now we have a plant."
	During a camping trip: "Everywhere we went, he used it (the science bag). To learn about the cave, he took out his magnifying glass and measuring tape."	I went for a walk with my son and he found what I thought was the shell of a bug. He said, "there's a butterfly in there." I said, "yeah, okay." I didn't want him to be disappointed but I let him bring it home. He put it in a jar and watched and watched. Would you believe that one day a butterfly came out of it? My son said he had done this in school but it was amazing to me that he recognized the cocoon in the street. I didn't know what that was. I knew to let him do things – to let him experiment – from the program.
	"My child is measuring everything with the measuring tape – how tall his sister is, the size of our heads and waist. He's very serious about it and we all enjoy it."	I think my children do think and make predictions. We went camping and we kept hearing a little animal and we guessed what it could be. The next day we saw that it was a frog. My son [who attended the program] had made more predictions than my daughter.

While parents reported pleasure and increased motivation resulting from the worm investigation for both themselves and their children, they also required greater guidance than initially expected. Parents behaved as "co-explorers," completing children's experiments for them or anticipating findings. Although this was a strong indication of parental engagement and a positive psychological and affective state, it diminished the opportunities for children to organize their own learning. This was the only significant 'challenge' that presented itself – if you call it a challenge – we really found it to be a wonderful opportunity. As a result, during the second session, parents were coached on how to act as facilitators and were successful in that role. This was an opportunity for verbal persuasion, to support parents' self-efficacy development through the researchers' guidance and encouragement that parents could be science teachers for their children. The need for this conversation with parents arose from the data collected from the first family session, and was originally unplanned, but served as an important development in the experience of parents. The researchers had built a rapport with parents from the last science investigation and sharing of a meal. There was a good sense of familiarity among nearly all participants and researchers as they informally shared parenting stories and life experiences. Researchers were well positioned to provide verbal persuasion for parents to facilitate their own child's learning.

Parents responded positively, successfully facilitating and guiding during the second night of investigations, instead of taking over for their children. After the activities, they expressed the importance of their children being well prepared in STEM proficiencies, and for the significance of foundational experiences. We learned that parents enjoy the STEM activities and respond well to taking a teaching role, letting their children explore, after they are instructed on best practices for doing so – for example, using questions to scaffold learning and focus children or encouraging students to support ideas with evidence. In response to the follow-up survey, one parent in the study responded to a question regarding whether she would like to learn more about STEM topics: "Yes, I would like to make more moments teachable moments." As this example illustrates, parents may successfully adopt a notion of themselves as science teachers. When asked in the final survey at the end of the second session 'How did you feel about being a co-teacher today with your child?' Responses included:

- "I liked being directly involved with teaching her."
- "I feel like I get to bond more as a co-teacher with my child."
- "I loved it because I know he's excited when I help him."
- "I think that parents being present made a difference – without us they might have felt unsure of themselves."

All parent responses were positive answering this question. This positive feeling seemed to turn into a sense of self-efficacy for doing or supporting science investigations for their children because similar feelings were expressed in the follow-up focus group a year later and much evidence of more science going on at home was reported (see evidence of students work relating to practices in Table 2). Further, parents reported purposefully seeking out more science experiences (or now labeling them as such) for their children, from nature walks; to going to the beach to hunt for shells; or taking them to a science event at the high school. Not one parent mentioned watching science-related television programming during this focus group. Parents had a more authentic idea of what doing science looked like and what skills were important. Parents described many examples of children measuring and observing and using these skills to understand natural phenomena.

The follow-up focus group a year later provided rich evidence of parents' self-efficacy for doing science and supporting science learning with their children and employing the science practices, e.g., analyzing and interpreting data. Further, asking parents to act as facilitators of science learning led them to take on that role after the sessions ended. Birbili and Karagiorgou, (2009) noted that teaching parents to ". . .ask better questions has benefits for parents themselves: It can enhance their self-esteem, as they feel that they are giving their children the support they need" (p. 20). Parents reported that the program gave them the tools to approach science and empowered them to feel like they could do it successfully with their children. One family observed the birds in the neighborhood and recorded that some ate worms from the ground but others only ate at the feeder. They reported observing the birds for a while before identifying them on the internet. The parent commented that watching birds had always been a pleasant pastime but now it seemed like a valuable activity for her child. She also understood how her own role in "helping my son be a scientist" helped him build skills and stamina to observe the birds and record their behavior. All the parents noted that they enjoyed engaging in these science activities with their children, and that it helped them all to better understand what science is and that science is everywhere. The overarching feeling from parents was that not only is doing science with their children easier and more accessible than they thought, but it is fun, as evidenced from their quotes below:

> *It [Science] wasn't as hard as I thought it would be. I think because they're so young, that anything is really a science experiment if you help them to ask the right questions, or ask them the right questions.*
>
> *"[The most important thing was for] us to learn to take something everyday and see that you don't have to be scientist to do science or ask the right questions."*
>
> *But going back to when we took science, it was boring, you had to do it like this and that's it .. . but now, the way they were learning, it's fun. The simplest thing we do every day, it has science.*
>
> *It's just so easy to sit back and say, but instead we can say "this is how we measure something—we just taught them a little math or science. It's easy but you have to do it.*

Interestingly, two parents also made comments indicating they might be helping foster other parents' science interactions with their children. One mom described how other moms would copy her actions at the playground, when she was prompting her daughter to think about science in their everyday surroundings: "I'll ask her questions and hear another mom asking the same question that I asked Mia." A different mother recounted how she encouraged other parents to do more science:

> *There are a lot of parents that can utilize this. Another parent said, 'how are you doing with this math and science? I told her, after the workshop it made more sense, it made me have more fun with them—you don't understand that you can really tie it together where now you use it every day. It's fun for them and you can do it!*

Although only two participants described sharing program experiences with other parents, their accounts are remarkable: they show personal growth and self-efficacy development to the degree of actually noting how their experiences and science-related parenting can inform other parents.

In the surveys and follow-up focus groups, parents illustrated the format of the family sessions was something that fostered the development of self-efficacy through supporting some of their needs. An important part of developing self-efficacy is having a positive psychological and affective state. Meeting families' needs helps support learning and self-efficacy development. Parents expressed gratitude for the meals each night and for the ability to bring other siblings, if needed. "The dinner is a motivation, because it's hard to figure out how to get the food on the table . . . and have advance notice to schedule it [when there is an evening event the family wants to attend.]" In addition, having the program bilingually was hugely important to the Spanish-speaking families. "Having this in Spanish means a lot to me. I understand better. At home we don't speak English well and we don't understand 100%. Spanish I do understand. I was better able to teach my child."

Parents expressed a desire for more programs like this in their district and that they would continue to seek out science experiences for their children. The importance of having the mastery experience of doing science through the program was evident throughout our interactions. Parents explained that they needed to see it modeled for them, to have the guided learning experience of doing it in this setting to open up the world of science. They also took away an increased sense of importance for science work for their young children. One parent explained: “Before this, I focused more on the reading and writing, you gotta prepare them to write their names, I really didn’t think about the science.” In just two family sessions this program seemed to go a long way in developing parents’ self-efficacy for identifying and doing science with their children.

Discussion

Students’ Development of Capabilities of NGSS Practices Four and Six

At the start of this study, the kindergarten participants lacked a familiarity with science practices and science in general. Through two interactive investigations with their parents, the children were able to develop the capability to utilize elements of NGSS science and engineering practices four and six. This dramatic development was aided by the participation of their parents, whom also developed during the study. At the time of the focus group, children completed a year of kindergarten and two months of first grade, Spanish-speaking parents spoke about how the experience helped them support their children’s science work at home or understand what children were doing in school. English-speaking families described attending more science-related community and school events. Evidence from data showed children implementing scientific practices employed during the family sessions as part of the study, and at home after the study, as reported by parents a year later. These results are important because of the dramatic shift that took place and because of the specific population targeted for the study. It has been shown that students of low SES have a reduced opportunity to learn, and that parental involvement may be a way to ameliorate the gap between these students and their wealthier peers (Tate, et al, 2012; Singh, et al, 2002). Further, parents reported high levels of student engagement in children’s personal science pursuits during the year following the program, fostered by parent encouragement, questioning and resources (time, space and experiences). Student interest in science at a young age not only sets the stage for future interest and achievement in science, but possibly for a career in science (Heilbronner, 2013; DeJarnette, 2012). Our findings suggest that through parental involvement and support, children not only developed scientific practices capabilities but also developed an interest in scientific explorations and acted upon them. Involving parents may be a good pathway to address gaps for our low SES students, which could also strengthen community ties, as an added benefit. The researchers in this study found camaraderie among the families involved in the study and a great rapport between themselves and the families.

Our findings were based on evidence from both the English- and Spanish-speaking groups that participated in the study. The children’s engagement, ability to use the practices and seek out science experiences was evident in both groups. This is also significant and may also provide insight for teaching EBs. One critical difference in this study was how parents were encouraged to conduct all activities in Spanish. Rather than promote the idea that science learning was only valuable in the English language, parents were encouraged to explore, describe, and discuss activities in Spanish. In fact, the researchers stressed that learning science concepts in the Spanish language would reinforce science learning in the classroom where instruction was conducted in English.

Parents' Development of Self-efficacy for Supporting Children's Science Learning

Although the children's development in this study is meaningful, perhaps the parents' development was even more noteworthy. By the follow-up focus group, a year later, parents in both the English- and Spanish-speaking groups recognized the importance of science and were motivated to support their children's learning and action in science pursuits. However, at the onset of this study, many parents expected that science was only taught in school with very formal approaches that they could not recreate at home. Experiencing the activities described in this paper, with their children, highlighted fundamental scientific practices and made evident for parents how questions and prompts deepened their children's critical thinking and learning of these concepts. Many parents commented how engaging their children's curiosity about routine occurrences at home really enabled the children to practice new skills of observation and prediction.

The lens of self-efficacy is useful to consider these findings. The four modes of self-efficacy development (*mastery experiences, verbal persuasion, vicarious experiences and psychological and affective states, described below*) were evident in the program design. Parents began by having a *mastery experience* in science, utilizing science practices to explore worm behavior in the context of stimulus and response. The parents' enthusiasm and success in the investigation was likely the first step toward developing their self-efficacy. Practicing these skills at home, with their children, between family sessions would be another opportunity for mastery experience and for developing self-efficacy for science work. Coming into the second family session, parents were particularly targeted by researchers and instructed on how to act as facilitators of science learning for their children, furthering the mastery experience. Helping parents to ask better questions provides more learning opportunities for children and for parents to learn how their children think - "…parents need to practice question asking in specific and meaningful ways" (Birbili & Karagiorgou, 2009, p. 28). This, along with encouragement provided throughout the two sessions, was an element of *verbal persuasion* by the researchers. Parents had become friendly and chatty with researchers, making our efforts to persuade them that they could be successful in teaching and doing science with their children a credible argument. As noted in the findings section, a year later, a couple of mothers even reported themselves as spreading the word for parental involvement with science! The family science and engineering sessions with dinner were set up purposefully to engender a feeling of community and foster parent-to-parent discussion of the science investigations and parenting, related to science education. These conversations were evident during the investigations, focus groups and dinner portions of the evening. These were all opportunities for parents to have an opportunity to hear *vicarious experiences* – other parents, like them, doing science with their children. Finally, the fourth mode of self-efficacy development as described by Bandura (1997), psychological and affective states, related to parents' feelings related to doing science with their children. The fun atmosphere of the investigations – hands-on, using songs, in a cheery kindergarten classroom – followed by an informal dinner gathering, may have helped ease anxiety surrounding the science work being done. Parents overwhelming reported science as a fun activity to do with their children a year after the initial session. That fun aspect was a way to counteract nervousness or apprehension surrounding the topic of science.

Conclusion and Discussion

This study examined parental interaction with kindergarteners from linguistically diverse and low-SES backgrounds in science learning contexts, in both English and Spanish, and qualitatively revealed some ways to promote early student learning and enthusiasm for STEM content along with improved self-efficacy for parents in science teaching with their young children.

An additional projected benefit of greater parental involvement is that parents will develop or improve their own familiarity with STEM domains and topics and become more scientifically literate as a result. The importance is increasing daily of developing citizens with sufficient STEM understandings. Calls for improved science education for urban populations focus on the need to understand science concepts and the nature of science in order to make informed health decisions, understand environmental issues, and generally to be an informed citizen (Tate, 2001; Tate, et al, 2012). Informed citizens are in a better position to make decisions for themselves, their families, and their communities.

The broader impact of this model is to educate parents and children together, using their home languages, to enhance parents' self-efficacy and promote learning in STEM, which is supported by the work of Hoover-Dempsey, et al. (2005). In addition, by attending family science and engineering sessions, parents encountered neighbors and friends learning the same strategies to support their children's learning through structured at-home activities. Supported and encouraged in a collaborative environment, English-speaking and Spanish-speaking parents could envision themselves as teachers and supporters of science learning and bring this role to everyday play and exploration activities that took place in their homes.

Our focus on early childhood education is based on critically important and compelling precedents. Successful Head Start initiatives, widely implemented across the United States, underscore the importance of early intervention initiatives (US Department of Health and Human Services, 2012). Bringing parental involvement to the forefront in science education of our youngest students helps students in their earliest years of schooling and strengthens the community by fostering stronger partnerships between parents and schools. The science family sessions described in this study provided a way for parents to learn how to scaffold science experiences for their young children and have productive STEM dialogues (Kisiel, Rowe, Vartabedian & Kopczak, 2012).

NOTES

[1] García, Kleifgen and Falchi (2008) coined the term "emergent bilinguals" to refer to individuals in the beginning stages of acquiring a second language. For this study, "emergent bilingual" is preferable to "English Language Learner" in that it acknowledges the children's existing language skills rather than emphasize the English they *do not know*. The choice of terms and descriptions for any group aptly conveys an underlying message; in that sense, choosing to use the term

"emergent bilingual" is an acknowledgement of the strengths, skills, and potential of the young children featured in this study.

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