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**THE INFLUENCE OF PROFESSIONAL DEVELOPMENT ON
INFORMAL SCIENCE EDUCATORS' ENGAGEMENT OF
PRESCHOOL-AGE AUDIENCES IN SCIENCE PRACTICES**

A Dissertation in

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by

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ABSTRACT

There is little research on professional development for informal science educators (ISEs). One particular area that ISEs need support in is how to engage preschool-age audiences in science practices. This study is part of a NSF-funded project, *My Sky Tonight (MST)*, which looked at how to support ISEs in facilitating astronomy-themed activities with preschool-age audiences. This dissertation focuses on the influence of a six-week, online professional development workshop designed for ISEs working with preschool-age audiences. I used three primary sources of data: pre/post interviews and a video analysis task from data of 16 participants, as well as observations of implementation from a subset of seven participants who agreed to participate further. I developed and used the Phenomena-driven Practices of Science (PEPS) Framework as an analysis tool for identifying engagement in science practices. Findings from this study show that ISEs identified affective goals and rarely goals that reflect science practice engagement for their preschool-age audiences. They maintained these initial goals after the professional development workshop. ISEs describe the ways in which they engage children in science using primarily science practice-related words, but these descriptions did not show full use of science practices according to the PEPS framework. When observed implementing science activities with their preschool audiences, the ISEs demonstrated a variety of forms of science engagement, but only a few used science practices in ways consistent with the PEPS framework. Engagement in the professional development workshop did not result in a transition in the ways ISEs talk about and implement science with young children. While the write-ups for MST activities were not written in a way that supported engagement in science practices, a subset of MST activities were designed with it in mind. The professional development workshop included little time focusing on how ISEs could engage children in science practices, specific to each activity. These two factors

may have played a major role in why participants showed limited improvement in their use of science practices in their goals and implementation.

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Sincerely,
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Chapter 1

Introduction

Learning happens across many settings and for people of all ages. The majority of learning that occurs in a person's life happens outside of school (Banks, Au, Ball, Bell, Gordon, Gutierrez et al., 2007). Places like museums and other informal science venues spark interest in visitors and provide them with a variety of ways to make meaning from their experience. Engagement in science at these institutions can allow visitors to participate in the practices of science. In turn, engagement in science practices may help visitors “recognize that science and engineering can contribute to meeting many of the major challenges that confront society today, [...]” (National Research Council, 2012, p. 43). Science centers may also provide ways for visitors to use exhibit models to construct explanations about dynamic processes such as earthquakes or tsunamis. Through educational programming, participants investigate chemicals as simple as water and make claims about the pollutants near its source. By supporting visitors' engagement in the practices of science, institutions allow visitors to leverage their prior knowledge and experience (Calabrese Barton, 1998; National Research Council [NRC], 2009) as a starting point for engagement. Then, as they begin to understand the science content, they can use evidence to develop explanations.

A large population of weekday visitors tends to be between the ages of three and five years (Reach Advisors, 2010). There are also museums and science centers that specifically cater to this age group. Recently, there has been a reenergized push to create quality science learning experiences for preschool audiences in the museum community (IMLS, 2013). Research shows children as young as three years old can think about and use science (Carey 2009; Gelman, Brenneman, Macdonald & Roman, 2009; NRC, 2007; Schulz & Bonawitz, 2007) and that early

experiences with science are important to the development of scientific thinking and reasoning that are needed when children begin school (NRC, 2007). It is important that informal science educators understand how to engage young children in the practices of science in order to create an equitable learning experience for all children (NRC, 2007, 2012). But how are informal science educators engaging with these audiences and what supports do ISE's need to do engage them successfully in science practices? The purpose of this dissertation is to document the goals that ISEs hold related to engaging preschool-age audiences and their understanding of science practices before and after professional development. Data was collected to describe the ways in which ISEs talk about and facilitate science with preschool-age audiences and sought to identify elements of professional development that support ISEs understanding and use of engagement in science practices.

Informal Science Educators (ISEs) and the Practices of Science

Latour and Woolgar (1979) and Kuhn (1962) illustrated how scientific work is conducted and how knowledge is constructed. Latour and Woolgar showed that scientists do not follow the five steps of the scientific method in order during their endeavors. Kuhn described the way knowledge was produced and taken up by describing the social elements involved. He explained the need to convince people to think differently about how science happens. These authors showed that science is not always linear, it does not always follow the same steps in order, and most importantly, that a set of steps are not enough to describe scientific processes. Therefore, a reconceptualization of the way we looked at "doing science" emerged. Regrettably, educators often portray the ordered steps of the scientific method - observation, hypothesis, prediction, experimentation, and conclusion - as an accurate depiction of how scientists embark in scientific experimentation and discovery. As convenient as a five-step model may seem, this is not an accurate description of how scientists do science.

This reconceptualization of science, sparked by the work of Latour, Woolgar and Kuhn, comes in the form of science practices. “Doing science” is less about reciting facts or following a list of steps, and more about using skills and knowledge to engage in scientific inquiry (NRC, 2012). A focus on science practices may be one robust way we can understand learning in various contexts – and in both formal and informal settings. With this focus, educators have the potential to increase the ways that learners make meaning from their experiences (NRC, 2009).

A considerable body of research on learning focuses on what young learners cannot do (NRC, 2007); however, now we are seeing, with increasing clarity, the wide range of abilities children have when entering school and the wealth of experiences they have already participated in by the time they get there (Institute of Museum and Library Services, 2013; National Research Council, 2007, 2009). The National Research Council report *Taking Science to School* (2007) synthesized the research on the complexity of how children learn and provides four strands of science proficiency that can be used to guide the development and facilitation of learning activities with children. The strands encompass the ways in which learners should use content knowledge (i.e. define the evidence used to make claims), reinforces the importance of a learner evaluating information against specific criteria, describes how learners negotiate the nature of science content (i.e. claims can change if new evidence is found) and describes the norms of science as learner participation in scientific practices.

The Institute of Museum and Library Services (IMLS) report *Growing Young Minds* (2013) makes the case for early learning programs. “Neuroscientists tell us that the type of learning that occurs in these institutions—self-directed, experiential, content- rich—promotes executive function skills that can shape a child’s success in school and life,” (IMLS, 2013, p. 4). This report states that many children are beginning kindergarten without the language, emotional or cognitive skills needed. National reports also argue that early learning opportunities should be strengthened because experiences early in life affect children in their older years (NRC,

2007, 2009). Early successes in science have been shown to correlated strongly with future success. Museums and similar institutions are poised to provide opportunities for early engagement in science to visitors.

According to the NRC report *Learning Science in Informal Environments* (2009), the goals for science learning at informal science education venues include: creating positive affect (i.e. inspire and excite learners), communicating new science content, fostering engagement with natural phenomena and furthering an appreciation for the value of science and scientific developments. So, how do informal science educators meet these goals? Engagement in science practices is one potential strategy for success. Informal science educators may need help knowing how to engage their audiences in science practices because 1) they often have little to no training (Bailey, 2006; Tran, 2007), 2) they teach the way they were taught (Cox-Peterson, 2003), and 3) they work with multi-age audiences (Bailey, 2006; NRC, 2009). They may also need support in knowing what a reasonable learning goal is for a particular audience or content area. Do they believe that it is important to engage learners in science practices and if so, do informal science educators understand how to do that? There is little research yet that answers these questions. To add to this problem, some educators may think that children are not capable of doing science at such young ages as three, four and five years old, but, research demonstrates that they are in fact very capable (Gelman, Brenneman, Macdonald, & Román, 2009; NRC, 2007, 2009).

ISEs' Goals for Preschool-Age Audiences

Research suggests that the most common goal for audiences served by informal science educators (ISEs) is related to fostering interest and excitement (Bailey, 2006; Plummer, Crowl, & Tanis Ozcelik, in progress; Plummer & Small, 2013; Tran, 2007). In a study of informal science educators engaging young children in science, Plummer, Crowl, and Tanis Ozcelik (in progress) found that some educators still have a narrow view of what children can do. One participant stated, "A lot of times, I think science is one of those tough ones to really explain to kids; that

they are doing science." In the same study, many participants did not focus on describing young children's science capabilities. When asked if young children could do science, participants often mentioned the importance of getting young children interested in science and excited about participating in it rather than fostering engagement in science practices. Specific science practices were stated as a way that young children do science but practices such as observing, experimenting and questioning were often listed with no deeper explanation of how or why these occur. The most frequent response given was that young children doing science involves observing, but often this practice was described superficially. It was referred to as *looking at something*; however, Eberbach and Crowley (2009) point out that authentic scientific observation involves much more than just sensory perception. True observation, or *noticing* as they define it, involves knowing something about the domain in which one is making the observation as well as understanding how to observe in a systematic way. Plummer and Small (2013) interviewed planetarium professionals and identified interest and content-related goals to be most common among participants. Despite what seems to remain common across each of these samples, NRC (2009) states that the goals for science education should encompass more than just fostering interest. The six strands for science learning include encouraging interest and motivation, but also emphasize the importance for engagement in the practices of science. Fostering engagement in science practices may not be something that educators know how to do. While their current goals are important, they may stem from a lack of understanding about all that can actually be accomplished in informal settings with young children. The reality is that young children cannot only be taught to make observations (e.g. "look at that") but they can also be productively scaffolded to gain deeper levels of understanding (e.g. "do you notice how the color changes when...") (Eberbach & Crowley, 2009).

Professional Development

Museums and other informal settings need well-trained staff that can facilitate science at an appropriate level for children ages three to five years. Professional development is a common piece of education reform efforts; however, there are noticeably fewer studies about the impact of professional development with informal educators than there are for formal classroom teachers. What structures are in place to support informal science educators in improving their ability to engage preschool audiences in the practices of science? Given that informal science educators come from various backgrounds and with a diverse range of previous experiences and education, professional development opportunities may be necessary in order to create a shared language and to professionalize the occupation (Tran, 2008). Professional development can increase the content knowledge for those who need it. Research has found that pre-service and beginning teachers who are not confident in their content knowledge either avoid science or use hands-on activities to engage children (Appleton, 2002). It can also provide educators with new ways of teaching, such as allowing children to engage in science practices while participating in the hands-on aspect of the activity. A body of research has unpacked the important features of professional development for formal classroom teachers (i.e. Borko, 2004; Desimone, 2009), but will these same features support professional learning for informal educators?

Professional development may be a solution to improve the knowledge and practice of informal educators; however, we have a lot yet to figure out when it comes to understanding the best ways to support informal science educators. There are no standard requirements for most informal science educators (Tran, 2008). Some institutions or universities offer professional development workshops as well as certification and degree programs in museum studies. Few, however, have been evaluated in a way that allows an outsider to understand the impact on an educator's learning or that provides the field with generalizable applications for future workshops.

We can look to the literature on professional development for formal school educators as a starting point but there are differences between their work and their environments (Bailey, 2006; Tal, 2012; Tran, 2008). These differences may suggest that professional development will function differently with informal science educators if taken directly from the formal education best practices. Informal learning occurs in short spurts, is less structured than school and is often influenced by physical features of the learning environment, such as exhibits or objects (Tal, 2012). A successful professional development workshop will address these differences.

Overview of this Study

An appropriate goal for engaging preschool-age audiences in informal science learning is through the use of science practices (NRC, 2009); however, informal science educators may need support in doing this. This study is part of a NSF-funded project, *My Sky Tonight*, which looked at how to support informal science educators in facilitating astronomy-themed activities with preschool-age audiences. This dissertation focuses on the influence of a six-week, online professional development workshop designed for informal science educators working with preschool-age audiences at sites across the United States. The purpose of this dissertation is to 1) identify ISEs' goals for teaching science to young children, 2) explore ISEs' understanding of science practices, and 3) describe the ways in which ISEs' engage preschool-age audiences before and after a professional development workshop. By identifying how ISEs' engage preschool-age audiences in science and whether or not engagement in science practices is occurring and valued, I add to the body of literature addressing how to increase the capacity of the field to teach science to young children and suggest important characteristics of professional development workshops.

This study addresses the following research questions:

1. What are the goals of Informal Science Educators (ISEs) when engaging preschool-age audiences in science, before and after professional development?

2. What do ISEs know about science practices, prior to professional development and how does that change after?
3. How do ISEs describe how they engage preschool audiences in science?
4. How do ISEs implement science when teaching activities from the professional development workshop?

Chapter 2

Review of the Literature

Using data from participants engaged in the *My Sky Tonight* six-week online pilot professional development workshop, this dissertation expands the knowledge base pertaining to informal science educators' (ISE) goals for teaching science to preschool-age audiences and the effective elements of professional development to support ISE's understanding of and engagement in science practices. In this chapter, I will review the research on:

1. The nature of informal science learning;
2. Preschool-age audiences' capacity for learning astronomy and engaging with science practices;
3. Science practices from research-based documents and my own framework developed from the literature;
4. Informal science educators and the work they conduct;
5. Professional development in informal, formal and online settings.

The professional development workshop in this study was designed to help ISEs learn to facilitate astronomy programs to preschool-age audiences. Thus, the research reviewed in this chapter is relevant to the work that ISEs do as well as the effective elements for professional development found in research. My proposed model for effective supports of professional development for ISEs follows the review of the research.

Informal Science Learning

Lifelong learning is a term that has come about in the past decade to describe the full set of experiences that a person has that contribute to their own knowledge base (NRC, 2009). During an individual's life, the act of learning happens in many places. It happens in school, but school is just one place of many where learning may happen regularly. Outside of the school setting, where humans spend most of their living moments, learning happens in designed settings such as museums, zoos and libraries. Learning happens at home during family conversations,

while watching television or while reading for leisure. It happens during exciting moments – while watching a space shuttle launch at Cape Canaveral – and during much more mundane moments such as dropping a cell phone in the toilet. The learning that happens in non-school settings goes by various names: free-choice learning, out-of-school time learning and informal learning. The term free-choice learning for example, places the agency on the learner (Falk & Dierking, 2000). This definition works well to describe how visitors might explore exhibits during a visit to a zoo or aquarium. Out-of-school time learning, according to the Program in Education, Afterschool and Resiliency (PEAR, pearweb.org), refers to afterschool programs and summer programs that occur outside of the typical school day or year. This term encompasses only a slice of the learning time spent outside of the classroom, where much of the learning is guided. I choose to use the term informal learning because it refers to learning in a very broad sense, anywhere, anytime, and can account for all the activities described above.

The features of informal learning are often different than the learning that happens in school. As stated in *Learning Science in Informal Environments* (NRC, 2009): “Many academic achievement outcomes (1) do not encompass the range of capabilities that informal settings can promote; (2) violate critical assumptions about these settings, such as their focus on leisure-based or voluntary experiences and non-standardized curriculum; and (3) are not designed for the breadth of participants, many of whom are not K-12 students,” (p. 3). Tal (2012) reviewed the learning outcomes of informal settings, explaining that these include “content, social, and interest-oriented outcomes,” (p. 1117), which are more general than the typical outcomes of school learning. Informal learning typically involves an increased level of choice (Falk & Dierking, 2000). The level of choice varies depending on the learning activity and venue; however, the overarching theme is that a wider variety of learning opportunities exist across the lifespan than just school settings and options they afford to students (Tal, 2012).

The way that the learning experience is facilitated in informal settings also differs from school settings (Tal, 2012). Some visits to an informal learning site are unguided, while others are docent- or educator-guided. Some experiences are planned, like educational programs, while others are opportunistic, like a guided nature walk. Programming can be supplemental to school curricula, designed for specific grade levels. It can also encompass rich, hands-on experiences for families through special events and overnight retreats. Programs may be designed with families or multiple generations in mind, and for participants with drastic differences in previous experiences and prior knowledge. School learning tends to be designed for the individual at a specific level of learning. Prescribed scaffolds that are designed from implied previous knowledge are used to move learners forward. In informal settings, learning outcomes may be similar to those of school, where the goal is to leave with a new understanding of a scientific phenomenon, for example. It may also be considered a successful learning outcome that the learner was able to experience the phenomenon and leave with a piqued curiosity and an interest to explore more in the future (NRC, 2009).

Preschool-Age Audiences

One demographic that visits informal learning venues regularly, with family members or a class on a field trip, are preschool-age children. As this study is looking at how ISEs' engage three to five-year-old children in science, the following sections highlights the research done with these audiences, within the domain of astronomy. The goal of this study was to explore if ISEs engaged children in science practices before and after a professional development workshop.

Astronomy with Preschool-Age Audiences

Most often astronomy is thought of as a science that can only be done at night, when the sun has set and the stars are visible. Therefore, one argument might be that preschool audiences cannot engage in astronomy because they go to sleep so early. Though there are few studies on

preschool-age children learning astronomy, the following studies challenge this argument by exploring how young children learn astronomy, during daytime hours.

Miller, Trundle, Smith, Sackes, and Mollohan (2013), conducted a study focused on understanding young children's conceptions of day and night before and after instruction. In this study, the intervention occurred over eight days and included an element of pretend play. Children were invited to a campsite set up in the classroom. Through activities such as reading books and recording observations from the books about day and night, listening to nocturnal animal sounds on a CD, and comparing photographs of day to night scenes, children engaged with content and then were interviewed by researchers. Before the intervention, less than half of the two and three year olds could discern between a day and a night picture. After, nearly all children were able to make the correct identification. Before the intervention, few four and five years olds were able to provide evidence as to whether the picture was a day or night scene. After, 86% were able to provide appropriate evidence.

Others have described studying children's conceptions of day and night as well. Valanides, Gritsi, Kampeza & Ravanis (2000), conducted semi-structured pre and post-interviews with five and six year olds inside a specially designed room. The interview analysis accounted for verbal and non-verbal responses. In pre-interviews, only 1% of the thirty-three-child sample used movement of the Earth as an explanation for day and night. Researchers implemented a thirty-minute teaching intervention that blended play with science learning, and purposely presented information that opposed the children's current beliefs. The treatment was designed to present counter information in order to cause disequilibrium, and to increase the chance that children would reorganize their existing ideas. After the treatment, 64% of the students used the Earth's motion in their explanation. This study also included asking children about their ideas of the shape of the Earth and Sun. Children were given a choice of different shapes and asked to choose which best represents the shape of the Earth and the shape of the Sun, individually. More children

chose the shape of the Sun to be a sphere than the shape of the Earth during pre-interviews, but the number of children choosing a spherical shape for both increased after the teaching intervention. One point of discussion put forth by the authors as to why more children did not take up the correct conception may be due to the program including a play element. They state that, “It is also possible that children were totally absorbed in the playful activity and, not considering it a learning activity, they failed to take any learning advantage from it,” (p. 38).

In a study by Kallery (2011), four, five and six year olds were taught about the sphericity of the Earth and the causes of day and night utilizing visual and verbal modes of teaching. A researcher and early childhood educator lead activities, often using manipulatives, such as a globe, to aid in the children’s understanding. Instructional videos were also used. Children in this study showed an increased awareness of the concepts after the instruction as well as an increase in interest for astronomy. The researcher points out the importance of whole group discussion and linked questions to help draw out what children know and helping them to explain how they understand a concept.

Limited studies have looked at preschool-age audiences doing astronomy. The studies that have focused on this topic, have conducted their work during the day, in spaces designed for the research study. They have not helped the field understand how educators can engage their audiences in science practices through astronomy, nor have they studied engagement in learning environments, such as a museum programs or workshops.

Preschool-Age Audiences Engagement in Science Practices

There are studies that describe how young children engage in science practices. However, a large percentage of them tend to focus on children six years old and up. The following is a review of research on studies that include children ages three to five years.

Siri, Ziegler and Max (2012) conducted a study with five and six year olds. They provided stations where children could explore the properties of water in different ways. The

researchers looked closely at verbal and non-verbal actions. When they analyzed all of the actions and interactions between children, they found that children do participate in processes of science. “What might appear as being messy at first sight when young children engage in “doing science” is revealed as being a discursively organized process, which increasingly bears the features of the (often not immediately detected) emergent normative practices of science,” (Siri, Ziegler & Max, 2012, p. 315).

Asking questions is an important scientific practice. In a chapter about the science process skills of children, Jirout and Zimmerman (2015) outlined the skills of young children as they related to asking questions, conducting investigations and making interpretations of data. They claimed that curiosity and uncertainty motivated children to ask questions. According to Jirout and Klahr (2011) and Jirout and Zimmerman (2015), without support, children are not able to ask questions from uncertainty that lead to the use of other process skills, such as investigation or interpretation. Choinard, Harris and Maratsos (2007) suggest “problem directed question asking skills do not develop until elementary school,” (p. 1). Whether the questions children ask are problem-directed or not, people who work with young children tend to agree that children are naturally curious. Jirout and Klahr (2012) argued, however, that there is variability in the definition of curiosity when researchers are pressed to define it.

Schulz and Bonawitz (2007) conducted an experiment with four to six year olds in which children were placed in two scenarios and allowed to explore freely. First, children were given an option to either play with a new toy they knew nothing about or a toy that they knew but one that still had a bit of uncertainty attached. The second scenario gave children an option to play again with a new toy or one they knew very well. In both cases, children chose the option with some amount of uncertainty. In the first scenario, they chose the toy with limited familiarity. In the second scenario, they chose the new toy because there was nothing uncertain about the other toy.

In each scenario, the choices children made may have been motivated by curiosity. Leveraging curiosity may be one starting point for engaging children in science practices.

Piaget (1959) provided a starting point from which early childhood learning can be described; however, his ideas have been challenged by the National Association for the Education of Young Children (NAEYC) as well as research documents that synthesized related fields of research (NRC, 2000; NRC, 2007). We now agree that science can be taught to young children (Gelman, Brenneman, Macdonald & Roman, 2009; Edson, 2013) but can young children conduct investigations and interpret evidence? Piekny and Maehler (2013) conducted a study for preschool and elementary aged children. Building off the work of Sodian, Zaitchik, and Carey (1991), Piekny and Maehler asked children to choose between a large and small door cut into a shoe box (mouse house) in order to 1) ensure that any mouse could get into the house and eat the food and 2) figure out if the mouse was large or small. In the first task, children were asked to produce a particular outcome. In the second, they were testing a hypothesis. Children in this study were given no support by the researchers. In all cases of four and five year old children, the number of correct responses was below the chance level. No children under the age of seven in this study were able to justify a hypothesis with evidence.

Finally, studies have shown that there is a difference between older children and those under the age of five years old in the ability to identify patterns and make claims (Ruffman, Perner, Olson, & Doherty, 1993). When children were given evidence and consistent claims, all ages were successful. The difference in abilities came when researchers provided faked evidence. In a study conducted by Ruffman et al. (1993), children were told a story in which green foods cause tooth loss. Then, the researchers told children that they “tampered with the data” so that a story character who didn’t see the first set of evidence would now believe that red foods cause tooth loss. Children under five years old were not able to understand that their hypothesis would have been different from the story character. These findings are in the same vein as Piekny and

Maehler (2013), showing that interpreting evidence related to a hypothesis is hard for preschool-age children. Without support from adults, children ages three to five years may not be successful in asking questions, conducting investigations or interpreting data.

Science Practices

If the professional development is to support informal science educators doing science with preschoolers, we must first identify how to recognize success. Success for informal science educators, in this case, entails fostering meaningful engagement in the practices of science with preschoolers.

Science practices involve more than skills or steps. The term *practices* reinforces the need for content and skills to go together when doing science. Meaningful engagement in science should be contextualized; it should not be in isolation of a phenomenon. When Latour and Woolgar (1979) analyzed how scientists conducted science in the lab, they realized that it was not a strict set of steps that the scientists followed, but rather an inquiry-based investigation with interplay between understanding *how* (practices) to investigate and *what* (content) is occurring during the phenomenon (NRC, 2012). Using this idea, it is impossible to do science without contextualizing it in a phenomenon.

In this study, scientific phenomena refer to any measurable occurrence that can be explained by science. Measuring the phenomenon can be done by way of tools or by observations. For example, the orbital mechanics of the earth-moon-sun system becomes measurable in one way by the patterns of the moon phases. The optical phenomenon of magnification can be explored and observed by using a magnifying glass or binoculars.

The following is a description of four research-based documents that inform the science practice framework for preschool-age audiences used to analyze data collected for this study. Each provides an overview of how to do science with learners but they were written for different audiences.

- *Preschool Pathways to Science* is a research-based guide that helps educators develop science-based experiences for preschool-age audiences (Gelman, Brenneman, Macdonald, & Roman, 2009).
- *Starting with Science* is an inquiry-based book that helps teachers plan and implement science for preschool- and kindergarten-age children (Edson, 2013).
- *Framework for K-12 Education* is an evidence-based guide that identifies the science that K-12 students should know (NRC, 2012).
- *Learning Science in Informal Environments* is a report summarizing findings from research and evaluation documents that focus on learning that happens in settings such as museums, aquariums, nature parks and zoos (NRC 2009).

As will be shown in the analysis of each of these texts, none were sufficient to serve as a framework for this study on their own. I used elements of each to support my development of a framework specific to engaging preschool-age audiences in the practices of science.

Preschool Pathways to Science shows that children as young as three years old have a wealth of experience with the world and they are capable of abstract thinking (Gelman et al., 2009; NRC 2007, 2009). The research also demonstrates that they can think about and use science by making comparisons and predictions, for example (Carey 2009; Gelman et al., 2009; NRC, 2007; Schulz & Bonawitz, 2007). *Preschool Pathways to Science* describes preschoolers as “scientists-in-waiting,” (p. 2) because children explore and experiment in their own world, making science an easy fit (Bowman et al., 2001). I chose to include this document because it is well grounded in early childhood learning and development literature.

Preschool Pathways to Science also identifies five keys science practices appropriate for this age group. They are 1) observe, predict, check, 2) compare, contrast, experiment, 3) vocabulary, discourse, and language, 4) counting, measurement, and math, and 5) recording and documenting. Despite the categorization, there is often overlap between practices. There is no

one order to go in or one set of practices to start with, but, often when children make observations, there are ways to extend the experience to include predicting and checking, for example. At the same time, there is no requirement that in order to engage fully in a practice, you have to fulfill each one in the list.

Starting with Science (Edson, 2013) outlines science practices similar to those found in Gelman, Brennenman, Macdonald, and Roman (2009). These include observing, prediction, questioning, investigating, collaborating, communicating, interpreting information, and using tools to gather information. An element of doing science for preschool-age audience highlighted in this document is the need for support and guidance from adults to ask and answer investigable questions. The table below shows examples of how necessary support from an adult is to preschool-age audiences' engagement in science practices. It is important to note that the practices in this document are described for children older than preschool-age.

Table 2.1 Evidence of Adult Support from Edson (2013)

"At every level, observation requires on-going support from the teacher..." (p. 7).
"[...] the teacher's timely questions and scaffolds provide the foundation for productive predictions," (p. 7).
"Children need to be immersed in productive questions modeled by their teacher..." (p. 8).
"With appropriate support and scaffolding, young children can actually design and execute simple investigations..." (p. 8).
"When young children do science, they have to talk. [...] They need a classroom environment that promotes such talk and questioning," (p. 10).
"[...] when teachers model how to use a magnifying lens, an index or a weather chart, they initiate children into the use of tools of science in a natural and meaningful context," (p. 11)

The *Framework for K-12 Science Education* (NRC, 2012) describes science and engineering practices relevant to learners. These include asking questions that can be answered using data, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence and obtaining, evaluating and communicating information. The list of practices, and the ability to engage with a subset of them at a time is a common theme amongst documents that I reviewed that outline science practices for children. This document, in

particular, places emphasis on the ability to collect appropriate data to answer a defined question. Data, whether first hand (collected by the learner) or second hand (given to the learner) is a necessary part of engagement with science practices.

Finally, the 2009 NRC report, *Learning Science in Informal Environments*, outlines strands of informal science learning for learners of all ages. In particular, Strands 2, 3, 4 and 5 are important to this study.

- Strand 2 describes how learners are able to use evidence to explain phenomena through models or argumentation.
- Strand 3 describes how learners are able to engage in scientific reasoning. This includes asking and answering questions about observations and using these explorations as a means for predicting, testing and making claims about their world.
- Strand 4 describes the way that learners begin to see science as a way to understand their world.
- Strand 5 describes that learners are able to collaborate and leverage science tools and new vocabulary.

The strands are very similar to a set from a previous National Research Council report (2007), however, in this document they are situated within out-of-school time learning experiences and descriptions. This perspective is useful to this study given the participants are informal science educators.

Missing Elements from Key Documents

Each of the four documents outlined above supported my thinking about science practice engagement but there is not single document that encompasses all of the important elements to engagement. In *Preschool Pathways to Science* (Gelman et al., 2009) and *Starting with Science* (Edson, 2013), the authors outline sample lessons, but in both books, direct engagement with

phenomena is missing. For example, *Preschool Pathways to Science* suggests “observe, predict, check” as a category of related practices. One example that they give for this category involves looking at a book cover, predicting what the book will be about, and then checking for accuracy by reading the book. In *Starting with Science* (Edson, 2013), the author outlines a sample activity where students work to identify a pet for their classroom. In the activity, there is a butterfly and a fish in each classroom. The description of engagement in science practices explains, “[...] the children will be part of research groups and small- and large-group discussions. They will observe and record information and apply that information/evidence to choose an appropriate classroom pet.” (Edson, 2013, p. 142). Both of these cases are missing engagement with scientific phenomena. Even if the book is a science-themed book, there is no engagement with an observable or measurable scientific phenomenon as the activity is currently written.

The *K-12 Framework for Science Education* (NRC, 2012) outlines the scientific and engineering practices that all students are supposed to learn and participate in; however, this document is written for K-12 students. It is based on research for children of this age as well, making it inappropriate for preschool-age audiences. Developmentally, children five and under are just learning to participate in science in similar ways to older children and adults. They are just learning to ask “why” and how to answer it as well. They are also just learning how to collect and use data. This document assumes that learners are proficient in many of these skills already.

Finally, *Learning Science in Informal Environments* (NRC, 2009) acknowledges preschool-age audiences but does not give readers a concrete idea for how to do science. The purpose of this book is to review and synthesis the research done on science learning, not to provide educators with one specific framework for engagement. Rather, the strands outlined in this book are to act as guidelines with no specific content lists or delivery methods. In the next section, I outline a framework specific to preschool-age audiences and the important aspects of engaging them in science practices.

Phenomena-driven Engagement in the Practices of Science (PEPS) Framework

The idea of using science practices as a way to engage children in science has been emphasized in the documents described above and applies to children as young as preschool-age in formal and informal settings. The *Phenomena-driven Engagement in the Practices of Science Framework (PEPS)* used in this study requires that in order for children to engagement in authentic science, there must be:

- a scientific phenomenon in which to engage
- data involved, whether collected first hand or not (NRC, 2012)
- a scientific question or goal statement that leads to an investigation

Engagement in a scientific phenomenon is missing from other documents that describe engaging children of any age in science practices. A phenomenon is an observable, measureable event that can be explained using science. Observations by preschool-age audiences are most often made using their senses as opposed to measurement tools. For example, the force of magnetism can be observed when children try to pick up a variety of magnetic and non-magnetic objects.

Given that engagement in science is data-driven, it is to incorporate methods of first hand or second hand data collection. First hand data collection implies that children engage directly with a phenomenon. When first hand data cannot be collected, children can use data that was collected previously and given to them, such as second-hand data. A chart on paper, a video of an event or phenomenon occurring, as well as photographs or images of real phenomena count as second hand data.

Engagement with a phenomenon and data allow children to answer a scientific question or a goal statement by conducting an investigation. More often, engagement is guided by an investigable question posed by an adult, but children may also have investigable questions. These

questions prompt children to engage in specific practice, collect data and use the data in some way.

I have organized science practices into three categories: collecting data, analyzing data and explaining data. In order to qualify as engagement in science practices, a child does not need to participate in all of the practices nor in a subset of practices from every category (Gelman et al., 2009). If the engagement involves a scientific phenomenon and uses data to perform even one practice, it counts as engagement in science practices for preschool audiences.

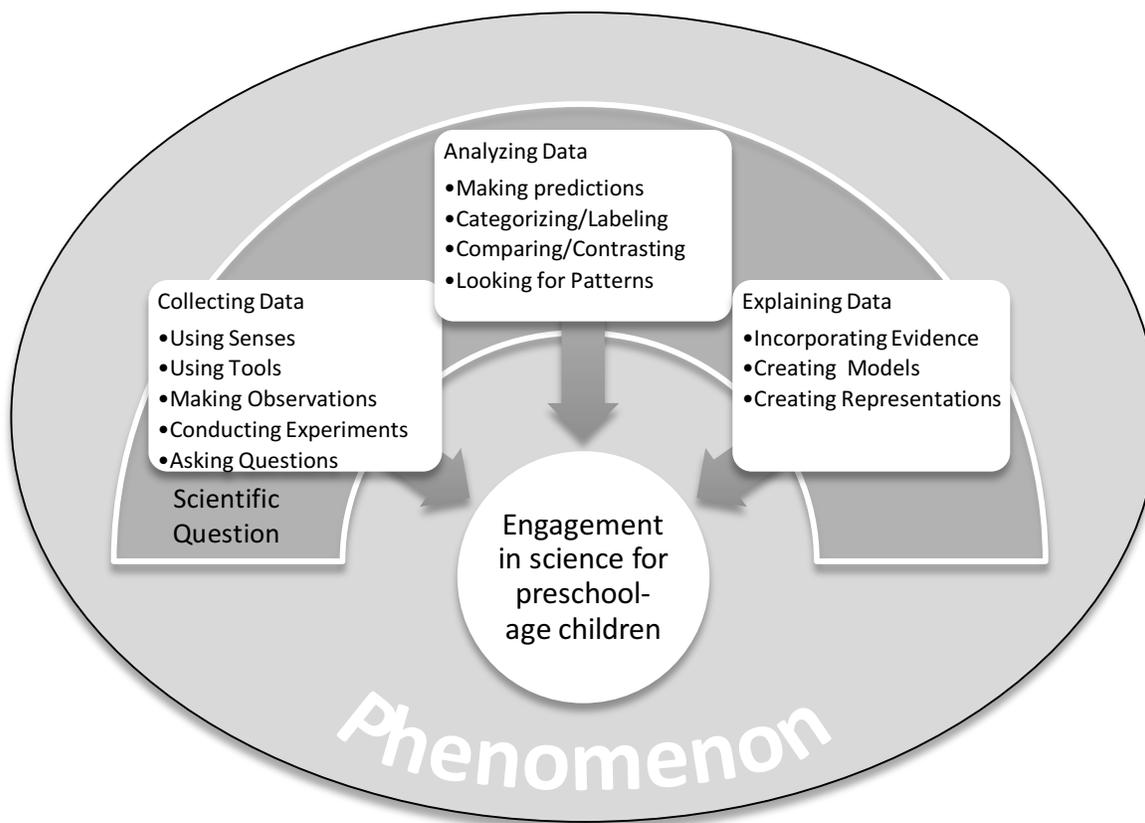


Figure 2.1 Phenomena-driven Engagement in Science Practices Framework

This framework is specifically created for preschool-age children's engagement in science practices and will be used as an analysis tool in this study. The descriptions to follow are in no specific order.

There are many ways that young children may *collect data*. As stated previously, support from an adult or more knowing other is important. In order to collect appropriate data about a phenomenon, a child must understand what or how to collect data. This may happen either by engaging prior knowledge or by the support of someone else. They might use their sense of smell, for example, but they would need to understand which part of the flower to smell. They might also use their sense of touch but they have to understand how to quickly touch something that is hot so skin does not get burnt, for example. They might consider using their sense of taste, however, it is important to know when something might be harmful to taste. They may experiment in a guided way, by pouring water onto a slanted surface to see what happens; or, in a natural way by purposefully knocking over their glass of water during dinner.

In order to collect useful data from the experiment, however, the child must use a specific lens and have a question in mind, or have a question provided by an adult. With an adult's help, practices in this category become meaningful actions that can result from purposeful or accidental activities. For example, a child must first know enough science to ask a question specific to the phenomenon or have a goal statement provided to them. Adults play a key role in this for young children. They may point out something for the young children to notice, providing a starting point from which to ask a question. For young children, it may be more likely that an adult provides the question or a statement to be explored. Tools may be useful in making necessary observations, as a way to extend the child's senses, but a child must first know which tool makes sense to use. Adults often play a key role in the young children's learning as they scaffold the experience of using tools.

Analyzing data focuses on doing something with the first-hand or second-hand data. From birth, children are learning to label things in their world. With guidance, children can learn to label data that helps them explain a phenomenon. They may use these labels to compare or contrast data, or they may look for patterns in data. For example, magnets stick to some things but

not others. A child might make two piles of objects – one that magnets stick to and one of other items. With guidance, a child can predict which pile new items might go in.

Finally, children can learn how to *explain data* via their findings by incorporating evidence, claims and reasoning. For example, children may be given second hand data or photographs of phases of the moon after claiming that the moon is round. They can use that data as evidence that the moon is round. They may also draw a picture of the moon phases, creating a representation of the moon. Finally, with guidance from an adult, they could make a model of moon phases, using a ball and light source. This kind of model provides children the ability to understand the rotation and revolution of the moon and sun.

This framework is based on four documents that outline learning (Edson, 2013; Gelman, Brenneman, Macdonald, & Roman, 2009; NRC 2009, 2012). The way the PEPS Framework is designed, it is suited to the capabilities preschool-age audiences as they learn in informal settings. It fits the notion outlined by Latour and Woolgar (1979) and Kuhn (1962) that scientists do not follow a defined list of steps. The practices that are apart of the framework are the same as those involved in the inquiry-based investigations that scientists pursue.

Making craters with flour and different sized balls, is an activity that preschool ages can partake in engagement with science practices. The phenomenon is the gravitational pull of the moon on small objects. The phenomenon is observed by the impact craters left on the moon's surface. What follows is a description of the activity, and the ways in which the children and the educator interact to allow for engagement in science practices according to the PEPS Framework. In this activity, a large cake pan or tub is filled with a three-inch layer of flour. With a group of four or five children, the educator can display the different balls and tell the children that the flour is a model of the moon's surface. Using pictures of the moon's surface (second-hand data), children are able to see real craters. The educator can point out that craters vary in size and depth. She can show children examples of craters inside of craters, as well as the rays that are created

upon impact. After explaining that craters are formed when space rocks hit the moon's surface leaving a divot, children are given the challenge of making their own craters on their model moon surface (goal statement). The educator asks one child to choose one ball and then passes that ball around to each child. The children use their senses to feel the texture and weight of the ball (data collection). Then, the educator asks the child who will be dropping the ball, to predict what the crater, formed by their ball, will look like. After the predictions are made, the educator shows the child how high to hold the ball and then tells the child to drop it into the flour. Before anyone else touches the ball, the educator helps the children make observations of the impact (data collection). Often, children notice the lines that radiate outward from the impact site. Then, the educator removes the ball and queues children to make observations about the crater again (data collection). The educator can prompt the children to use descriptive words to describe the shape and depth of the crater. This gets repeated, one ball at a time, allowing children the opportunity to predict and observe what happens when balls of different size and weight are dropped onto the model surface.

To connect second-hand data to the data collected through the children's observations, the educator again shows the children real images of the moon's surface. Children can make comparisons between the shapes and characteristics of the real craters and the representations they made in the flour (data analysis).

Informal Science Educators

In order to create a successful model of professional development for informal science educators, it is important to understand the educators' goals for teaching. The closer the match between the educator and the professional development workshop goals are to one another (also known as coherence), the greater the chance of new information uptake (Desimone, 2009; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

There are few general statements that can be made about educators working in informal learning settings because there is no single trajectory that they tend to take as they move into this career (Bailey, 2006; Tran, 2008). ISEs may have previously been school teachers; others may have worked in science labs or field-work locations and were motivated to teach others what they learned; and, yet others may have happened upon the job post while looking for something else. Some have training working with children whereas others have only ever worked with adults. Some have a strong background in science, and others have no training or expertise in any STEM-related field. In a previous research study, ISEs reported that their background training, included science, education, psychology, English, communications and interior design domains (Plummer, Crowl, & Tanis Ozcelik, in progress).

The work of informal science educators is just as varied as their backgrounds. From engaging with visitors in an exhibit gallery, to facilitating a class for a school group to leading a planetarium show, an educator could spend as little as 10 seconds with a child to as long as a few hours each day for a week. Teaching is different from school teaching in that there are often multi-age groups. This is, in part, due to the organization of the learning environment (Tran & King, 2011). Instead of an environment organized by age, gender or ability, objects or phenomena often guide the learning. This can be done through designed spaces, such as planetariums and botanical gardens, or by educator-led demonstrations all based on a specific content domain, such as electricity or chemical reactions. Teaching tends to be interdisciplinary and situated within a relatable context (Tran & King, 2011).

Studying informal science educators can inform the field of best practices and in return, have a positive impact on educators' practice. Informal science educators face similar challenges to formal school teachers. For example, they tend to be isolated in their practice (Allen & Crowley, 2013). This may occur due to the small number of educators at any single site but it is further complicated by a lack of sharing knowledge across sites and settings (Tran & King, 2011).

Educators tend to resort to what they know or how they were taught, when engaging visitors, making it a common practice to draw on classroom techniques (Tal & Morag, 2007; Tran 2007) and to use didactic models for teaching and learning (Bevan & Xanthoudaki, 2008; Cox-Peterson et al., 2003; Tran & King, 2007). Due to these findings, many studies have concluded that more training is needed to assist informal science educators with engaging audiences in ways that promote meaning making experiences for visitors (Bevan & Xanthoudaki, 2008; Castle, 2006; Tran, 2008; Tran & King, 2011).

Beliefs and goals for teaching science impact the way informal science educators engage their audiences too. Research shows that beliefs about learning and goals for teaching are similar for informal science educators across institutions (Tran, 2007). In a study of four ISEs, Tran (2007) found that ISEs often teach science in segments, allowing them to adapt as needed.

Informal science educator goals are most commonly related to developing interest in science and a desire to return to the venue to learn more (Plummer, Crowl, & Tanis Ozcelik, in progress; Plummer & Small, 2013). Content is often valued but not a requirement. In alignment with Plummer, Crowl, and Tanis Ozcelik (in progress) and Plummer and Small (2013), the main goals of the ISEs in Tran (2007) included creating an exciting and memorable experience for the visitor. Goals for science learning as outlined by research synthesis documents can range from affective to cognitive to conceptual and include fostering engagement in science practices as well as identity development (NRC, 1996, 2009).

In a study of planetarium educators, Plummer and Small (2013) identified inspiring interest and developing content knowledge as the top two goals that the educators had for their audiences. The authors also examined their data related to educators' goals and beliefs against six lenses that included learner-centered, knowledge-centered, assessment-centered, motivationally-oriented, sociocultural-centered, and physically-oriented lenses. The lenses were derived from looking across research documents focused on learning and used as a way to describe how

planetarium educators make choices about how to teach. Findings suggest that educators rarely described goals and beliefs that only fit one of these lenses; two or three lenses were often reflected in their descriptions of their goals and methods of engaging their audience.

Another study analyzed interviews with informal science educators from a variety of venues across the United States (Plummer, Crowl, & Tanis Ozcelik, in progress). When asked if young children were able to participate in science, every participant responded with an affirmative. Their descriptions of ways that participants engaged in science varied from ideas about play to using their senses, to engaging in a variety of science practices. The goals for young audiences reported by the participants were similar those in Plummer and Small (2013). The most common answers related to piquing interest, curiosity and engagement. Other goals referred to comfort with and awareness about the natural world.

Professional Development

Museum studies and informal science education programs are growing, but they are not yet providing a large enough workforce or on-the-job training to meet the demand in informal science institutions. For this reason, professional development that is specifically designed for informal science educators (ISEs) is crucial to supporting the missions of the institutions. “High-quality professional development is at the center of every modern proposal to enhance education,” (Guskey, 2000, p. 16). As the research base grows on professional development for ISEs (e.g. Allen & Crowley 2013; NRC, 2009; Tran, 2007), the time is right to focus on quality professional development for all educators, especially as it pertains to engaging young children in science.

There is a standing expectation that many professionals will participate in some form of professional development or professional learning during their career. In order for this professional development to have an impact, it must be relevant to the work of the participating

educators (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007; Yoon, Duncan, Lee Scarloss, & Shapley, 2007).

Measureable outcomes such as an increase in teacher understanding of concepts or skills (Davis & Krajcik, 2005; Desimone, 2009), how professional development has changed teacher practice (Fishman, Marx, Best, & Tal, 2003; Gess-Newsome, 1999; Heck, Banilower, Weiss, & Rosenberg, 2008) and how providing professional development to teachers can in turn positively impact student learning (Desimone, Smith, & Frisvold, 2007; Hamilton, McCaffrey, Stecher, Klein, Robyn & Bugliari, 2003; Hill, Ball, & Schilling, 2008; Lee, Deaktor, Enders & Lambert, 2008) are typical foci of research on professional development. This study focuses on features of professional development that support participants' learning.

The subject matter and setting may differ for informal and formal teaching and learning but best practices for supporting educators may cross boundaries. Therefore, this review will focus on effective features of professional development. Science centers have been providing science-based professional development to schoolteachers (Holliday, Lederman, N. & Lederman, J., 2014) but it has not been well-documented (NRC, 2009). I will begin by reviewing the literature on professional development for informal science educators, but as there are few studies published, I will then turn to the literature on professional development for school teachers.

Features of Professional Development for ISEs

Tran, Werner-Avidon and Newton (2013) conducted a study on the experiences of 17 ISEs who participated in a professional development workshop and then implemented the workshop for their colleagues at their home venue. The researchers' goals were to identify indicators of successful professional development and the necessary supports to ensure it. Through phone interviews with each facilitator two years after beginning the implementation at their venue, researchers collected reflective descriptions of the facilitators' experiences. Researchers found that there were four supports that assisted in making the professional

development for informal educators a success. The four supports are described here in detail and more generally in Table 2.2.

Table 2.2 Supports for Professional Development of Informal Science Educators from Tran, Werner-Avidon and Newton (2013)

Support	Reason
Structured but Flexible Curriculum	Educators should be able to easily adapt the materials to fit their program structures, audience and learning space.
Model the Approaches	Allow time for facilitator to model activities and time for participants to try them on their own.
Broad Participation	Allow for participation from all levels of staffing.
Organizational Culture	Value places on continued professional growth for individuals, departments and for the organization as a whole.

First, due to diverse types of programming at the participants' venues, professional development needs to be designed around a curriculum that can be adjusted to fit different program structures, audiences and learning spaces. Second, it is important for the facilitator to model the approaches. This refers to both modeling the activities for participants and allowing participants time to try it on their own during the workshop. This provides a space for reflection and discussion among participants and builds confidence in the participant to facilitate the activities after the workshop. Third, in order to create a learning culture, professional development should ideally be available to all levels of staffing at an institution, creating a community of practice. Last, it is important for the organizational culture to foster the desire to be better and place value on continued professional learning. There are three levels to this: individual, department, and whole organization.

A second study of extended professional development set within informal learning venues followed eight ISEs for five months as they learned and iteratively implemented a program about climate change to field trip groups at a natural history museum (Allen & Crowley, 2013). Through interviews, observations and debriefing meetings after each group visit, the researchers found that successful professional development for museum educators should be on going, iterative and allow time for reflection to occur. The importance of a community of practice

(Lave & Wenger, 1991) emerged as a necessary support for learning as well as implementing new vocabulary and pedagogy. In a community of practice, participants share goals and information and learn together.

The idea of building a community was also an important part of what Tran, Werner-Avidon and Newton (2013) described with the “broad participation” and support. In order for educators to use similar language when talking about their practice, and, to support one another professionally, it is important to have others with which they can reflect. The idea of broad participation means that co-workers are also involved in the learning. In schools, this often means teachers in a cohort or who plan together. This allows participants to engage with others who are learning the same thing, in turn, reinforcing what has been learned. Tran and King (2007) would argue that the field of informal science learning has not yet created a community of practice. Except for large institutions, there are rarely many people who do the same job at the same place of work. To that end, broad participation becomes impossible for small organizations. The typical size of informal science learning organizations makes it difficult to have a shared language unless educators look beyond their own organization. For this reason, it is useful to look to the field of professional development for teachers as well.

Features of Professional Development for Teachers

Informal learning institutions can provide novel experiences and a wealth of resources and expertise that teachers cannot normally access (Holliday et al., 2015). There is very little research that focuses on the effective features of professional learning sessions held in informal learning institutions (Grenier, 2010). Holliday et al. (2015) describe a professional development workshop for teachers held in a large science center. They found that the informal learning environment and the resources it can provide were exciting to teachers; however, while the novel environment fostered positive affect, it did not foster content learning in the ways the researchers had hoped.

Just as ISEs bring their classroom teaching pedagogy to informal settings (Tran, 2008), it may be useful to review the professional development literature from formal education settings in order to look for boundary-crossing elements that will support ISEs. Garet, Porter, Desimone, Birman and Yoon (2001) and Penuel, Fishman, Yamaguchi and Gallagher (2007) conducted large quantitative studies with teacher professional development to find characteristics of the workshops that teachers felt were most effective for their learning. In both studies, coherence and time for participants to try and reflect upon the new information were found to support effective professional development.

Supovitz (2001) and Yoon, Duncan, Lee, Scarloss, and Shapley (2007) discussed the optimal length of professional development with no conclusive length determined. Supovitz (2001) found that it took 80 hours or more to change the practices of educators. Yoon et al., (2007) reviewed a number of studies that included professional development lengths of five to 100 hours and found that a minimum of 14 hours had the potential to positively improve practice.

Borko (2004) and Desimone (2009) argue that a model for providing and assessing professional development is needed to move the field of formal education forward. Borko (2004) suggests both a model of professional development and a research agenda for studying professional development. Borko's model simultaneously uses an individual and a group focus. At the individual level, the focus is on the knowledge and instructional practices of individual teachers. At the group level, the focus turns to the activities of the community of teachers during and after the professional development workshop is over. This multifocal approach gives the research the power to make claims about individual teacher's instructional practices as well as finding evidence that that the professional development can or can not be linked to their instructional practices.

Figure 2.2 shows Desimone's entire model for analyzing a professional development workshop (Desimone, 2009, p. 185). Her model first focuses on specific features of the

development. She identifies five features that are important (Table 2.3): content focus, active learning, coherence, duration and collective participation. *Content focus* refers to the need to have the professional development set in a subject matter (for example, astronomy). There also needs to be ways in which participants *actively learn* through such things as observing a teacher and then reflecting on it with others in a discussion forum setting. It is important to have a sense of participants' subject matter knowledge, skills and beliefs before beginning so that the professional development can be designed in a way that matches or is complimentary to currently held knowledge, beliefs and skills. This *coherence* may determine the rate of uptake of the professional development learning goals: the stronger the coherence, the higher rate of uptake. The *duration* of time that participants engage with the professional development material should be such that it allows continued engagement long enough to have an impact on practice. Finally, to increase the chance for discourse that could be beneficial to teacher learning, the group involved in the professional development should have something in common (i.e. work at the same institution or teach the same subject). This can be described as *collective participation*. Her model is built upon findings from a number of other research studies (Garet, Porter, Desimone, Birman, & Yoon, 2001; Gess-Newsome, 1999; Lave & Wenger, 1991; Penuel et al., 2007; Supovitz, 2001; Wayne et al., 2008; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007; Yoon, Jacobson, Garet, Birman, & Ludwig, 2004).

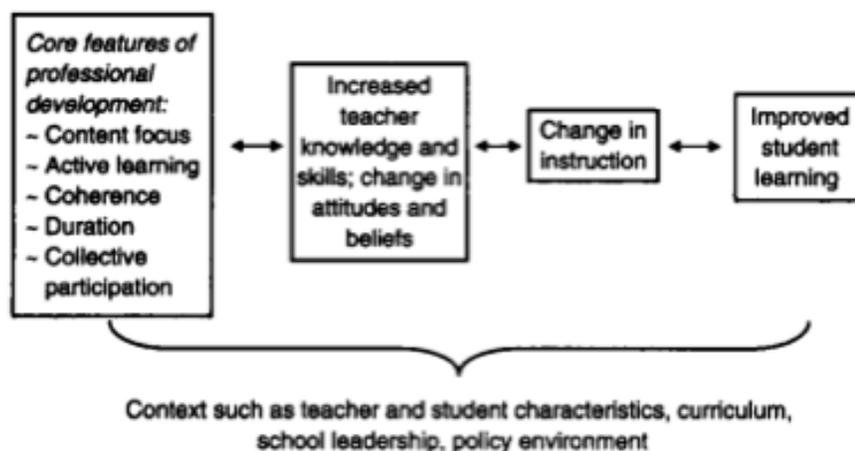


Figure 2.2 Conceptual Framework for Studying Professional Development (Desimone, 2009).

If all five features are integrated into the design of the professional development, the outcome should be increased teacher knowledge and potentially a change in attitudes or beliefs that result in a change in instruction and therefore improved student learning (as shown in Figure 2.3). This model does not describe specific activities or propose a model for instruction (i.e. focus groups, communities of practice) but instead suggests five elements that need to be taking into consideration when preparing a professional development session. This model is useful because it focuses on specific features of professional development not singularly, but in relation to teacher knowledge, skills and beliefs, teacher practice and student learning.

Table 2.3 Core features of professional development (Desimone, 2009)

Feature	Description
Content Focus	Situated within a subject matter area.
Active Learning	Important for teachers to have opportunities to actively engage in learning activities and reflection.
Coherence	Should compliment participants' skill and knowledge.
Duration	Should last weeks or months, totaling a minimum of 20 hours.
Collective Participation	Best when participants have something in common. For example, they work in the same venue or content domain.

Similarities and differences exist between the features outlined by Desimone (2009) and the ones outlined in a study of an ISE professional development model by Tran, Werner-Avidon and Newton (2013). First, it is important to notice that the focus is slightly different between the two. Desimone (2009) describes a professional development session for teachers of a specific subject matter. Tran et al. (2013) describes professional development sessions for ISEs with a focus on practice. Precedence is placed on encouraging ISEs “to build a common language, foster habits of reflection on their science facilitation practice, and nurture a learning community among colleagues.” (Tran, et al., 2013, p. 335). Both studies describe the importance of participation from people with the same organization or school in order to support learning. Both studies also place value on active participation. Desimone (2009) refers to it as “active learning” and Tran et al. (2013) refers to it as “modeling the approaches,” but both describe the need for participants to try the new things they learn and reflect upon them. One feature from Tran et al. (2013), which is missing from Desimone (2009) is the idea of organizational culture. This may be due to the implied nature of reoccurring professional development for teachers in school but not for ISEs.

Effective Features for Online Professional Development

One more area important to cover in this discussion about professional development, is the way in which professional development is formatted. Until now, I have focused on face-to-face interactions; however, the increasing demand for professional development has created a wider variety of options, including workshops that are held completely online (Fishman, Konstantopoulos Kubitskey, Vath, Park, Johnson & Edelson, 2013; Moon, Passmore, Reiser & Michaels, 2014). The online interface allows teachers to join in when they are available and take their time covering the material. It also allows facilitators to leverage resources that may not be available locally (Dede, Ketelhut, Whitehouse, & McCloskey, 2009).

In a randomized study of teachers using the same curriculum, Fishman and colleagues (2013) explored the difference in classroom practice and student learning when a professional

development for teachers was held online versus in person. They found no significant differences in practice or learning between the two conditions. Other studies of online professional development found similar results (e.g. Fisher, Schumaker, Culbertson, & Deshler, 2010; Frechtling, Sharp, Carey, & Vaden-Kiernan, 1995).

Moon and colleagues (2014) credits the work of Fishman and colleagues (2013) as providing the foundation for best practices in online professional development. In order to tease out which elements of the online professional development are successful and to know whether or not they match current models for best practices, each element of the workshop should be linked to theory. Moon and colleagues (2014) put forth three tenants of online professional development. Professional development should be embedded in a content domain, involve active learning opportunities, and connect to the practice of the participants.

The challenge with online professional development is figuring out how to continue the support once the workshop is complete. One way might be to create a community of practice amongst participants (Lave & Wenger, 1991). Schlager and Fusco (2003) argue that successful professional development will result in a strong community of practice; however, Donnelly et al. (2000) reports that few professional development workshops held online have been sustainable enough to foster one.

Online professional development may be important for informal science educators as they are often few in the same geographical area having similar focuses in their jobs. Communities of practice can form between ISEs in institutions of any distance apart, if we can harness the power of online professional development. When describing the importance of communities of practice with informal science learning institutions, Allen and Crowley write, “This community can help practitioners to challenge dominant notions of teaching and learning together, differentiate practices and strategies for engaging different kinds of audiences, and support ongoing professional development through conversation and reflective practice,” (2013,

p.18). There is no research that focuses on online professional development for ISEs. This study is an important contribution to the field.

Proposed Model of Professional Development for Informal Science Educators

This study used sociocultural and situated learning lenses as a theoretical framework to explore and explain learning that occurred during a professional development workshop. Learning arises through activity, inseparable from context or culture (Brown, Collins, & Duguid, 1998; Hull & Greeno, 2006; Rogoff, 2003). Individuals develop and learn through their involvement in social activities and cultural practices (Vygotsky, 1978). Professional development workshops are created for this purpose. They bring together similar groups of people to learn with and from one another as, together, they promote shared values.

Brown, Collins and Duguid (1989) describe learning as situated within a context. Hull and Greeno (2006) uses the term situative learning because he argues that everything is situated. As a learner interacts within the culture, she is constructing information to help her be successful. Her participation in the culture has the power to advance and change it (Rogoff, 2003). The culture of ISEs and the work they do varies, as within any culture, but they share a common language and have many similar values (Bailey, 2006; Tran, 2007). From the lens of engagement in science practices, sociocultural learning theory provides insight into both individual and collective activity (NRC, 2009). I used a sociocultural lens to explore individual participants' understanding of the workshop materials and content. I also used a sociocultural lens to look at their experiences and interactions in the context of their implementation of the workshop materials.

The learning system, encompassing the interaction of this culture with the professional development context, is comprised of the elements of the professional development workshop (designed by a facilitator) and the knowledge and skills that the participants bring to the

workshop (Borko, 2004). These elements are set within a context that, in this case, is the domain of astronomy learning for preschool-age audiences.

A situative perspective allows researchers to identify learning as a change in participation (Brown, Collins, & Duguid, 1998; Lave & Wenger, 1991). In this study, I looked for a change in the ways participants talk about and use science practices when planning for and facilitating activities with preschool audiences. This lens also provides a way to look for patterns that are common across interactions between participants and across the professional development program as a whole. From a perspective of culture, individuals learn and develop through their involvement in the cultural practices (Rogoff, 2003). Extending that, cultural shifts can happen when participation changes.

This study uses sociocultural and situative learning perspectives and brings together findings and model structures from formal and informal learning domains to create a set of elements that are important to include. Features of professional development workshops have been the focus of research for over decade (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007; Wayne, et al., 2008; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Features of professional development that increase teacher knowledge and improve practice are important to consider. What follows is a description of a framework that is mainly a blend of Desimone's and Tran and colleagues' frameworks, with support from others that I hypothesize will foster productive professional development for informal educators.

Duration

Duration puts emphasis on the need for professional development to last long enough to allow for participants to learn and reflect upon the information being shared (Penuel et al., 2007). It is superficial to attach a required number of hours to duration, because, using a sociocultural lens on learning means that it takes time to learn and time to understand how to be a part of a new community of practice (Lave & Wenger, 1991). Also, despite the ubiquitous technology in online

professional development workshops, there is yet to be a good model for sustaining the support for the participants after the workshop is over (Donnelly, Dove, Tiffany, Adelman & Zucker, 2000). A good model may be to support educators through at least their first implementation. Another model to consider is that of iterative implementation such as Allen and Crowley (2013), which included two training sessions and debrief meetings after each of the first five implementations.

Coherence

Coherence refers to the extent to which the beliefs and goals of the participants match the beliefs and goals of the professional development workshop. The stronger the match, the more likely the participant is to learn and use the materials at a later time (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). As informal science educators arrive at these jobs with very different backgrounds (Bailey, 2006), participants will likely have different strengths and weaknesses in terms of content knowledge and teaching practices. It is important to take into account participants' prior knowledge, goals, and beliefs in order to design a relevant, lasting experience that impacts practice. When all involved have shared goals and beliefs, we know from sociocultural learning theory that it is much easier to form a community a practice, where participants learn from and support one another (Lave & Wenger, 1991; Vygotsky, 1978).

Learning is difficult to separate from context, so if informal science educators are being asked to teach astronomy to preschoolers while fostering engagement in science practices, professional development should address how to do this successfully. Research shows that when educators are knowledgeable of specific content, they are more likely to engage learners in discussion about it (NRC, 2000; Penuel et al., 2007). Even though Wayne, et al., (2008) claim that there is not enough evidence to say which features of professional development are best, they found that professional development workshops for teachers that focused on content had a

stronger, positive influence on student learning. A focus on content or engagement in practices should align with the interest of the participants, providing another element of coherence.

Active Learning

In order to maximize learning, participants should be given the opportunity to try out activities during the professional development, reflect on their own practice related to the materials presented and discuss ideas and concerns with others (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Tran et al., 2013). It is also important that educators engage first-hand in active learning during professional development if they are to use it in their own practice (Gess-Newsome, 1999; Penuel et al., 2007).

Active learning is strongly supported by situated and sociocultural learning theories because participation in the community of practice, with the cultural tools, is the way learning happens (Hull & Greeno, 2006; Lave & Wenger, 1998; Vygotsky, 1978). Rose (2004) found that the skills of blue-collar workers are built through interactions and experiences with others at their place of employment. When people with shared values and language interact, learners can thrive (Rogoff, 2003; Rose, 2004).

Organizational Culture

Organizational culture refers to the extent to which an organization as a whole values professional development for employees. From sociocultural learning theory, we know that learning often happens between members of a community of practice. An organization has the power to foster a sense of community, where all participants have a shared goal. The element of organizational culture is typically out of the control of the professional development provider but it is important to keep in this framework because it may impact participation. An outside facilitator may not be able to change the departmental or organizational values on professional development but recognizing that support may vary, facilitators can explain the need for value to be placed on professional development and encourage and empower participants to be advocates.

Furthermore, recognizing that not all organizations value it enough to allocate resources to it, providers should find and develop accessible new avenues for facilitation.

In order for informal science educators to be successful, support and participation from all levels of their organization is important. A collective participation, where staff from varying levels of management participates in the same professional development workshop, will establish a shared language for participants. Shared knowledge and shared learning are the basis of a profession (Tran & King, 2011).

Summary

In this chapter, I have shown how informal science learning encompasses much of how people come to learn and understand their world. Through visits to science museums and similar institutions, people of all ages can engage in meaningful learning experiences. The informal science educators who work in these institutions arrive at their jobs in a variety of ways with diverse education and training. Families with preschool-aged children comprise a subset of the total audience that informal science educators engage with regularly; however, not all of the educators may have training in working with young children. Therefore, as a field, we should support them through professional development opportunities, tailoring them to the needs of the people who work in the field.

There are few generalizations that can be made about informal science educators; however, we have a basic idea of their goals for teaching science to preschool-age audiences and their understanding of best practices in doing this, from which we can build. Given the differences in previous educational training and experience and understanding that institutions have varying program structures (e.g. guided versus unguided activities, differences in program length), a model of professional development is needed that is robust enough to handle these variables and acknowledge the beliefs and goals already held by the educators. I have proposed elements of a professional development that should be attended to in the planning stages and

during implementation and have outlined the need to integrate appropriate science practices into the goals of the workshop.

Chapter 3

Context

This study is part of larger NSF-funded research project titled *My Sky Tonight: Early Childhood Pathways to Astronomy (MST)* that includes a partnership between researchers and practitioners in science education and early childhood education across the United States. The goal of the project is to build capacity within the field of informal science education to effectively engage young audiences (preschool-age, three to five years old) in astronomy. This project will deliver a toolkit of activities for informal science educators, professional development workshops to train educators in using the activities and a website to continue the support to educators in the field. The project will also build awareness of the abilities of young children to engage with astronomy content. Currently there are no other forms of professional development or curricula focused on teaching astronomy to preschool-age audiences. From a previous research study (Plummer, Crowl, & Tanis Ozcelik, in progress), findings showed that informal science educators (ISEs) do not always have the content knowledge or know how to teach astronomy to preschool-age audiences, during the day, in the short amount of time they visit. This dissertation study is based on the pilot professional development workshop offered by the My Sky Tonight development team.

Development Team

The development team responsible for the design and facilitation of the online workshop consisted of staff members at the Astronomical Society of the Pacific, researchers from two universities and museum partners from numerous sites across the country. The lead professional development facilitator was an astronomy educator at the Astronomical Society of the Pacific named Abby. Abby has been working in the field for 14 years and has run several online professional development workshops for informal science educators. She also participated in the

development of the toolkit activities. She had two co-workers, Simone and Victoria, who assisted in the workshop lesson planning, preparation and facilitation. Simone focused most of her time on astronomy content, providing lessons and resources such as songs to participants. Victoria led the effort of preparing materials for activities and assembling the toolkits for dissemination. During webinars, she focused on toolkit activities and materials.

There were three lead researchers involved in the workshop. Julia, my advisor, focused her time in the professional development on teaching ISEs about science practices and showing them examples of what it looks like when children engage in science practices during museum programs. She produced short video clips of children engaging in science practices and created a three-page document for participants describing what they are and how to support them. During the workshop, she was also involved in describing and showing how some toolkit activities included ways for children to engage in science practices. Joy and Martha were also researchers involved in the project. They are tenured faculty at universities. They focused on ways to include and highlight developmentally appropriate strategies into toolkit activities. Each researcher spent time during webinars discussing the topic and described how these were a part of the toolkit activities.

Finally, there were museum partners involved in the development of the workshop and toolkit activities. These included staff members from two informal science centers. Janna works at a small science center and primarily focuses exhibit floor activities and programs on early learners and their families. Eva, also a participant in the workshop, works at a large science center. Her focus is also on early learners, preschool-age through second grade. Both Janna and Eva bring decades of experience teaching three to five year olds and both participated in conversations and evaluations of the pilot toolkit activities.

My Role

I played a role as both a researcher and museum partner. Working with my advisor, I helped the (MST) team understand how participants talked about and then engaged children in science practices. However, my 11 years of experience working in science centers positioned me to also provide insight from a practitioner's perspective. I played a role in the development of the pilot toolkit activities and the professional development workshop. I was also a participant observer in the workshop (Borko, 2004). Having a background in astronomy and having worked in informal science learning institutions across the country, I also have experience teaching these topics to children.

Workshop Overview

There were three main elements to the workshop: asynchronous, synchronous and physical. The workshop lasted six weeks, from March 24-May 2, 2014, and was conducted completely online (primarily asynchronously) through the Astronomy from the Group Up (AFGU) website. The asynchronous participation allowed for a flexible schedule to accommodate all participants. Each week of the workshop focused on a different theme. The developers created a weekly structure of engagement for participants. Materials for each week were posted to the online website, often on the first day of the week. The toolkit (physical element) was mailed to participants during week two of the workshop. Participants used the materials in this kit throughout and after the workshop to test activities designed by the development team. A discussion forum also allowed participants to ask or answer questions or post ideas to the group. Once per week, a one-hour (synchronous) webinar, allowing participants to ask questions and receive feedback in real time. Developers were the main presenters and the purpose was to deliver content to ISEs related to astronomy and the MST Toolkit activities. Webinars consisted of astronomy content lessons, activity demonstrations from a toolkit and researchers who spoke about science practices and developmentally appropriate strategies.

Timeline

The first week of the workshop focused on introductions and the second week reviewed children’s abilities and misconceptions about astronomy. Week three through five concentrated on the three central themes of astronomy activities: looking up and seeing further, noticing patterns, and exploring new worlds. For each theme, ISEs’ were encouraged to test different toolkit activities. The final week served as a wrap-up. At the end of the workshop, participants had the opportunity to design and share a lesson or set of lessons called an Action Plan, tailored for their own site. A bulleted list of each weekly agenda is outlined in Table 3.1. A more detailed description of typical events such as joining the webinar, as well as a full description of week two, follows.

Table 3.1 MST Pilot Professional Development Workshop Timeline

Week	Weekly Themes	Weekly Activities
Week 1	Welcome and Introductions	<ul style="list-style-type: none"> • Join the Webinar • Review Workshop Overview including expectations and weekly themes • Post an introduction online • Complete a pre-workshop survey online • Do a night sky observation twice • Watch a video of children engaging in science and respond to prompts.
Week 2	Children’s Astronomy Questions, Misconceptions, and Abilities	<ul style="list-style-type: none"> • Join the Webinar • Read science practices document then watch and reflect on a short video • Watch and reflect on a video on developmentally appropriate strategies • Make moon observations starting now for future weeks and match what you see to moon phases cards • Continue to do night sky observations • Complete weekly survey
Week 3	Looking Up, Seeing Farther	<ul style="list-style-type: none"> • Join Webinar • Look through the toolkit of materials that just arrived. Choose one activity from a list of three to test at your site then reflect on it • Continue moon and night sky observations • Complete weekly survey

Week 4	Noticing Patterns	<ul style="list-style-type: none"> • Join the Webinar • Test and reflect upon another activity from the toolkit • Continue moon and night sky observations <p>Complete weekly survey</p>
Week 5	Exploring New Worlds	<p>Join the Webinar</p> <ul style="list-style-type: none"> • Test and reflect upon a final activity from the toolkit • Continue moon and night sky observations • Being writing Action Plan • Complete weekly survey
Week 6	Wrap-Up, Project Sharing	<ul style="list-style-type: none"> • Join the Webinar for wrap up and next steps • Share Action Plan online • Review and rank all toolkit activities • Complete post-workshop survey

During the six weeks of the workshop, participants could log into the AFGU website anytime they chose using a username and password they created. There was a link on the site to join the webinar each week. Participants would log into their AFGU profile, click on the webinar link and be entered into the room via Instant Presenter. Within Instant Presenter, they had a window to view the synchronous webinar, a discussion forum for questions that could be seen in real time and a list of users who were in the room. Audible communication was one-way, from the presenters, but participants could interact via the chat text box at any time. Webinars lasted for one hour and were then archived so that any participant could go back to it at anytime and watch it. This also allowed participants who were unable to join the webinar on time to still view it in its entirety.

Throughout the six weeks, there were reoccurring tasks such as making moon and sky observations, testing and reflecting on the activities and taking a weekly survey. Content was interwoven into the webinars along side the activities. Presenters would give a brief overview of what could be see in the night sky, including the phase of the moon at the time. Participants were asked to begin to make regular observations. This was also meant to help them begin to recognize

patterns, like moon phases. With the exception of the first two weeks, every webinar included a description of how to set up and facilitate a selection of toolkit activities. Participants were then tasked with trying out the activities during the week, with visitors of their venue, and provide feedback to the developers. At the end of each week, participants were asked to take a survey about the week. Feedback specific to activities' content were collected and used to inform the following week's webinar.

Introduction to Science Practices in MST Workshop

During the first week, participants were asked, on their own time, to watch a set of video clips and describe how they saw participants engaging in science. The second week of the webinar, participants were introduced to developmentally appropriate practices and science practices by presentations given by the researchers: Joy, Martha and Julia. Abby welcomed everyone to the webinar and introduced Joy. For about 25 minutes, Joy discussed her research on children learning and facilitated a conversation about metaphors that describe children. She began with a slide that read, "Children are like ____." Many participants responded in the chat box with the word *sponges*. Joy then outlined four metaphors that people use to talk about children; the first one being that children are like sponges. She also introduced the term *developmentally appropriate practice* and would return to that later in the workshop.

Next, Julia introduced the idea of engaging children in science practices. She showed short video clips of children doing science, described how they were engaging in science practices and also provided participants with a document that described the practices (Appendix A). She also sent a link to participants for another set of video clips of children engaging in museum programs, to give them more practice identifying engagement in science practices.

Next, Martha presented some of the research that she has been working on with Joy around children's understanding of astronomy. Finally, Abby concluded the webinar by describing that she would like participants to use moon phase cards to match the moon's shape

over the next few weeks. She encouraged them to look for patterns. As she often did at the very end of webinars, she also answered questions that participant had entered into the chat box.

During the webinar in week two, participants were provided with video links to observe children in a museum engaging in science practices. Only a few videos were able to load given internet connectivity, but participants were provided with a link to watch them after the webinar ended. They also received a three-page document written by Julia, outlining the practices and what they might look like in astronomy with preschool-age children. They were asked to watch the clips while using the three-page document to identify and describe instances of science practice engagement.

A discussion forum was also available for participants to post questions and respond to others. There was one thread specifically about science practices, started by Abby, the lead facilitator. She linked to a video that Julia created, of children engaging in science practices. Participants were asked to watch the video and respond to two questions: 1) How did the children engage in science practices? and 2) Can you think of examples of children engaging in these practices in your venue? Julia responded to each post. Many of the posts described what was happening in one or a portion of one video clip and related that to something in their own museum.

Toolkit activities

Table 3.2 shows the nine toolkit activities that were included in the pilot workshop. Each activity varied in the setting in which it is easiest to implement. For example, some activities were designed to be facilitated by an educator, such as in a workshop, while others were able to be stand-alone activities that an ISE could choose to station on the exhibit floor.

Table 3.2 MST Pilot Professional Development Workshop Toolkit Activities

Activity Name	Brief Description
Bear's Shadow	The book <i>Moonbear's Shadow</i> by Frank Asch is read aloud to the group and then children are given a similar set up as to the story. By using the felt pond/grass placemat, small tree, plastic

	bear and a flashlight, children can recreate shadow scenes from the book.
Build A Space Explorer	This activity allows children to use recycled materials to design and build a spacecraft to explore a planet or moon landscape.
Magnification Station	Children are provided with a variety of magnification tools as well as zoomed in pictures of object on the table. They can match the picture to the object or use the tools to explore objects around the room.
Moon Phase Matching	Large mats with pictures of moon phases are placed on the floor. Using a large die with corresponding phases, children can take turns rolling it and jumping on the matching moon phase.
Moon Sand	A tub of sand is set up with figurines of astronauts or space vehicles. Children can use pretend play to create a story.
Night Tent	This small tent creates a dark environment to explore constellations. Small glow stickers are placed on the inside of the room. Children are given flashlights and allowed to go in and identify the constellations.
Sky Seek and Find	This activity starts with a bin full of dried beans that has daytime and nighttime sky object hidden within. Children search through the bin, find objects and identify if they have seen them in the day or night sky.
Sky Window	Using a picture frame (made of blue paper facing out on one side and black paper facing out on the other) attached to a craft stick, children place stickers of day and night sky objects either on the blue side for day, or black side for night. They can hold their window up and look through it as they peer into the real sky to match what they see.
Sun's Energy	Using a felt board, children work together or with an adult to create a story of the sun's energy by making creating an energy chain from the sun, through food, to the child.

Goals of Developers

In order to understand the goals of developers for ISEs' engagement during the workshop and when engaging preschool-age audiences, I reviewed documents created by the development team and interviewed Abby. The greater the coherence, or the closer the match between the educators' and the professional development workshop's goals are to one another, the greater the chance of new information uptake (Desimone, 2009; Penuel, Fishman, Yamaguchi & Gallagher, 2007).

I coded four documents, using themes that emerged from the interview responses from ISEs about their goals, in order to look for links between what ISEs gained from the workshop in

relation to what developers were hoping would be gained. The four documents were: MST Workshop Overview, MST Activity Matrix, MST Activity Descriptions and an interview with the lead facilitator, Abby. The MST Workshop Overview document was created for participants. It acted like a syllabus for the six-week workshop. It included the weekly theme, overview of what to expect each week and the names and organizational affiliation of each moderator and guest speaker. The MST Activity Matrix was created as an internal document for developers. It was a spreadsheet that listed each MST Toolkit activity down the left side and included the following columns to fill in for each activity: topic, content learning goals, intended venue, developmentally appropriate practices, science practices and cultural and linguistic sensitivity. The MST Activity Descriptions were one-page outlines of each activity. They included a section about goals, set-up, bulleted description of the activity, related science practices, questions to ask children and a picture of the materials. The interview with Abby, the lead facilitator of the webinars, also revealed that she wants the ISEs to, “feel comfortable with the basic science and content covered by the activities in the toolkit. To have them feel comfortable with developmentally appropriate practices. In particular, as applied to science activities for 3 to 5 year-olds. And to have them use the My Sky Tonight activities and feel comfortable with them and give us lots of feedback on them.” Table 3.3 shows the goals that emerged from each document and from the interview with Abby. The evidence column provides either a quote pulled from each document or a list of items that provide support of the goal.

Table 3.3 Developers’ Goals for Engaging Preschool-age Audiences

Document	Goal	Evidence
MST Workshop Overview	Conceptual learning	“Each week, we’ll focus on a different theme around how young children learn about astronomy, covering both the background astronomy knowledge and children’s developmental stages as they apply to learning astronomy, as well as how you can
	Participating at Age-Appropriate Level	
	Engaging in Science Practices	
	Fostering Parent-Child Interactions	

		support children and their families in engaging in scientific processes.” (page 1)
MST Activity Matrix	Conceptual Learning	Content Learning Goals column
	Participating at Age-Appropriate Level	Modality column
	Engaging in Science Practices	Science Practices column
	Participating at Age-Appropriate Level	Developmentally Appropriate Practices column
MST Activity Descriptions	Creating a Comfortable Learning Environment	Goals section (includes general engagement goals)
	Engaging in Science Practices	Science Practices section
	Conceptual Learning	Background section
	Creating a Comfortable Learning Environment	Quick Set-up section (describes ways to engage children)
	Creating a Comfortable Learning Environment	Questions to ask section
	Supporting Children’s Abilities	Supplementals – for example, challenge cards and songs
Abby (lead facilitator) Interview Transcription	Creating a Comfortable Learning Environment	“I believe their goals were to learn how to get their preschool-aged visitors engage in astronomy activities, and to have a set of well-tested hands-on activities about astronomy for that age group. Some of them learned more about how to work well with that age group, especially doing science, and for others they learned more astronomy and then how to talk to that age group about astronomy.”
	Supporting Children’s Abilities	
	Conceptual Learning	
	Participating at Age-Appropriate Level	

From this table, it is clear that the developers show a preference toward *providing a comfortable learning environment, fostering conceptual learning and participating at age-appropriate level*. Preference, in this case, is shown by the number of separate documents where these goals emerge. Also, built into the workshop by developers, were developmentally appropriate practices and science practices that were tailored to the preschool-age group. Developmentally appropriate practices, as outlined by the National Association for the Education

of Young Children (NAEYC), are guides for adults who work with young children. Each practice is grounded in child development research and takes the individual and culture into consideration.

Chapter 4

Methodology

In this study, I describe informal science educators' goals for teaching science to preschool-aged audiences before and after they participate in a six-week professional development; the ways in which their understanding of science practices changed; and show specific cases of the ways in which ISEs talk about and engage young learners in science. Figure 3.1 shows the professional development system that I analyzed in this dissertation (Borko, 2004; Greeno, 2011). Using this system lens allows the focus to be wider than just on the individual without losing sight of each individual. The properties of this system of individuals include the participants' goals for teaching science to preschoolers and their understanding of science practices both before and after the workshop, the implementation of the six-week online professional development workshop and ISEs' understanding of how to engage preschool-age audiences in science.



Figure 4.1 *My Sky Tonight* Professional Development System

Participants

A total of 21 informal science educators (ISEs) joined the MST workshop. There were 18 female and 3 male ISEs. The criteria for choosing workshop participants was as follows: work in an informal science institution (museum, nature center, planetarium, or other similar site); work regularly or plan to work regularly with preschool audiences; be available during the dates of the workshop and able to dedicate approximately five hours per week to the work; and have an interest in teaching astronomy to preschool audiences. Every participant had experience working with visitors under the age of 18 years, but only five had previous experience with preschool-age children. Participants were from informal learning institutions across the U.S. The group included informal science educators from planetariums, environmental education centers, children's museums, natural history museums and science centers.

Sixteen ISEs were active throughout the whole six-week workshop. They represented 14 different sites. This set of 16 completed the pre- and the post-workshop interviews and are the sample I use in this dissertation. A subset of this group (n=7) participated in both interviews and allowed the developers to visit, observe and video record them teaching preschool-age audiences at their venue.

Data Sources and Collection

To answer the research questions, I used three primary sources of data described below. The first two sources, pre/post interviews and a video analysis task, include data from 16 participants. The third source, observation of implementation, was collected from a subset of seven participants who agreed to participate further.

Pre- and Post-Workshop Interviews with ISEs

I conducted semi-structured interviews with each registered participant before and after the workshop to better understand ISEs goals and the ways in which they engage preschoolers in

science. The Pre-Workshop Interview Protocol can be found in Appendix B. The Post-Workshop Interview Protocol can be found in Appendix C. A total of 16 people completed both pre- and post-workshop interviews. My interview protocol built on questions used in previous research (Plummer, Crowl, & Tanis Ozcelik, in progress). Interviews were conducted over the phone and audio recorded for transcription.

During the interview, I asked ISEs about their goals for working with preschool-age audiences. I accepted all answers without placing preference on or prompting responses related to science. I also asked about science practices. In a previous study with informal science educators, science practices were often mentioned with limited specificity (Plummer, Crowl, & Tanis Ozcelik, in progress). I probed with general questions to provide the opportunity for practices to emerge during participants' responses. For example, I asked if there were any specific techniques or strategies that the ISE made sure to include in lessons to help students engage with science. Once the participant exhausted his or her ideas, I asked targeted questions to clarify practices that were discussed. When no practices emerged from their answers, I specifically mentioned that I was interested in using a science practice framework for engaging preschoolers and asked if they had any familiarity with it. Using the same set of questions but adding in prompts based on observations during the workshop, post-interviews probed for changes in goals and understanding of science practices.

Video Analysis Task

During the first week of the workshop, participants were provided a link to three, short video clips. At the end of each clip, they were asked to reply to a survey question. The question asked them to describe the ways in which they saw children engaging in science, in each clip. During the post-workshop interviews, I asked participants to participate in the same activity. While we were on the phone, I asked them to watch the clips and talk about how they saw children engaging in science.

Observation of Implementation and Post Interview with ISEs

The seven participants resided in California, Washington, New Mexico, Illinois and Michigan. Due to the geographic distribution of participants, for the seven ISEs who agreed to be observed either Abby, Julia or I visited their venue while they were facilitating activities from the MST Toolkit. We audio and video recorded the ISE in practice using at least one MST Toolkit activity with preschool-age audiences. Then, either Julia or I conducted a brief post observation interview, which can be found in Appendix C.

Data Analysis

In this section, I will describe how I analyzed the data to answer each of my research questions. As an overview of the entire study, I have included my Research Design Matrix, Table 4.1. The matrix shows the data sources and analysis methods for each research question.

Table 4.1 Research Design Matrix

Research questions	Data sources	Data analysis
1. What are the goals of ISEs when teaching science to preschool audiences before & after PD?	- 16 pre/post phone interviews - Video Analysis Task	- Pre-developed codes (Plummer, Crowl, & Tanis Ozcelik, in progress) -Constant comparative analysis (Strauss & Corbin, 1994) -Member check during post interviews
2. What do ISEs know about science practices, prior to professional development and how does their understanding change after PD?	- 16 pre/post phone interviews	- Pre-developed codes (Plummer, Crowl, & Tanis Ozcelik, in progress) - Phenomena-driven Engagement in Science Practices Framework - Constant

		comparative analysis (Strauss & Corbin, 1998)
3. How do ISEs describe how they engage preschool audiences in science?	- 7 pre and post phone interviews	- Pre-developed codes (Plummer, Crowl, & Tanis Ozelik in progress) - Constant comparative analysis (Strauss & Corbin, 1998)
4. How do ISEs implement science when teaching activities from the PD workshop?	- Video recorded observations of 7 participants	- Pre-developed codes (Plummer, Crowl, & Tanis Ozelik in progress)

Analysis of Goals

During pre-workshop interviews, participants were asked, “What are your goals for working with preschool-age audiences?” I summarized their goals for engaging preschoolers in science by analyzing transcripts of their responses. I used initial codes from a previous study on informal science educators as a starting point for identifying goals (Plummer, Crowl, & Tanis Ozelik, in progress). As needed, I “elaborated and modified” initial codes as new data was played against them (Strauss & Corbin, 1994) to ensure little overlap. Using a constant comparative analysis (Strauss & Corbin, 1994), I created a list of 29 initial codes. Each response was coded with ideas such “learning through play” and “to create an environment where kids want to participate.” Then, looking across the participants, similarities were identified. These initial codes were then combined into a single code titled “to create a comfortable learning environment.” I then looked at the entire set of initial codes and grouped them into 8 categories.

During post-workshop interviews, participants were asked, “Here’s what I remember you saying were your goals when we first spoke... Are there any you’d like to add, subtract or change?” By asking the question this way, it became a member-check (Lincoln & Guba, 1985). I

also asked about their current understanding of science practices since participating in the workshop.

Understanding Use of Science Practices

In order to explore ISEs understanding of science practices, I first searched each pre-workshop interview for any and all descriptions of ways in which ISEs engage preschoolers in science. Using the Phenomena-driven Practices of Science (PEPS) Framework I developed, I specifically noted if ISEs answered or described engaging in science practices. The criteria for this was to include a scientific phenomenon in which to engage, first-hand or second-hand data and a scientific question or goal statement that leads to an investigation. At times, they used science practice language, but did not provide enough detail to fit the criteria in the PEPS Framework. During the post-workshop interview, I specifically asked each participant what he or she learned about science practices and if they found them useful. I looked across the data for patterns that emerged related to young children's engagement in science.

Next, I searched participants' responses to the Video Analysis Task clips for use of science practice language. Once science practice language was identified, I looked closer to see if the description fit the PEPS Framework. I collected all cases of science practice language use and science practice engagement descriptions during coding.

Describing Engagement in Science Practices

To understand how ISEs engage children in science practices, I again used interviews, but I focused only on seven participants who completed the entire workshop and agreed to allow our team to video record their programs. I used categories from Table 4.2 developed originally for a previous study (Plummer, Crawl, & Tanis Ozcelik, in progress) that encompass engaging children in science practices, according to the PEPS Framework, as well as other forms of science engagement.

Table 4.2 Science Engagement Methods and Descriptions

Category	Codes	Description
Science Practices	PEPS Framework	a scientific phenomenon in which to engage; data involved, whether collected first hand or not (NRC, 2012); a scientific question or goal statement that leads to an investigation
Other engagement with science	Science Activity	These are often hands-on science-themed activities that do not require the use or collection of data or any engagement in a related phenomenon.
Other engagement with science	Demonstration	This category refers to the passive participation in science that occurs when a facilitator demonstrates a phenomenon.
Other engagement with science	Content Delivery	This is often passive participation by learner. The facilitator does not engage audience to participate, rather reads a non-fiction science book or states facts about a phenomenon.
Other engagement with science	Science Conversation	This category requires some back-and-forth between facilitator and learner. It often comes in the form of question-answer.
Other engagement with science	Creative Engagement with Science	This category encompasses pretend play, singing, dancing and fiction stories with accurate science. Most often there is active participation by the learner.
Home Engagement with Science	Home Engagement with Science	Occurs when facilitator encourages children to do science after program ends, often when they go home.

Engaging Children in Science Practices

For a subset of participants (n=7), Abby, Julia and I visited and recorded them facilitating activities from the MST toolkit, with audiences at their institutions. In order to analyze the ways in which ISEs engaged their audiences, I used the categories in Table 4.2 (Plummer, Crowl, & Tanis Ozcelik, in progress) to code video instances.

The two codes that are most similar are the *science practices* and the *other science engagement - science activity*. In both codes, learners are engaging with a phenomenon but only

during engagement with science practices are they working with data. The two examples that follow explain what it would take to turn a science activity into engagement with science practices.

Examples of engagement in science practices versus a science activity. In order to show the difference between engagement in science practices and engagement in a science activity, I will describe two different scenarios. One scenario involves children learning about the purpose of binoculars and the phenomenon of magnification. The second is an example of a designed environment made to resemble the moon's surface. Children were given time to explore as if they were astronauts in space.

Using Binoculars. During a *science activity* children made binoculars and then peered through them to view objects taped to the walls of a classroom. To make them, children taped two, short cardboard tubes together. In this instance, there is no engagement with science practices.

Using Binoculars to Engage in Science Practices If, on the other hand, children had been able to test out a real pair of binoculars first, to view the pictures on the wall, it would have given them a chance to experience the phenomenon of magnification. Through conversation with and guidance from an adult, children could collect data related to the fact that looking through the binoculars makes things further away appear closer. Or, that looking through them makes small objects appear larger. After experiencing the phenomenon, the activity of making the cardboard binoculars has the potential to become an activity in making a model of a pair of binoculars.

Using the Moonscape Lesson. In a unit about the moon, a tie-dyed sheet made to look like a cratered lunar surface was placed over a small mattress. Children cut holes for their faces into large brown paper bags and wore them as helmets. They made air packs by taping two water bottles together, covering them with aluminum foil and using yarn to make shoulder straps. Some even rubber banded sponges to their feet as moon boots. When children were allowed to freely

explore the lunar landscape and use their imaginations to jump on the mattress, the activity was very play oriented.

Using the Moonscape Lesson to Engage in Science Practices. In order to turn the experience into a science practice-themed engagement, children needed some data about the phenomenon of the represented environment. Allowing children to view real video footage of astronauts walking on the moon and helping them notice the ways in which astronauts moved in lower gravity with spacesuits on, could have given children a secondary data source from which to draw. Then, when children were on the designed lunar surface, they could have modeled those movements.

Conclusion

In this chapter, I have described the parts of the *My Sky Tonight* Professional Development System that I analyzed. In order to document the goals that ISE's hold for engaging preschool-age audiences and their understanding of science practices, I interviewed all of the participants (N=16) before and after the workshop. I analyzed this data through the use of constant comparative analysis (Strauss & Corbin, 1994) and initial codes developed during a previous study (Plummer, Crowl, & Tanis Ozcelik, in progress). For a subset of these participants (n=7), I used the pre- and post-workshop interviews plus video-recorded observations of their MST Toolkit implementation to describe the ways in which they talk about and facilitate science engagement for preschool-age audiences.

In the follow two chapters, I will show the findings of this analysis. Chapter five comprised of data from the entire sample of participants and focuses on the first two research questions. I describe findings related to the goals that ISEs held before and after the workshop as well as the ways in which they talk about doing science with preschool-age audiences. Chapter six focuses on the subset of seven observed participants and narrows in on the ways they describe

science engagement and the ways they facilitate science engagement with preschool-age audiences.

Chapter 5

ISEs' Goals and Understanding of Science Practices

In this chapter, I will describe the goals that informal science educators (ISEs) hold before and after a professional development workshop for engaging preschool-age audiences in science. I will also show how their understanding of science practices changed due to the workshop. The data in this chapter is derived from the whole sample of sixteen ISEs who participated in the workshop and completed the pre- and post-workshop interviews.

ISEs' goals for teaching influence the way they engage their audiences but little is documented about these goals (Tran, 2007; Plummer & Small, 2013). This study focused on teaching science through engagement in science practices. By looking at the responses from pre- and post-workshop interviews, I am able to make claims about ISEs' current and revised goals.

In this chapter, I detail the finding from the following research questions:

1. What are the goals of ISEs when teaching science to preschool-age audiences before and after the professional development workshop?
2. What do ISEs know about science practices, prior to professional development and how does that change after?

Goals of ISEs Before the Workshop

The goals that participants (N=16) had for teaching preschool-age audiences before participating in the workshop are listed in Table 5.1. The total percentage does not equal 100% because, like most informal science educators (ISEs), the participants had multiple goals (Plummer, Crowl, & Tanis Ozcelik, in progress; Plummer & Small, 2013).

Table 5.1 ISEs' Goals for Preschool-Age Audiences

Goals	Percentage of Participants	Codes

	(N=16)	
Fostering Positive Affect	63%	To foster interest, excitement, curiosity, to have fun, to want to visit again
Creating a Comfortable Learning Environment	63%	To foster engagement/an environment where children want to participate, to learn something, to learn through play
Supporting Children's Abilities	56%	To provide increased choice, to provide new experiences and space for further exploration
Conceptual Learning	19%	To learn something new
Fostering Parent-Child Interactions	19%	To provide parent-child activities, encourage parents and children to learn together
Building an Awareness of their World	19%	To introduce children to the outdoors, to create an awareness of things around them
Participating at Age-Appropriate Level	13%	To provide age appropriate explorations, to bring science to a level they can understand
Engaging in Science Practices	6%	To engage them in observations and investigations, to build a foundation of science behaviors

A Full list of codes can be found in Appendix E

Two goals that emerged as most common: *Fostering Positive Affect* and *Creating a Comfortable Learning Environment*. First, participants (63%) described *fostering positive affect* as their priority. For example, when asked about her goals for preschool-age audiences, Margot responded that it was, “[P]rimarily to have fun, but also to have an educational component to it.” From the group of participants with the theme of fostering positive affect as a main goal, *creating a fun experience* was at the top of their list of codes.

Participants also designed their programs to *get preschoolers excited* about the topics. Descriptions of how they do this involved a variety of hands-on experiences. As Mia was describing how she plans programs, she said that she hopes that preschoolers are, “just excited about some of the projects that we’re doing. I think that’s the main thing, because if you love something and you’re excited about it, then you want to learn more.” Other answers in this theme ranged from hoping to *foster interest, excitement and curiosity* to *encouraging the children to*

want to visit again. During the interview, Shannon explained that, “My goal is to get them to understand the activity that’s going on and to be able to spark their interest in whatever we might be doing.” It was typical to hear that participants wanted to pique learners’ interests. ISEs in this study placed an emphasis on the importance of the experience itself being fun for the children because they believe, if the children enjoy their time at the nature center or the museum, they will visit again for years to come.

The other top goal (63%) centered on the idea that ISEs work to *create a comfortable learning environment* by designing facilitated programs specific to this age group that *foster engagement* and *create a foundation for future science learning*. Some, like Kimbra, have ambitious goals to have kids feel like the park is their backyard. Others combine the idea of comfort, fun and piquing interests. They believe it is important to allow time and space for children to explore and discover on their own. Some participants explained that they understand that not all preschoolers will learn the same thing from an experience.

“Well, my primary goal is always for them to have fun. I think part of them having fun is learning. I don't feel like all three to five-year-olds are going to learn the same thing, no matter what I'm teaching. They're going to take out of it what's interesting to them and what they're excited about. So as long as they're learning something, and it may be different for different kids because different kids are at different stages,”

(Hope, pre-workshop interview).

Fifty percent of the participants specifically described encouraging play, a code under *Creating a Comfortable Learning Environment*, during their programs as a vehicle for learning. Some participants set up stations of activities as a way to set up numerous experiences. They allowed children to choose their own path. There was no expectation that every child would try every station. Often, ISEs reported intending this learning to occur, at least in part, through play. Also, participants who work in planetariums claimed they are very aware that a dark room can be

scary to young children. For this reason, they place great importance on creating a program and a space where children feel comfortable and want to participate.

Finally, *Supporting Children's Abilities* was the third most common goal (56%) of the top goals held by participants. One way this happens is by creating experiences that allow for different modes of learning. Jason, who works in a planetarium, has goals to create opportunities for children that will *make the content accessible* to them no matter their mode of learning. "Through play or physical activity we can get a different group of learners. I think a system like this is really helpful [...]," (Jason, pre-workshop interview).

Another code included a goal of *providing new experiences* to children as a way of supporting their abilities. Hope's description is representative of this code. "Well, I want them to be having fun and be doing something that their teachers are not able to provide them. I want to do something different for them," (Hope, pre-workshop interview). Participants described their programs as being different than school in that they provide *increased choice during exploration* and work to *foster empathy for the world around them*.

The less frequent goals that emerged included *Engaging Children in Science Practices*, *Designing Age-appropriate and Developmentally Appropriate Explorations*, *Fostering a Conceptual Understanding*, *Building an Awareness about their World* and *Providing Experiences for Parents and Children*.

Goals of ISEs After the Workshop

During post-workshop interviews, I restated the goals that participants identified during their pre-workshop interview for engaging young children in science and allowed them the opportunity to add or change what they initially said, based on what they now know from the workshop. Overall, participants maintained their initial goals as expressed prior to the workshop. Only one participant, Cora, added to her initial goals; she added that she would like to build a

foundation for science practices. “That's a good framework and you know that it's age appropriate, developmentally appropriate with good supports,” (Cora, post-workshop interview).

ISE's Understanding of Science Practices

In order to understand their learning during the professional development workshop, I asked ISEs about their understanding of science practices in the pre- and post-workshop interviews. I also provided a video analysis task for ISEs to complete during the first week of the workshop and again during my post-workshop interview. Below I describe the findings from each of those data sources.

Interview Responses about Science Practice Understanding

During the pre-workshop interview, I asked participants first if they had any frameworks or strategies that they used to engage young children in science. I coded every response, paying specific attention to ideas and language that related to science practices. No participant said the term “science practices” but one was able to describe an example in depth. Only descriptions that matched the Phenomena-driven Engagement in the Practices of Science (PEPS) Framework counted as science practices. The description to follow is an example of an interaction with snails that was designed by a participant who works regularly with preschool-age audiences. This is an exemplar of the sample with respect to engagement of young children in science practices.

Well, I think coming to my mind first is just, because I did it recently, having snails and learning about habitat, and looking outside for little living things that live under leaves and under rocks. And going out with little kids and seeing what we find outside, around the museum. And then back in the classroom, getting a chance to look at those things more closely. So let's just say snails, for example, because in California we have land snails and we can collect them. And they're just, kids just feel very, snails are just cute. They're kind of a favorite with kids that age. You know, they can feed them the lettuce and then they can make a little playground for them out of blocks. And so all that time they're just really observing with all their senses, and they're describing what the snail is doing and how it's moving. And we're kind of collecting their observations, and building on what they already know and what they're noticing about that. And then we'll of course sing a little song about the snail to also help with the language and just knowing how integrated learning with that age group is that you want to include little songs and movement. And read a storybook

about it and then make a little model of the snail out of paper. I guess those would be the main things.

(Eva, pre-workshop interview)

The description above includes information about how children collect and use data while engaging with a phenomenon (in this case, a living thing), which are necessary parts of engaging in science practices. In this scenario, the ISE is taking children outside to explore the natural world. They collected snails that are common in the area and took them back to the classroom. While they had them in the classroom, children were able to make observations using their senses and notice things about the snails. These are two forms of data collection for preschool-age audiences. Using the data, children created a representation of a snail out of paper. Eva mentions helping them build on their prior knowledge and then extends the experience to other forms of science engagement beyond science practices. This level of activity description was not common in the interviews.

Other than Eva, Aimee was the only other ISE who provided enough of a description to be counted as understanding science practices. Aimee facilitated planetariums shows for preschool-age children. She would start by showing the children the night sky and talking about objects in it. Then, she focused in on the moon. She showed them images from a distance, compared them to the size of earth, as well as close up images of the surface. She described how gravity was lower and asked children to predict what it would look like for astronauts to walk in lower gravity. She would allow children to stand in the aisles and act it out. Then, she would project short video clips of astronauts walking on the moon and ask children to revise their ideas about how they move. By allowing children to use second-hand data from images and videos of astronauts walking, she engaged children in the experience of people walking in lower gravity on the moon (phenomenon) in an active way. The combination of asking a scientific question

providing second-hand data as well as allowing them to act out the effects of the scientific phenomenon, she was providing engagement with science practices.

In order to show the variation in the data, I have highlighted the responses from three ISEs. Table 5.2 shows ISEs' responses to the open-ended and the targeted questions asked during the pre-workshop interview, as well as the targeted question asked during the post-workshop interview. Science practice words are bolded in the table. The open-ended question asked ISEs to describe any strategies or elements they use when developing programs for preschool-age children. None of the participants stated including engagement in science practices as part of their regular programs.

The targeted question started off describing that I design programs for young children with science practices in mind. I then asked if they engage children in science practices during their programs. I told ISEs that I was thinking about using science practices as a way to engage preschool-age audiences and then I asked them what they knew about science practices. Of the sixteen ISEs in this study, two ISEs provided a description of science practices that matched the criteria from the PEPS Framework. These include Eva's description above about collecting and observing snails, as well as Aimee's engagement with the effects of gravity on human motion. Beyond those two, three ISEs said they have never heard the term and ten others gave varying degrees of less descriptive engagements in science.

Finally, during the post-workshop interview, I asked ISEs what they had learned about science practices and to describe their impressions of those as a way of engaging 3-5 year olds. During the post-workshop interview, I directly asked participants what they learned about science practices. Of the sixteen ISEs, eight (50%) replied with a positive comment, either remarking that they learned something new or that it reinforced ideas they had previously. Darren is a good example. He admitted that he has a science background but needed concrete examples of the ways in which preschool-age audiences participate in science. Five (31%) responded that it was

not new information or that it was not very helpful to them in their practice. Lindsay is a good example of this kind of response. She finished the workshop feeling like the information provided for engaging preschool-age audiences in science was mainly common sense that she had gained from her background in education. The other three (19%) of ISEs either did not learn enough to remember or understand science practices. Jason explained that he is still unsure about how to engage preschool-age audiences in astronomy content without direct instruction.

Table 5.2 ISE's Science Practice Understanding Interview Responses

Name		Science Practices
Lindsay	Open-ended, Before	I don't use any specific things.
	Targeted, Before	I know like prediction , which is kind of something that we all do here. It is just kind of second nature before we would do something we would just ask , what do you think is going to happen? I guess that is just the educator in me. Those types of things. I guess I'm not really sure I don't know, maybe I would have to think about it.
	Targeted, After	I don't think, for me personally, it was helpful. I think a lot of it, when I read it, I don't know if it's because I have, I mean, it probably has a lot to do with the fact that I have an education background, but a lot of it I thought was common sense
Darren	Open-ended, Before	Well, one of the things I've tried to do is to demonstrate everything also just explaining, really get down and just show them exactly what we're going to do, kind of model how to turn over a log to look for bugs, how to put something in a little microscope to get a closer look at it. Definitely with the younger age, keep the verbal instructions really simple and to a minimum and just do more showing.
	Targeted, Before	We try to do different question techniques. Instead of just asking yes or no questions. Doing more discussions with kids about what they think things might be. Not trying to just ask what type of plant is this?
	Targeted, After	Yeah. Well, I think, yeah, part of it because I do have a science background, so I, when I think of science, because I think of the little more advanced stuff, so it was nice to see that those simple things do kind of count towards, you know, doing scientific stuff, being a scientific practice. So, I knew, like, observation and analyzing, collecting data were things that I knew were science based but I just never thought of, how you know, like creating a representation or a model , you know, like picture to explain something or using those tools to observe or getting information as being science. So, I thought that was kind of eye opening to me

Jason	Open-ended, Before	So we don't really like... Linda (pseudonym) has done, that's my counterpart here I think you were speaking to her before. She's done a lot more focus on how the youngest engage in astronomy. I'm excited to learn more about it because I don't have a lot of opportunity.
	Targeted, Before	Scientific methodology? Science practices? I'm assuming it's just scientific process. But in a different... Right. And recording . It can be hard if they don't write. But there are other ways to record. Well, this is something that we've talked about that was in... I'm familiar with it in an academic setting, but I've never put it into practice. And they interviewed a bunch of kids on video and audio asking them to explain how the moon went through phases. And then they went and had a couple of lessons about it. They played with moon models, they did the phasing activity. They talked about different stories, about the dragons eating the moon and then the moon grows back and then the dragon eats it again. And then at the very end they interviewed the kids again and had them explain how the moon goes through phases. And you got very different answers. So using a method like that you're still recording. You're doing an experiment , but it's helpful even for kids who are verbal, but not able to write.
	Targeted, After	The science practices. Approaching something like the earth's rotation with kids, they addressed it in an interesting way and I really see what they were going for why the sun moves, why the moon moves, why the stars move, but I'm not sure how we could really incorporate that without wanting to build off that idea. I'm trying to think how to say this. Using the same set of ideas and build a more complex model for the kid allow the kid to address why do these objects move, why do they move the same way. I'm not sure how we would lead to that without just telling them.

Every participant was able to list actions such as observing, asking questions, making predictions, but only Eva and Aimee gave enough detail or linked together the idea of engaging in data collection and analysis directly with a phenomenon, or using second hand data such as a chart or picture when direct interaction with a phenomena was not possible. Of those that emerged from the data, making observations and asking questions were the most frequent science practice words.

The ISEs in this table were chosen because they were representative of the larger group. Lindsay worked at a space-themed science center as a science educator and had a background in

education. Darren worked at a nature center as an educator and interpreter and had a science background. Jason worked at a large science center, mainly in the planetarium, and had a science background.

Video Analysis Task Responses to Science Engagement

My second measure of science practice understanding was ISEs responses to a video analysis task. Three short clips of preschool-age children engaging in science practices were presented to ISEs. A very general question asked participants to describe any and all instances of children engaging in science in each clip. The first time this task was presented was during the first week of the workshop. ISEs were given a link to view the clip and a separate link to the questions. The questions were administered over an online survey website so that responses could be captured and saved. The second time ISEs were asked to participate in this task was during the post-workshop interview. I asked participants to watch the video and discuss the ways in which children were engaging in science.

Table 5.3 below presents the response from the same three ISEs in Table 5.3 for consistency. Again, the science practice related words are bolded. All ISEs are answering this prompt: *How are children engaging in science in this clip? Describe any and all instances. Please be as detailed as possible.* The first row for each ISE shows their responses from the task during the first week of the workshop. The second for each ISE shows the responses given during the post-workshop interview.

All responses are for the first clip that ISEs watched. The clip involved preschool-age children using binoculars during a museum program. The binoculars were attached to tripods so that children could walk up and look through them. The program leader pointed the binoculars toward a small park with trees and park benches. Children took turns looks though the binoculars, pointing at what they were looking at and crafting explanations about the phenomena that they were experiencing.

Table 5.3 Video Analysis Task Responses

Name		Video Analysis Task
Lindsay	First Week	The children are using scientific tools and making observations of bigger/smaller and whole/half .
	Post-Workshop Interview	<p>The little girls are observing, of course they're using science tools. Julia is asking them questions, and so they are pointing. She asked them a question, and then they didn't respond, I guess, fully. And so she's kind of asking again, and they they're pointing to where it is. So she's really engaging them and inquiring about what they are seeing and really wanting them to show her what it is instead of just telling. The first one, I thought was harder to identify science practices in it.</p> <p>I don't know if it was because it was so quick or if it was because it's something I would just naturally do, but I don't recognize the practices and things like that. She's definitely asking them about comparing and contrasting sizes and directions, so there's a lot of factual stuff going on.</p>
Darren	First Week	They are making comparisons between observing an object with and without binoculars. They are using a scientific tool . The children are also discussing and sharing their results with others.
	Post-Workshop Interview	Okay, so, I see the girls looking through the binoculars, sort of the, you know, using tools to make their observations . And, right now one of the things that we didn't really talk about but it is a science practice, is they're sharing their information with each other. So they're kind of talking about what they're seeing and making comparisons about the size, they said it was smaller, and you look at it, without the binoculars.
Jason	First Week	The subjects are making observations with a control (unaided eye) and comparing them with the experimental observations using an apparatus (the binoculars) that they were (seemingly) unfamiliar with. By comparing what they saw in both instances they concluded that the objects in question seemed larger and that less of the object could be seen in the experimental case.
	Post-Workshop Interview	Okay, one girl is actively using the binoculars . The youngest one is trying to answer questions about them. They've clearly seen something through the binoculars and they're trying to identify it without the binoculars. They're comparing their observation with the instrument versus without the instrument. One girl stated the conclusion that the object is smaller in real life than through the binoculars. One girl is realizing that not only is it smaller the field of vision is limited, so you see less of the object through the binoculars, whereas you can see the entire object without the binoculars.

Once again, there were no noticeable differences between the answers ISEs gave at the start of the workshop and after the workshop ended. At first glance, the responses appear to be longer, but when looking for science practice ideas, they are a near exact match in the before and after workshop responses. The use of science practice language is evident, but not the engagement in science practices as outlined by the PEPS Framework. This is representative of the entire sample.

Conclusion

In this chapter, I have outlined the data related to ISE's goals before and after the professional development workshop as well as ISE's understanding of science practices before and after. In both cases, there was almost no change in the goals ISE's held for engaging children in science and almost no change in the ways that ISE's talk about their understanding of science practices.

The top three goals of ISEs in this study included fostering positive affect, creating a comfortable learning environment and supporting children's abilities. ISEs in this study also had ideas about science practices that were inconsistent with ideas held by members of the development team, yet still important. Their descriptions of science practices were based on lists of science practice language with too little detail to know whether or not the activities they implemented at their venues matched the criteria of the PEPS Framework.

This study is focused on the ways in which ISEs engage young children in science practices; however, their goals do not reflect science practices before or after the workshop. This may explain why there was no change in goals. It also shows that the professional development workshop did not influence their goals. Coherence between the goals of ISEs and the goals of the workshop is important for learning (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007). This data suggests that the workshop did not contribute to their understanding of engaging young children in science practices.

Chapter 6

ISEs' Descriptions and Enactment of Science Practice Engagement

In this chapter, I used interview transcriptions and video recorded observations of seven ISEs to describe the ways in which they talk about and enact science engagement with preschool-age audiences. The questions answered in this chapter are:

3. How do ISEs describe how they engage preschool audiences in science?
4. How do ISEs implement science when teaching activities from the professional development workshop?

Table 6.1 shows an overview of the participants described in this chapter. The table details how long they have been in the informal science teaching field, what type of program I was able to observe, the length of the observation that was video recorded, the goals of the video recorded program and a list of all implemented activities. Given the diversity in these columns, the seven participants in this subset are representative of the larger sample (N=16).

Table 6.1 Observed ISEs

	Margot	Cora	Aimee	Hope	Eva	Mia	Kimbra
Type of venue	Nature Center	Natural History Museum	Preschool	Natural History Museum	Science Center	Nature Center	Nature Center
Years in the field	23	12	11	7	25	5	30
Observed program	Single day of weeklong half-day camp	Single day of a weekly preschool program	Single session at two different preschools	Single day of two weeklong half-day camps	Part of each day of a half-day summer camp	Stand-alone program	Stand-alone program
Length of observation	121 minutes	64 minutes	104 minutes	127 minutes	159 minutes	66 minutes	67 minutes
Goals of program observed	To tell a story about the moon	To spark imagination and connect to exhibits	To have fun, try new activities, learn something	To learn something about space and astronomy	To start week of open-ended and inviting, learn something and engage in science & development	To have fun	To learn about the sun and energy

					ally appropriate practices		
Composition of program	Moonscape (MST), Meteor Painting	Space Explorer (MST), Night Tent (MST), Moon Sand (MST), Sky Window (MST)	Moonscape (MST), Sky Window (MST), Magnification Station (MST)	Moonscape (MST), Night Tent (MST), Ore Moon Phases, Magnification Station (MST)	Day/Night Model, Sun Model, Bear Shadow (MST), Magnification Station (MST)	Moon Phase Matching (MST), Bear Shadow (MST), Sky Window (MST)	Solar Ovens, Sun's Energy (MST)

ISE's Descriptions of Engagement in Science included Science Practice Language

During the pre-workshop interviews, I asked participants if young children could do science. Every participant answered affirmatively and then followed with a description. I used those descriptions along with data from the earlier study (Plummer, Crowl, & Tanis Ozcelik, in progress) to generate the codes below in Table 6.2. A full list of codes can be found in Appendix F.

Table 6.2 Young Children's Engagement in Science

Category	Codes
Discovery / Exploration	Hands-on explorations; Discovering world around them; Free explorations
Always Doing Science	Naturally do science; Do science without knowing it
Affective	Interest/curiosity (natural, already exists) and motivation; Engaging and developing interest; Exciting and fun (play included)
Age Appropriate	Age-appropriate level; Unable to understand topics as well as older children; Developmentally appropriate
Science Practice Language	Asking questions; Observing; Using senses; Making hypotheses; Constructing explanations; Recording data; Comparing and categorizing data; Using tools; Labeling and identifying patterns; Making claims from evidence; Collecting data; Creating representations; Experimenting; Making predictions; Investigating; Communicating / participating in science with others; Processes of science

The science practice language category has the most codes associated with it and emerged as most frequently (65%) described. This was partially due to the encompassing nature

of science practices and that, when analyzing the data, an in-depth description of engaging children in a science practices counted as equally as a simple listing of individual practices. I made the choice to include all instances when ISEs used science practice words or language in order to capture the breadth of responses given by ISEs. I could not always say for sure if the descriptions were true engagements with phenomena and data due to the amount of detail given. The responses often included science practices words such as *observation* and *prediction*. For this reason, I decided to include them all. This was done for all codes in Table 6.2 Young Children's Engagement in Science.

Table 6.3 shows the categories that emerged from ISEs' responses, including the percentage of responses in each category. The examples from ISEs in Table 6.3 show the varying levels of detail in the responses given by participants. I have included two examples for each category that represent the larger set of responses for each, in order to show some of the differences. For example, looking closer at the example in Table 6.3 for Science Practice Language, I have included two answers with very different amounts of descriptions. The response in the Example 1 column provides enough detail to understand that children are collecting data through observations in order to make comparisons. Without understanding more about what children were observing, it is not possible to say if they were engaged with a phenomenon; however, I still counted this in the science practices language category during this analysis. The example in that same row, under the Example 2 heading is much more vague yet still included because the participant begins to describe experimenting.

Table 6.3 ISEs' Examples of Young Children Engaged in Science

Category	Example 1	Example 2
Science Practice Language (65%)	"To me that means that they are engaged in the same practices of science that would be most appropriate to their age level which would be observing. Not only looking at things, but finding out how things feel and how things smell, really using their senses to	"Yes. All the time. I think that's what kids do mostly is poke at things and see what happens." (Kimbra, pre-workshop interview)

	make observations and do comparing.” (Eva, pre-workshop interview)	
Discovery/ Exploration (11%)	"But they're playing catch, they're bouncing a ball. They're trying to get one thing from one place to another place. They think, "Well, if I roll the ball over towards the basket where the balls go, maybe it'll go in the basket." But at that same time, they roll it towards there, and it doesn't quite go into the basket. And they go, "Oh, well, maybe I need to roll it more to the side." (Aimee, pre-workshop interview)	"Well number one they are -- they have their own opinions and they are engaged in the world." (Cora, pre-workshop interview)
Always doing science (7%)	"Absolutely. I think they do science everyday whether they're playing in a toilet and flushing it to see what happens to the water. Everything they do, everything is an experiment to them. So I think they're naturally scientists. That's just how you learn about the world around you. Pick up a rock and eat it. Does it taste good? Does it not taste good? They are already scientists. We are just giving them an outlet to do it in maybe a more controlled environment." (Hope, pre-workshop interview)	"All that they're doing is science. They're always experimenting. They're always testing their limits. They're always asking questions. They're always making observations, and they're always drawing conclusions.” (Margot, pre-workshop interview)
Affective (4%)	"I think a lot of times younger kids, especially depending on their background knowledge, they don't have an expectation of how it should happen. So they do something and say, "Hey, the red and the yellow together just made orange." It's very exciting and it's new." (Hope, pre-workshop interview)	"But it's when you're with them, it's the full engagement of their interest. If you gauge your activity correctly, that's how they are." (Cora, pre-workshop interview)
Age Appropriate (4%)	"Looking at similarities and differences which is part of science and then having a question where they need to collect some data, even if it's just looking at different white powders and compare and have their teacher record. They get to do tests on things, such as mixing water with some things and even putting the results up in a simple graph, all the things little kids can do. " (Eva, pre-workshop interview)	"And you have to keep it simple, though. You can't pile on different things or you will lose them." (Cora, pre-workshop interview)

The data represented in Table 6.3 shows that ISEs often use science practice language to describe how they engage young children in science. This analysis did not identify whether the

engagement examples included engagement with science practices as described by the PEPS Framework.

Missing Scientific Phenomenon or Data during Implementation of Science

In this section, I used the video observation of seven ISEs to understand how they engage children in science. There were two coding schemes. I will describe them below and then display a flow chart to explain how they worked together to form my analysis.

ISEs' implementation instances were first coded using the PEPS Framework. The framework outlines specific science practices, the importance of data and the need for a goal statement or investigable question. It situates everything within a phenomenon. When an engagement did not meet the framework criteria, it was categorized as *other engagement in science* and coded as *science activity*, *demonstration*, *content delivery*, *science conversation* or *creative engagement with science*, as shown in Table 6.4. The codes were generated by observing ISEs in this study and a previous study (Plummer, Crawl, & Tanis Ozcelik, in progress). There were cases when implementation instances were labeled with more than one code of *other science engagement*. The code of *home engagement with science* was used when ISEs suggested science for children to do at home. Video recorded observations were only conducted at the venues in which ISEs were teaching. There were no home visits.

Table 6.4 Methods of Science Engagement

Category	Codes
Science Practices	PEPS Framework
Other engagement with science	Science Activity
Other engagement with science	Demonstration
Other engagement with science	Content Delivery
Other engagement with science	Science Conversation
Other engagement with science	Creative Engagement with Science
Home Engagement with Science	Home Engagement with Science

Once implementation instances were coded with Methods of Science Engagement, I looked closer at the instances and coded their implementation style, shows in Table 6.5. The

instances already coded with *science practices* were labeled *successfully engaged children in science practices*. All of the instances that were in the *other engagement with science* category were fit into two other implementation style codes of science practice engagement: *almost engaged children in science practices* and *did not engage children in science practices*. If an implementation of science did not include engagement in science practices (did not meet the PEPS Framework criteria) but was only missing engagement with a phenomenon or data, it was placed in the *almost engaged children in science practices* code. In these cases, it was common for ISEs to engage children in an activity but leave out an experience with the real phenomenon or with first- or second-hand data. This meant that with a slight alteration or addition to the lesson, the children would have the opportunity to engage in practices. If an implementation did not fit the other two codes, it was placed into the code of *did not engage children in science practices*.

Table 6.5 ISEs' Implementation Style

Codes	Description
<i>1. Successfully engaged children in science practices</i>	Met all criteria of the PEPS Framework
<i>2. Almost engaged children in science practices</i>	Missing direct engagement with a scientific phenomenon or with real data, but, otherwise met PEPS Framework criteria
<i>3. Did not engage children in science practices</i>	Missing both elements of the PEPS Framework criteria

Figure 6.1 shows the order in which I made decisions about my data. This flow chart incorporates both of my coding schemes into one graphic that can be used to determine ISEs' implementation style.

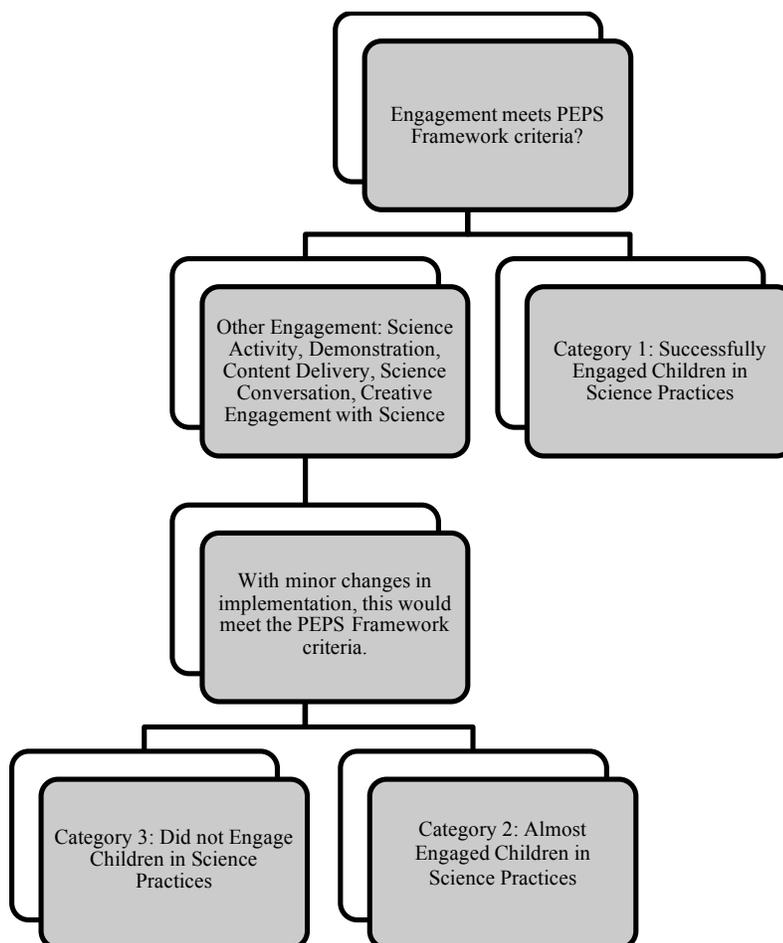


Figure 6.1 Flow Chart of ISEs' Implementation Style

Below, I describe each of the three implementation styles by giving an example from each of the three codes. Each description below contains italicized codes that show the Methods of Science Engagement used by ISEs. The descriptions include an example from each of the Implementation Styles codes, showing the criteria necessary for a video recorded instance to fit into one of the three categories.

Instances of engagement in science practices. Two participants, Eva and Aimee, engaged children in science practices during at least one of their observed activities. The

description to follow is one example of a science lesson that engaged children in science practices.

Exploring shadows using the MST Bear's Shadow activity. Eva facilitated an activity that engaged children in a great deal of observing and noticing while they were experimenting with shadows. She read a fiction story to children and then asked children to recreate the scenes from the book. Four children sat at each table. They were given flashlights, a felt scene from the story, a cardboard tree and a plastic bear (main character in the story). On each table there was a set of challenge cards, which were pictures from the book of the bear and his shadow. Children chose one scene at a time and tried to recreate it, using their felt scene, the tree and the bear. The flashlights were used to represent the sun.

Eva spent time at each table, helping children engage in the *science practices*. She helped one child notice (by pointing) that by holding the flashlight over the top of the bear, there was no shadow. She pulled a new challenge card over to her to encourage the child to continue exploring, using the data he just collected about what happens when the flashlight is directly above the bear. Eva moved on to another child at the table, allowing the first child to continue exploring. She helped this second child notice where the shadow of the tree fell, pointing out to him where the flashlight, tree and bear were located with respect to one another. She asked if he could hide the bear in the tree's shadow. The child was successful.

Instances of almost engaging children in science practices. This type of engagement was the most common among all of the video recorded instances. The example below highlights the ways that Hope facilitated an activity and describes how the activity could have been altered to engage children in science practices.

Creating moon phases with cookies. As a follow-up activity to a moon-themed exploration done earlier in her class, Hope created a print out that showed the phases of the moon using Oreo cookies for children to reference as data. After describing that they were going to use

their snack to first do science, she held up her opened up an Oreo, icing facing out, and asked, “What kind of moon is this?” As a group children responded “A full moon!” Then she passed out Oreo cookies to every child. Once everyone had a cookie, she asked the children to hold up their full moon. Next, she asked them to hold up the lid, the chocolate part with no icing. “What phase is it when we can’t really see the moon?” she asked. Many children replied, “New moon!” She continued the *science conversation* by asking if the moon was still there even though we couldn’t see it and she repeated the name of the phase. Then, as a group, they scraped off small portions at a time, holding up each one as Hope announced the phase. Finally, children were allowed to scrape off the rest of the icing, hold up their new moon and then eat the cookie.

This was not an activity from the MST Toolkit. Hope engaged children in *science conversation* through her question and answer. The moon phases print out became a placemat instead of useful data. If Hope had encouraged the children to use the moon phase page in front of them as data, it would have been closer to creating a representation of the phenomena. Using the second-hand data of the information on the sheet could have engaged children in the science practice of using data to make representations.

Instances of no engagement in science practices. This last category describes instances when I was unable to code science practice engagement or identify an activity that could be slightly altered so that it did foster engagement with science practices. Below is an example.

Building a Space Explorer MST activity. Cora created stations of activities for her preschool program, allowing children to rotate, every so often, to a new activity. She first gave children and their parents a tour of the stations and then she spent time at each one talking with children. During the introduction to the MST activity Build a Space Explorer, Cora asked children to sit on the edge of a tie dyed sheet. The sheet was meant to look like the surface of the moon or another planet, complete with boot imprints and craters. She pointed out the patterns on the sheet and connected the footprints to a human space explorer on a nearby poster. She

explained that children would build their own space explorer using the recycled materials that were set on the sheet. Using her laser pointer, she pointed, one by one to different kinds of space explorers. She started by pointing to a rover on a poster and asking children which of the materials available would be useful for building a rover. Before children answer, she picked up cds and suggested that they could be used as solar panels. Then she pointed out that they might need wheels and suggested bottlecaps. She continues with her *content delivery* as she points to an orbiter, complete with rockets, fins and satellite dishes attached. At this point, she moves the whole group to the next station to explain.

Once children have been introduced to all of the stations and are allowed to choose the ones they want to visit, she returns to the Build a Space Explorer station with a child and his mother. She sits down at the recycled materials with the child and focuses on helping him roll tape into bubbles for attaching objects to his explorer. As he builds, Cora talks to the child's mother about the school he attends.

This example of *creative science engagement* allowed children to use their imagination to create a space vehicle. In order to turn this activity into engagement in science practices, many changes would need to be made. The scientific phenomenon is not present, currently, and would need to be decided upon and then integrated in some way. As far as specific practices, there are many tools on a space explorer that help humans extend their senses. Cora began to point out the tools but did not engage children in a conversation about how these tools may be useful to humans. One way to facilitate engagement with data could have included providing children with images of landscapes from other worlds, helping them notice features of those landscapes, and then decide upon which tools would be helpful to humans for exploration. By noticing features of the land or environment, children could have been encouraged to use these observations to make choices about which tools to include on their own space explorer.

Observed Participants Science Engagement Styles: Summary of Analyses

ISEs describe the ways that they engage children in science using primarily science practice-related words. Across the seven, common responses included that children observe with their senses, make observations of their world and ask questions. Descriptions were not always detailed enough to compare to the PEPS Framework, so any response that used a science practice word, was coded as science practices. The decision to do this was made in order to capture the breadth of responses.

In order to understand the influence of the professional development, I looked at the consistencies in ISE's answers before and after participating in the workshop. A number of patterns emerged from the data set of the seven ISEs. I will describe the patterns related to the ways ISEs' talk about and facilitate science experiences for young children.

Description and implementation of Science Engagement

ISEs were consistent in how they described and implemented science before and after the professional development workshop. For example, in her pre-workshop interview, Hope described the ways in which she engages young children with a science practice lens.

I guess it would probably look like play to somebody from the outside. You know, they see kids as in there playing. But when I see a kid mixing two paint colors together and coming up with a new color, that's science to me. They're exploring. They're seeing what happens when you do something. So I think a lot of what they do would probably be considered playing or looking like play, but it definitely-- They're learning as they go, and they're questioning, and they're testing.

(Hope, pre-workshop interview)

Here, she mentions that it may look like play, however, she interprets it as doing science by testing and questioning. During the post observation interview, when asked to describe how she thought children were engaging in science, she again replied with brief descriptions of science practices.

I love the way that they asked questions. I think they used some of the tools that we had. I loved playing in there [Night Tent], listening to their stories and having them point things out. I mean, they're interesting in not only what we were showing them but, you know, I had a little girl that was really excited that

the black light was making her teeth glow. I think that's great because they're making observations about the world around them.

(Hope, post-workshop interview)

Of the seven ISEs observed, only one participant gave responses to questions that were not the same. The way that Kimbra talked about engaging young children in general and the way she described the engagement afforded to children during her facilitation of the MST Toolkit activity, did not match. She described her ways of engaging children via science explorations and engagement in science practices. However, the ways in which she described doing science with children during the observation was solely about learning content.

Interpretation of ISEs' Facilitation

My interpretations of how participating ISEs facilitate science from their pre-workshop interview descriptions were consistent with my coding of their implementation of activities during the video recording observations. One example of this can be found by looking at Mia's interview and observation. When asked during the pre-workshop interview about how she engages children, her descriptions focus most often on what the children are doing. She describes some of the science activities that she does as active and fun. Below is a description of an activity that she facilitated to an all-ages crowd.

I would take the youngest ones and have them run around the model Earth with a piece of string 25 times. Then that is the piece of string that tells you how far away the moon is. That was always a fun one because they're like, "We're going to go blast-off into space and go find the moon." I like stuff like that where they're actually doing something, and they've got their goal of blasting-off into space and going to find the moon.

(Mia, pre-workshop interview)

This description shows her preference of a fun experience for children. It is also consistent with her other descriptions of science activities. During my observation of her implementation, she altered a moon phase matching game to include running to the phase that matched the face of a large die. She let children take turns rolling the die, and then encouraged

them to run to the matching image. Her way of changing this activity matches the kinds of activities she described in her pre-workshop interview. In both cases, I coded her implementation style as engaging children in science activities.

Table 6.6 below details the activities that each ISE facilitated on camera and the methods of science engagement codes that emerged from that facilitation. The last column provides a short description of each ISE's way of engaging young children in their programs.

Table 6.6 ISEs' Observed Activities and Overall Engagement Style

ISE	Activities	Methods of Science Engagement (Table 6.4)	Overall Engagement Style
Margot	Moonscape (MST)	Content delivery, Science conversation, Creative engagement with science	Margot created longer, themed experiences that had the potential to engage children in the practices, if she had connected them to phenomena.
	Meteor Painting	Content delivery, Creative engagement with science	
Cora	Space Explorer (MST)	Demonstration, Creative engagement with science	Cora set up all of the activities at separate stations and allowed children and their caregiver to choose what to do. She spent some time at each station interacting with children by encouraging creative play.
	Night Tent (MST)	None, unsupervised	
	Moon Sand (MST)	Science conversation	
	Sky Window (MST)	None, led by docent	
Aimee	Moonscape (MST)	Creative engagement with science	Aimee created experiences where children's prior knowledge was primed through discussion and storybooks. Then, it was utilized to make observations and categorize objects.
	Sky Window (MST)	Science conversation, creative engagement in science	
	Magnification Station (MST)	Science practices	
Hope	Moonscape (MST)	Creative engagement in science, Science conversation	Hope facilitated whole group and small group activities that could have become engagements with science practices if she had incorporated data or data collection in some way.
	Night Tent (MST)	None, unsupervised	
	Oreo Moon Phases	Science activity	
	Magnification Station (MST)	None, led by docent	
Eva	Day/Night Model	Science practices, Science activity, Demonstration, Science	For each phenomenon that Eva chose to explore with children, she provided them with

		conversation	opportunities to experiment and collect data. Children used the data to make claims about the phenomenon.
	Sun Model	Science activity, Science conversation	
	Bear Shadow (MST)	Science practices	
	Magnification Station (MST)	Science practices	
Mia	Moon Phase Matching (MST)	Demonstration, Creative engagement with science	With the incorporation of data or data collection, Mia's implementation could have been fun for kids and engaging in the practices.
	Bear Shadow (MST)	Science Activity	
	Sky Window (MST)	Science Activity	
Kimbra	Solar Ovens	Demonstration, Science conversation	Kimbra's themed activities had the potential to connect with one another and to engage children in science practices but the sensory and observational data children started to collect were never utilized in any way.
	Sun's Energy (MST)	Content delivery	

In Table 6.6, most of the codes are derived from the Methods of Science Engagement (Table 6.4). However, two ISEs, Cora and Hope, created stations for children to rotate between. During this time, they facilitated only one station, leaving one unsupervised. For both ISEs, there was a docent to assist at another station, however, the Night Tent station was a stand-alone, unsupervised station. It is listed because it is part of the MST Toolkit, but it was not coded because it was not facilitated by the ISE.

Only Aimee and Eva implemented engagement in science practices during a subset of their activities. Despite the lack of presence of engagement in science practices, ISEs often used words related to the practices. This could be an indicator that, as a field, we are at least on our way. For example, Margot facilitated an activity that was not from the My Sky Tonight toolkit during her observation. With slight additions, the activity could have engaged children in science practices. Margot began a lesson of her summer camp with a science conversation about objects that are on the children's nametags. There were planets, the moon and shooting stars. There was a back-and-forth exchange of ideas and prior knowledge between Margot and the children related

to these objects. After a brief review of earlier activities related to the moon, the science conversation transitioned into focusing on shooting stars. Margot used a homemade shooting star (rocks and sand, wrapped inside of yellow cloth with strips of yellow, orange and red cloth hanging off to look like a tail when it is thrown) as a prop to explain that shooting stars are rocks in space that glow at night and then she demonstrated their movement in space. She described the activity that the children were about to do. When she finished, they were each given a small plastic baggie, told to collect a handful of rocks and one scoop of sand. Once the bag was sealed, they dipped their meteors in red, yellow or orange paint and threw them onto black pieces of paper.

This activity is a good example of creative science engagement. If the activity had been designed to help use their evidence (paint splash patterns on paper) to explain the phenomenon (how craters get their shape), it would have been an example of engaging children in science practices. It had potential to also engage children in science practices if there was data available to children about the composition of a meteor. By allowing them to use the data, they could have designed a model of a meteor to use to create their artwork.

Conclusion

In this chapter, I looked at findings related to how ISEs talk about doing science with preschool-age audiences, and then at how they implemented those engagements. The majority of the language used by participants to describe how they do science fits the language of science practice engagement; however, looking closer at those descriptions, only two ISEs provided enough detail to confirm engagement in the practices as defined by the criteria of the PEPS Framework.

There were numerous examples of *creative engagement with science* and *science activities*. This could be a starting point for future professional development providers when designing learning experiences for participants.

Chapter 7

Discussion

This chapter presents my findings as they relate to the research on effective features of professional development. First I present the main theme that emerged across the entire data set. I situate this issue within the literature and provide a brief overview of the findings related to it from each of my research questions. Then, I analyze the features of my proposed professional development model against what occurred in this workshop.

One theme emerged: there was no change measured after this professional development experience. Looking across the pre and post-workshop findings, ISEs showed no changes throughout this study in their goals for teaching science to preschool-age children, the ways they talk about doing science with preschool-age children or their understanding of how to engage preschool-age children in science practices.

Goals for science learning can range from affective to cognitive to conceptual and include fostering engagement in science practices as well as identity development (NRC, 1996, 2009). Similar to other studies (e.g. Plummer, Crowl, & Tanis Ozcelik, in progress; Plummer & Small, 2013; Tran, 2007), the ISEs in this study were very interested in piquing interest and encouraging children to use their senses. Even though learning content was valued by the ISEs, it was not a requirement. Despite the professional development developers' efforts and hope that ISEs would add the goal of engaging children in the practices of science, this was not evident from interview data or observations.

The ways in which ISEs described how children do science in their programs, both the observed programs and through descriptions of programs they have facilitated in the past, did not change. Every ISE interviewed in this study, as well as others documented in the research (Plummer, Crowl, & Tanis Ozcelik in progress), agree that children as young as three years old

are capable of doing in science. The data from this study shows that they often describe the ways young children do science using terms that refer to discovery, exploration and positive affect. Documents such as the National Research Council report *Taking Science to School* (2007) and the Institute of Museum and Library Services (IMLS) report *Growing Young Minds* (2013) describe the complexity of how children learn. The challenge to the field is to help ISEs foster engagements that incorporate elements of exploration and positive affect, but also engagements in rich experiences that allow children to collect data and make claims about phenomena that happens in their daily lives.

Finally, as ISEs were talking about their programs, there was no evidence that their understanding of science practices changed between their pre-workshop interview and post-observation interview. ISEs used science practice words during both interviews but after observing their implementation, I was able to identify that the activities they described doing, that they labeled as engaging children in science practices, were most often a form of *other science engagement*. Items in this category included codes such as *science activity*, *demonstration* and *creative engagement with science*. Research shows that engaging children in the practices of science can be beneficial because it helps them understand how scientific knowledge develops (NRC, 2012). Museums have the potential to be a site for enacting this.

I used four measures of ISEs understanding of science practices. The first two measures were from open-ended, decontextualized questions about ISEs goals for engaging young children and what they know about science practices. The next measures were from the ways in which ISEs talk about how they do science with young children. Their descriptions revealed how they engage children and whether or not the engagement included science practices. Finally, observations from ISEs facilitating science lessons with preschool-age audiences provided the final measure. What follows, is a summary of my findings for each measure as they relate to research.

Goals Rarely Reflected Engagement with Science Practices

Research suggests that the most common goal for audiences served by informal science educators (ISEs) is related to fostering interest and excitement (Bailey, 2006; Plummer, Crowl, & Tanis Ozcelik, in progress; Tran, 2007). Plummer and Small (2013) interviewed planetarium professionals and identified interest and content-related goals to be most common among participants. The ISEs in this study were similar. Even though the developers' goals for ISEs included learning about and adopting the goal of engaging preschool-age audiences in science practices, the fact is that the code of *engaging children in science practices* was one of the least frequent to emerge. ISEs were more invested in creating experiences that engage young children, foster positive affect and make content accessible. The MST activities met these goals for the ISEs and because of this, may have impeded their interest in taking away anything additional from the professional development workshop.

Probing for Science Practices Produced Lists of Actions

When ISEs were asked about their understanding and use of science practices, they either referred directly to the scientific method or they listed words that had a great deal of overlap with it. In this study, I termed them *science practices language*. Common responses included lists of actions such as making observations, conducting experiments and making hypotheses. This may stem from learning to use the scientific method when doing science. Research now points to specific reasons why engagement in science practices are a better strategy for engaging children in science than following the scientific method (NRC, 2012). For one, the scientific method assumes that scientists follow specific steps in order when conducting an experiment. Latour and Woolgar (1979) and Kuhn (1962) illustrated that the way scientists work is more than a list of concrete steps. Engaging young children in the processes of data collection and analysis will better position them to apply similar methods as they engage with more complex phenomenon.

Descriptions of Doing Science Included Science Practice Language

The ways that ISEs described how they engage young children in science often included language to suggest science practices; however, the descriptions were not detailed enough to conclude that they were engagement in practices in the PEPS Framework. It was rare to find a description that included how children would collect data about a phenomenon and how prior knowledge or support from an adult would guide them in doing the collection, observation or analysis. It was more common, as is consistent with the research, to hear descriptions about science as more about fun or hands-on activities (Appleton, 2002) than collecting data or making claims.

Observations of Doing Science Rarely Involved Science Practices

The observations of ISEs implementing the My Sky Tonight toolkit activities with preschool-age audiences did not show a great deal of engagement in science practices. In fact, only two participants of the seven chose this type of engagement. The other five participants facilitated their activities through other forms of science engagement, such as demonstration or science conversation. There was limited coherence between the goals of the ISEs and the project's goal of engaging children in science practices. Research has shown this lack of coherence as a factor in impeding participant learning in professional development experiences (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007).

Limited Change in Goals and Science Practice Understanding

The goals of ISEs did not change and their ideas about how to engage children in science, especially when it came to science practices, also did not change. ISEs' common ideas about teaching science included creating a comfortable learning environments and supporting the abilities of young children. These are not the same as engaging children in science practices; however, they are still important. Children between the ages of three and five are developing in major ways. The National Association for the Education of Young Children (NAEYC) promotes the importance of creating a safe space for young children to explore and knowing what is

individually appropriate for the child. The responses from ISE's are in line with the practices promoted by NAEYC.

Despite what seems to remain common across this sample of sixteen ISEs, NRC (2009) states that the goals for science education should encompass more than just fostering interest. The six strands for science learning include encouraging interest and motivation, but more strongly emphasize the importance for engagement in the practices of science. In order to help ISEs move toward the goal of engaging young children in science practices, targeted professional development opportunities need to be accessible to and utilized by ISEs.

Professional Development

This study focused on the pilot professional development workshop for the *My Sky Tonight* project. The workshop was designed to assist ISEs engage preschool-age audiences in astronomy. The data collected for this study was focused specifically on ISEs goals and science practice engagement.

ISEs in this study have varied backgrounds and lived in locations across the United States. Despite this, the work in which they participate and the audiences they serve create a backdrop for a community of practice to form within the professional development workshop. Communities of practice (Lave & Wenger, 1991) are groups of people who share common goals and a common language. These communities provide members with support structure. In this study, the community of practice that the ISEs did participate in centered on engaging children at science and natural history museums, planetariums and nature parks. If the community could have adopted the goal of engaging children in science practices, a sociocultural learning perspective would likely demonstrate more substantial learning gains.

In the next section, I will analyze the features of my proposed professional development model against what occurred in this workshop.

Science Practices Across Features of the MST Professional Development Workshop

The necessary professional development workshop supports may not have been in place to create the desired outcomes with respect to science practices, in ISE implementation. Below I analyze a number of features that have emerged from research findings as they relate to the My Sky Tonight professional development workshop.

Coherence. Many researchers focus on the extent to which the goals of the participants match the goals of the professional development workshop (and by natural extension, the goals of the developers). The stronger the match between the learning outcomes of the workshop and the perception by teachers of its applicability to their practice, the more likely the teacher is to learn and use the materials at a later time (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007; Yoon, Duncan, Lee, Scarloss, & Shapley 2007).

In this study, ISEs were interested in the professional development opportunity because they hoped to learn about new activities that they could use during their programs. There was strong coherence between their goals for activities and what the workshop provided; however, another goal of developers was to create activities that would foster children's engagement with science practices. The focus on engagement in science practices through astronomy content was apart of each of the activity write-ups that ISEs were given for this reason. Research shows that when educators are knowledgeable of specific content, they are more likely to engage learners in discussion about it (NRC, 2000; Penuel et al., 2007). Grigg, Kelly, Gamoran, and Borman (2012) found that even a small amount of professional development, when segments focused on specific teaching elements, can have an impact on practice.

As a member of the development team, I know that the activities in the toolkit were chosen because all members thought they would be fun and engaging for young children. It was also important to the team that the activities fit the abilities of three to five year olds. Both of these ideas can also be supported by the composition of the team. The development team was large and comprised of curriculum developers from the Astronomical Society of the Pacific,

science centers and children's museums. There were also researchers from multiple universities involved who have conducted studies with young children around science topics. The written goals in the documents I reviewed show a list of collective goals; however, not all developers had the same goals. This collective list of goals in Table 3.3 shaped the workshop. The webinars were most influenced by the differing goals. For example, Julia's main goal was to help educators engage children in science practices. When she was presenting to the group, she was focused on that idea. When others were presenting, they had different goals. The fact that there was such a variety of goals held by developers could explain part of the reason why ISEs did not change their understanding of science practices and why few of them engaged children in these practices during my observation. It may also explain why engagement in science practice was rarely enacted during implementation.

Potentially underlying the reason for no change in the ways ISEs engaged young children, could be the fact that their goals also did not change. ISEs did not report goals related to engaging children in science practices before or after the workshop. The professional development workshop was not able to encourage ISEs to change their initial goals in a way that allowed them to adopt the goal of science practice engagement. This study is consistent with the research that coherence between goals of participants and goals of professional development providers may lead to better learning outcomes and better use of the presented materials (Desimone, 2009; Penuel et al., 2007).

Regarding the presented materials, the activity write-ups may not have supported participants' understanding of science practices or ability to implement science practices. Each write-up included a bulleted list of set-up ideas, facilitation ideas and the science practices that matched the lesson. There were no step-by-step instructions about what to say or how to identify science practice engagement on the part of the children. The science practices were stated in a stand-alone box on the write-up page, possibly making them feel like an add-on idea or an

element that does not need to be infused into the implementation. Had the instructions been written in such a way as to include the science practices as part of the implementation, more ISEs may have seen a higher rate of science practice engagement. In the same vein as educative curriculum materials (Davis & Krajcik, 2005), the lessons may need to be written with the student learning in mind but also incorporate an element that supports educators as learners.

Duration. This feature puts emphasis on the need for professional development to last long enough to benefit participants. Many studies do not cite a specific number of hours but instead describe the importance of enough time to engage with the material of the workshop, use the materials on their own and then have continued support for that use (Birman, Desimone, Porter, & Garet, 2000; Kang, Cha, & Ha, 2013; Penuel et al., 2007; Saylor & Johnson, 2014). Through a sociocultural lens on learning, it takes time to learn a new culture. In the case of professional development, a specific number of hours of time may be less accurate than a focus on the people involved, their initial understanding of the ideas when they enter the workshop and how they progress with their understanding of the cultural norms. Allowing time for participants to try what they are learning in collaboration with a community of practice (Lave & Wenger, 1991) is important. The ability to work with others who have more experience, who can provide a level of scaffolding above what the learner was initially capable of, is described by sociocultural learning theorists as a fruitful way to learn (Lave & Wenger, 1991; Vygotsky, 1978).

In total, during the MST professional development workshop, there were six hours of synchronous engagement via the weekly webinars. There was also a suggested 24 more hours of engagement time with the materials and content outside of the webinar. It is not possible to know for sure how long each ISE spent learning outside of the workshop; however, the amount of time spent during the six hours of synchronous engagement specifically on science practices was very small. Only a portion of two webinars provided time specifically for science practice conversation. More engagement during the workshop, during synchronous and asynchronous

times, with science practices could have changed their understanding of science practice engagement in a positive way.

Active Learning. Learning happens when ISEs engage with others while situated within a community and a social context (Hull & Greeno, 2006; Lave & Wenger, 1998; Vygotsky, 1978). According to research, in order to maximize the learning, participants should be given the opportunity to try out activities during the professional development, reflect on their own practice related to the materials presented and discuss ideas and concerns with others (Desimone, 2009; Tran et al., 2013). It is also important that educators engage first-hand in active learning during professional development if they are to use it in their own practice (Gess-Newsome, 1999; Penuel et al., 2007).

The participants in this study had to work through much of the content and the activity implementation on their own. From a sociocultural perspective, cognitive learning is rooted in social interactions (Vygotsky, 1978) and too few of these occurred. ISEs joined the 60-minute webinar, once per week, for synchronous interactions but left to complete the rest of the week's activities alone unless they decided to reach out through the discussion forum. During the webinars, the majority of the conversation was one-sided. Developers presented information to ISEs and answered questions if they were posted in the chat box or discussion forum.

Aside from the video clips shown in the webinar during week two, ISEs were responsible for their own active engagement with science practices. It may have supported ISEs learning better if more emphasis was placed on the ways in which ISEs could practice identifying and implementing science practice engagement with children during the webinar and through the weekly assignments. People learn to do science by participating in it and there were few opportunities in this workshop for participations to do science with the community of practice in which they were apart.

Organizational Culture. Organizational culture (Tran, Werner-Avidon & Newton, 2013) refers to the extent to which an organization as a whole values professional development for, and its impact on, employees. In this study, ISEs' organizational cultures were unseen by developers except in one case. Aimee joined the study and the workshop while she facilitated astronomy programs and ran the planetarium at a large science center. A few weeks into the workshop, she had wanted to use what she was learning to alter the programming she facilitated; however, her impression from her supervisor was that the programs were not to be altered. After the professional development workshop ended, Aimee left her job to pursue early childhood education on her own, in local preschools.

Even though these organizational cultures were primarily unseen, the workshop could have helped ISEs take the case of science practice engagement back to their supervisors. Another facet of organizational culture may be the culture of education. Is it activity based or experience based, for example? In Aimee's case, leveraging this may have helped her articulate her interest in changing the established, well-known programming at her original venue to one that focuses more on engagement in science practices. Given that Eva already held goals of engaging children in science practices and described doing this regularly in her own programs, the culture of the organization in which she worked may have valued science practices. Organizations that do not value professional development or a culture based on engagement in science practices provide barriers to ISEs. In this study, not every participant was allowed to use paid, work time to participate in the workshop activities. This fact begins to illuminate the limited support that some ISEs may receive from their organizations.

Guidelines for the Field

There are a number of factors that led to why there was no change and little implementation found of engagement with science practices in this study. Below I use the elements of professional development, outlined above, as a guide. First, however, MST activities

and their write-ups were not designed to support engagement in science practices. They were initially designed with content and age-appropriateness in mind. Also, the professional development workshop included very little time focusing on how ISEs could engage children in this way, specific to each activity. These two factors play a significant role and are at the heart of why I did not see engagement in science practice implementation in my data.

Of the professional development elements described above, active learning has the most potential to change the ways ISEs engage children in science. In this study, it appears the current culture of informal science education is one often based on activities for children and families. The activities might use science tools or be a craft based on a scientific phenomenon, but few of the recorded or described engagements in this study were rich with engagement in science practices. The professional development workshop allocated most of its time to learning content and providing an overview the activities, with little to no mention specific to science practices. Thus, the culture of activity-based learning was supported far more than engagement in science practices.

Professional development providers should not underestimate the need to allow participants to try out all activities, both during the workshop with support and on their own at their site, so that there is a level of comfort for ISEs in facilitating the experience the same way in the future. Research shows little difference in the content delivery modality between online and face-to-face (Fishman, Konstantopoulos Kubitskey, Vath, Park, Johnson & Edelson, 2013; Moon, Passmore, Reiser & Michaels, 2014); however, as this study showed, expecting the majority of the active learning to occur outside of the workshop synchronous time may not be reasonable. Especially for organizations who do not place a high value on professional development, ISEs may have to do this learning outside of their daily tasks. If, as Bailey (2006) points out, they are feeling stressed by their workloads and time constraints, the newly learned content will most likely be a low priority.

The duration element is mentioned in this study, but purposefully does not promote a specific number of hours placed on an experience as an indicator of success. The idea blends into the active learning element, though, given that it takes time for developers to present new material, time for participants to understand it enough to try it during the experience, time to then try it at their own site and finally, time to reflect on it.

Finally, organization culture is an important element described, but in this study, a participant showed determination to engage children in science practices even when her organization did not necessarily place value on it. Beyond professional development providers, this element is important for directors and leaders in the field who have the ability to change their site's culture of education.

Conclusion

Reports show that many children are beginning kindergarten without the language, emotional or cognitive skills needed to be successful (IMLS, 2013). Museums and similar institutions are poised to provide opportunities for early engagement in science to visitors. Early opportunities to engage with science have been shown to correlate strongly with future success (NRC, 2007, 2009).

ISEs, like the participants in this study, are finding creative ways to engage young learners in rich science experiences. The focus of this research, specifically on the engagement in science practices, is important. With full acknowledgement that exploration and interest-building are important for all learners, a focus on science practices takes the mystery out of how knowledge is constructed (NRC, 2012) and places the power to “do science” in the hand of the learner.

ISEs are doing important work, despite the challenges they regularly face. According to Bailey (2006) ISEs often have more work than they can accomplish due to the budget demands on non-profits. They also often take on multiple roles due to low staffing. Nevertheless, they

work hard because their job is meaningful. If informal science educators are being asked to teach astronomy to preschoolers while fostering engagement in science practices, professional development should address how to do this successfully.

Implications

ISEs that work in early childhood education need support in understanding how to engage children that young in the practice of science. Professional development providers should take their background and training into account as they create the content and practice elements associated with the goals of the workshop. In this study, the participants with strong astronomy content knowledge would have appreciated not spending so much time learning about it during the webinars and more time on how to work with young children. The participants with education backgrounds expressed wanting more content knowledge. Professional development workshops should be tailored to fit the needs and goals of the participants.

Related to goals, it may be important for development teams to streamline the number of goals for the professional development. The MST pilot professional development workshop had a large development team and many, sometimes competing, goals. With fewer goals, more time can be spent on each one, allowing increased active learning for participants.

Curriculum that is developed for ISEs should be written with the goals of implementation in mind. In this study, the activity write-ups did not infuse science practice engagement, making it easy to skip the science practice engagement while still completing the activity with children. One way to strengthen curriculum may be to write it in a way that educates both the facilitator and the participant. Educative curriculum can help to “increase teachers’ knowledge in specific instances of instructional decision making but also help them develop more general knowledge that they can apply flexibly in new situations,” (Davis & Krajcik, 2005, p. 3).

The fact that a few of the ISEs' goals were engagement in science practices is positive. The way that ISEs described how they engage children in science also included science practice-related words. Professional development providers should capitalize on these factors.

In order for the workshop to support ISEs in using science practices, there needed to be more time to learn how to do it, then time to try it, and time to reflect on it (Allen & Crowley, 2013; Tran et al., 2013). A one-hour webinar for six weeks may not be enough, especially when only a portion of two webinars addressed science practices. It may also be unreasonable to expect ISEs to spend an additional four hours a week working through workshop material on their own, especially if it is during a busy time of year. The field as a whole needs to place a higher level of precedence on the need for professional development designed specifically for and supported by informal science learning institutions and their staff.

Limitations

A major limitation of this study relies on the fact that this was a pilot professional development workshop, meaning it was the first time this team of developers had facilitated this experience for ISEs. I wanted to see how to support science practices but one limitation was that the involvement from the science practice expert. The science practice expert only had limited input into the design of the workshop and only was able to spend a small amount of time during the webinars talking about them and showing video clips of children engaging in them.

A second limitation centers on the inability to have true before and after measures of how ISEs engage children in science. I had to rely on ISEs', sometimes brief, descriptions of how they engage children in science as my base indicator. Then, when I was able to video-record their implementation, it was only for a few activities, most often occurring in the same day. The subset of ISEs who were willing to be observed was also less than half of my sample. While I do think the representation across venues and types of facilitation methods was representative of the whole

group, there is not enough data to create rich descriptions of implementation-styles that are supported by goals and understanding of science practices.

My interview method was limiting as well. During the pre-workshop interview, I asked a very open-ended question about ISEs method for engaging children in science. When I did not hear the answer I wanted (when nobody said the term “science practices”), I asked more directly about their understanding of science practices. It may have been a better idea to put the question in a context. I did also ask ISEs to provide examples of they engage children in science. I did not ask many clarifying questions while they were describing their programming. The questions I asked did not always make it easy to reveal if the ISE had limited knowledge or just described their understanding or their engagement in a brief way.

The ISEs’ descriptions of science practices were extremely difficult to synthesize for this reason as well. Descriptions from some participants were too brief to be sure about the engagement. Others were detailed but because I was unable to see their implementation of any described activities, I relied on the lists of terms they used when describing how they engaged children in science.

The claim that the duration of the workshop was inadequate is a limitation, in part, because I cannot be sure how long ISEs spent working on related activities outside of the webinar time. I also do not know how actively each ISE was following along with the webinar. Not all participants were allowed to use paid, work time to participate in any portion of the workshop either, challenging the commitment of some.

Finally, I used member check to relay the goals that ISEs’ held before the workshop during the post-workshop interview. Initially, this was to help the ISEs remember the conversation we had two months prior, however, all ISEs just out right agreed with my description. It may be the case that no ISEs changed their thinking about their goals for working

with preschool-age audiences, but an open-ended question may have served to uncover more information about their thinking.

Future Research

There is very little research on professional development for ISEs, so there is room for future research on how to begin to create an experience that supports educators who have very different backgrounds, training and expertise. From this study, it was clear that goals of the ISEs influenced how they thought about and implemented science for young children. More research should focus on how to start by acknowledging the goals that ISEs bring to the workshop and focus on how to build from them instead of replace them.

There is more work to be done on the best way to design features of the professional development workshops as well. Designing curriculum for classrooms allows one to make assumptions about the setting, the age of the children and how to support them developmentally. Often in informal learning venues, groups consist of multiple ages, experiences and skills. Depending on the venue, the activity might be able to be facilitated in a classroom or it may need to be adaptable for a busy exhibit gallery floor or outdoor setting.

More research needs to be done on how to foster organizational cultures that support professional development for ISEs. In this study, Aimee left her original venue to pursue her interest in implementing new programs for young children when her supervisor did not support her new ideas. How can professional development become infused into the regular expectation of ISEs, just as in-service days are for school teachers? What will it take from a leadership standpoint to make regular professional development feasible for informal learning venues?

Outside of just the professional development features, more research needs to focus on the work that ISEs are doing. In research, it is common to take cameras into the classroom to video a lesson. This is less common for informal learning venues. By cataloguing the range of

programs, settings, constraints and audiences that ISEs are faced with, we will be better positioned as a field to support their work.

Also through cataloging what ISEs do, we can focus more on how they teach young children. This study has shown that engagement in science practices rarely occurred, even after training. Research, however, argues that the kind of rich experiences that engagement in science practices can foster, help children make meaning and understand the processes of science (NRC 2009, 2012). The Phenomena-driven Engagement in the Practices of Science (PEPS) Framework could be used to guide curriculum development and to study practice in order to illuminate the ways in which science practice engagement plays out in everyday implementations by ISEs. This may also be one step toward creating a shared language of engagement and bring a standard of professionalism that the Tran (2008) suggests is necessary.

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Appendix A

Science Practices for Young Children in Astronomy

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Science practices

One of our goals in *My Sky Tonight* is to help support informal science educators in engaging young children in the *practices of science* through astronomy. The practices of science are the ways in which scientists engage in the process of scientists continually extend, refine, and revise the current body of scientific knowledge (NRC, 2007). For children, engaging in the practices of science, or scientific inquiry, is a way for them to learn more about their world and begin to develop scientific habits of mind that will eventually help them become scientifically literate citizens. Children engage in the practices of science as they look for patterns in their observations, make predictions about events, ask questions, record and discuss their observations, and develop claims based on evidence. But these are just some of the ways that children can engage in doing science.

Years of research now show that young children have the capacity to engage in scientific reasoning and science practices (Gelman et al., 2010; NRC, 2007, 2012). Young children are curious about the world around them and are often referred to as “scientists-in-waiting” (Gelman et al., 2010). Asking questions and conducting their own investigations of the world around them are a natural part of young children’s everyday lives. Supporting young children in the practices of science is also an opportunity to deepen their understanding of scientific content and provide them with the capacity to extend their learning after they leave your venue.

And while they may have the natural capacity to engage in doing science, even at a young age, they will need opportunity, experience, and support to further develop their abilities in this area, especially in ways that extend their understanding of science. Adults can play an important role in helping young children learn science by helping to direct children’s attention, regulate the complexity of information, and by providing science activities that allow children to engage experiential learning (NRC, 2007; NSTA, 2014). When adults engage young children in doing science collaboratively, they begin to model the importance of culture and community in science practices. At every level of doing science, from young children in a museum to astronomers at an observatory, science is a process of working as part of a community that shapes what is done and what is learned (NRC, 2007, 2009).

Science practices in astronomy

Though there are many similarities in how scientists work across different scientific domains, it is also important to focus on what specific ways we do science in specific domains. One of the similarities across scientific domains is that *science is a process of reasoning about evidence* (NRC, 2007, 2009). In other words, one of the distinguishing features of science is the focus on developing explanations or testing hypotheses about phenomena, based on evidence. This can involve a variety of science practices that may look different in different domains. For this reason, I will be discussing some of the important science practices that can be supported through the *My Sky Tonight* toolkit with a particular focus on how these practices appear in *astronomy*. And though I will discuss these practices are listed, children often engage in combinations of practices when participating in *My Sky Tonight* activities.

Observation: One of the goals of engaging young children in *observation* is to help them develop new knowledge and use new explanations based on evidence. However, “[to] observe scientifically requires much more than sensory perception and using one’s senses” (Eberbach & Crowley, 2009, p. 40). Scientific observation relies on one’s knowledge of a particular domain to notice salient features of a phenomenon. Therefore, when we think about engaging young children in observing, it is important to keep in mind that what children *notice* is dependent on their prior knowledge of that phenomenon. For example, when asking children to observe the Moon, what they notice may depend on what they think is important to pay attention to. Whether they observe that the Moon is a different shape than the last time they observed it depends on whether they realize that the shape of the Moon is an important feature of that astronomical object. Whether they notice that there are dark or light patches (i.e. the lunar Maria) may depend on whether they know that these are a feature that astronomers often focus on when discussing the Moon.

Children need opportunities to make observations in ways that help them notice in new ways, such as focusing on the shape of the Moon or that the shadows outside don’t always point the same way. This may require parents and educators to help focus children by asking them scientific questions that engage them in conversation around their observations.

Analyzing data: An important element of science is making sense of data gathered in order to answer scientific questions. Analyzing data for preschool-age children can also respond to

scientific questions, such as “*Do these patterns of stars look the same as the ones over here?*” and “*Are the things we see in the daytime sky the same as what we see at night?*,” which can help guide children to start to make sense of their observations. *Analyzing data* can then include any attempt to make sense of their observations, including **comparing** observations, **contrasting** observations, and **looking for patterns** in observations.

Here “observations” (which is often what children use as data in early astronomy investigations) could include the children’s own personal first-hand observations, such as seeing the Moon in the sky or observing shadows outside or caused by a flashlight indoors. Observations could also include second-hand data, such as images provided by an educator or parent, such as pictures of the phases of the Moon, pictures of the day and night sky, or pictures of different landscapes on the Moon and Mars. So, a child could engage in this practice by comparing observations of what a model of a star (a ball) looks like when it is near to them or far. A child could also compare their observations, such as looking at photographs of the Moon’s surface and our own Earth’s surface then looking for similarities and differences between these surfaces.

Constructing explanations: One of the central goals of science is developing evidence-based explanations for the world around us. One of children’s early experiences with constructing evidence-based explanations can be as simple as **making a claim** using their observations as evidence to answer a scientific question. For example, after observing images of the day sky and the night sky, children can begin to make claims about what objects often appear in the daytime sky and what objects often appear in the nighttime sky. They should be encouraged to use their observations to make claims, though a verbal connection between a claim and evidence, made spontaneously, may be unlikely for many young children. Children can make claims based on their own personal observations as well. After investigating the relationship between different shaped objects and the shapes of shadows, children can start to make claims that reflect their new understanding that shadows appear in the same shape as the object that makes them. These opportunities for *sense-making* from observations is an important aspect of doing science with young children.

Using tools to gather information: Tool use becomes a practice of science when the use of tools helps us gather new data, improve our ability to analyze data, or construct new explanations. Astronomers rely on the use of tools to extend our sense and gather information otherwise out of

reach from naked-eye observation. As children engage with the *My Sky Tonight* toolkit activities, they can learn how tools can be used to extend their senses in ways that help them gather more information about astronomical objects or even objects closer to home. Any tool that enhances their own abilities helps them start to see how astronomers work. This may include learning about how some tools are better than others for different situations.

Children can engage in first-hand investigations that involve tools when they use magnifying glasses or binoculars to change how they observe objects, both near and far. Children can think about how scientists might use tools when they think about how scientists create machines that go into space to explore new worlds. These space explores require specific tools that help them investigate new places, collect data, and send information back to scientists on Earth.

Representations and models: Astronomy is rich with representations and models that help astronomers reason about evidence or explain new phenomena. The scientific practice of developing representations and modeling should be based on empirical evidence and for the purpose of communicating or testing ideas. One of the purposes of a representation or model is to construct an explanation. An example of communicating an explanation using a representation might include: A child could be encouraged to draw a picture showing how a light on an object forms a shadow. Their drawing and verbal explanation can help explain their understanding of a phenomena based on their own observations of how shadows are made. An example of a child using a model to test new ideas about a phenomenon could include: A child could use model of the surface of the Moon (such as a bin full of sand) to investigate how craters are made on the Moon (by throwing objects at the sand) or how astronauts might travel across the Moon (using figures representing astronauts).

Thus representations and models can include drawings and physical representations. They can also include other physical creations, such as gluing pictures of astronomical objects on a piece of paper to show what is in the day sky and what is in the night sky. Such a representation could be used to communicate the child's ideas to a parent; it could also be a tool to make predictions about future observations and a source of conversation as the child and adult compare future observations to their original representation.

Engaging children, physically and verbally, with representations and models is often associated with constructing explanations and is therefore a good opportunity for children to make sense of observations to help them learn more about astronomy.

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Appendix B

Pre-Workshop Interview Protocol

Audience and current practice

1. Job Title & How long have you been in this job?
2. What kind of training or education have you had to prepare you for this job?
3. Aside from that, do you have other formal education or training?
4. Tell me about any previous work related to your work in your current position.
5. How often do you work with 3-5 year olds?

Goals and beliefs about learning

1. What are your goals for your 3-5 year old audiences? (Write down during interview to reference for later.)
2. How do you and your *venue* help your audiences reach those goals?
 - a. Could you give me an example?
 - b. Describe a specific activity.
 - c. How does this help you reach your goal or goals?
3. Ask specifics about other goals mentioned by participant.
4. How do you know whether or not children in your audiences are meeting your goals?

Understanding of science practices

1. Can young children do science? Why/why not? What does it mean for a young child to **do** science? (Can 3-5 years olds engage in scientific inquiry?)
2. Can you describe successful activities where the young children were doing science in your museum?
3. What do you do as an educator to help young children do science?
4. Describe specific example, what were they engaged in doing, thinking, how do you know?
5. Are there any strategies or techniques that you use when designing programs for children? One way that I've been thinking about engaging 3-5 year olds in science is through science practices. You named a few _____. Are there others that you use?

Appendix C

Post-Workshop Interview Protocol

1. Think back to what you were hoping to get from this workshop. In what ways did it match what you were hoping to do? Where there any surprises? What elements did you like? Not like?
2. What things during the webinar helped you? What did you want more of?
 - a. Did you go back and watch the webinars?
3. Which were most helpful to you in learning how to do astronomy activities with preschoolers?
 - a. Webinar
 - b. Emails from Abby
 - c. Engaging with Discussion Forum Posts
 - d. One-page write ups of activities
 - e. Tool kit materials
 - f. Videos
4. On a scale of 1-10, 1 being not at all, 10 being fully, what do you rate your participation? Why? Are there things that could have been done to help you move toward a 10? Were there things that made it hard to participate fully (or participate as much as you wanted to)?

Goals

1. Here's what I remember you saying were your goals when we first spoke... Are there any you'd like to add, subtract or change?
2. Will the My Sky Tonight activities help you reach your goals? How? How will you be able to use the toolkit activities to reach your goals?
3. Aside from the Toolkit activities, what have you learned in the PD that will help you reach your goals for 3-5 years olds audiences?

4. In the first interview, I asked you if you thought 3-5 year olds could do science. You responded with a YES. Did any of your ideas about how children do science change as a result of something you learned during the workshop?

Science Practices

1. What did you learn about science practices from this PD? What was your impression of science practices?
2. Would you mind watching the clips that we saw during the first week and just talking me through what you see related to doing science and engaging in science practices?
VIDEO: How are kids doing science? What practices are included in this clip?
3. Think about the practices, processes, inquiries, or skills they might be participating in during that clip.
4. How do you think the children are participating in science practices in the clip?
For each practice that they state, ask for more specific details. “How do you see that as being part of the science practices?”

Appendix D

Post-Observation Interview Protocol

1. What were your goals for this program?
2. Do you think your audience reached those goals? How?
3. How would you describe the ways in which the preschoolers engaged in science?
4. [If no reference to science practices in question #3] Did you notice any preschoolers engaging in science practices? Which ones? How? What did it look like?
5. [Tailor this based on observations of program.] Did the preschoolers complete the activity as you expected? Was there anything unexpected that happened?
6. As we try to improve the workshop, it is helpful to us to know if there were specific things from the workshop that you drew upon when you designed and led this program. [If you saw the one-pagers or something else, reference those if they don't.]
7. [If no reference thus far to the one-pagers, ask this.] How helpful were the one-page activity descriptions?
8. Which activity allowed for the richest engagement with science?

Appendix E

Full List of ISE's Goals and Codes

Goals	Codes
Fostering Positive Affect	To foster interest, excitement, curiosity, to have fun, to want to visit again
Creating a Comfortable Learning Environment	To foster engagement/an environment where children want to participate, to learn something, to learn through play, to create a foundation for future science learning
Supporting Children's Abilities	To provide increased choice, to provide new experiences and space for further exploration, create experiences that allow for different modes of learning, foster empathy for the world around them, identify with nature, to extend learning beyond the institution, to inspire them to learn more, offer facilitated programs for preschool-age audiences
Conceptual Learning	To learn something new, learn new vocabulary
Fostering Parent-Child Interactions	To provide parent-child activities, encourage parents and children to learn together, foster parent-children interactions with science
Building an Awareness of their World	To introduce children to the outdoors, to create an awareness of things around them
Participating at Age-Appropriate Level	To provide age appropriate explorations and investigations, to bring science to a level they can understand, foster developmentally-appropriate experiences,
Engaging in Science Practices	To engage them in observations and investigations, to build a foundation of science behaviors, help them build a model that they can use for future learning experiences

Appendix F

Full List of Young Children's Engagement in Science Codes

Category	Commonalities	Codes
Discovery / Exploration	--	Doing science involves free exploration. // Doing science involves hands-on explorations. // Doing science involves hands-on explorations with phenomena. // Children doing science involves hands-on experiences. // Doing science involves exploration. // Doing science involves systematic exploration. // Doing science involves engaging with scientific phenomena. // Children doing science is not formal or structured. // Doing science involves discovery // Doing science involves discovering the world around them.
Always Doing Science	--	Children are always doing science. // Children naturally do science. // Young children can do science without knowing it.
Affective	Interest/curiosity (natural, already exists) and motivation	Children are interested in science. // Children are motivated to engage/explore phenomena in their world. // Children are motivated to engage/explore phenomena in their world. // Children doing science involves their curiosity.
	Engaging and developing interest	Doing science with young children includes developing their interest in science. // Young children doing science helps to develop their interest in science // Young children doing science involves developing interest. // Doing science involves engaging their interests. // Doing science involves wondering.
	Exciting and fun (play included)	Children do science because it's exciting to them. // Doing science involves excitement. // Children do science for fun. // Children are excited to do science because of the content. // Doing science involves play. // Children do science while playing.
Age Appropriate	--	Children can do science when it is at an appropriate level. // Young children can do investigations that are age-

		appropriate. // Young children cannot understand or relate to science topics as well as older children. // Engaging children in developmentally appropriate practices.
Science Practices	Asking questions	Children doing science involves asking questions. // Children doing science involves asking questions about the world around us.
	Observing	Children doing science involves making observations. // Children do science because they are observers of the world.
	Using senses	Children doing science involves using their senses.
	Making hypotheses	Children doing science involves making hypotheses.
	Constructing explanations	Doing science involves constructing explanations, even if they are wrong. // Children do science when they try to explain the world around them.
	Recording data	Children doing science involves recording data. // Doing science involves keeping records.
	Comparing and categorizing data	Doing science involves making comparisons. // Doing science involves categorizing things. // Doing science involves sorting and categorizing. //// Doing science involves matching (identifying patterns) // Doing science involves analyzing data // Young children doing science involves organizing data. // Children doing science involves drawing conclusions.
	Using tools	Doing science involves using tools and procedures to get an answer. // Doing science involves using tools.
	Labeling and identifying patterns	Doing science involves labeling/naming things. // Doing science involves classifying objects // Doing science involves identification.
	Making claims from evidence	Doing science involves making claims from evidence. // Doing science involves evaluating evidence
	Collecting data	Doing science involves collecting data // Doing science involves collecting objects for study. //// Doing science involves making measurements.
	Creating representations	Children doing science involves them

		using and creating models. // Doing science involves creating representations // Children doing science involves graphing data.
	Experimenting	Doing science involves testing their ideas (included once: about the natural world based on their observations). // Doing science involves experimenting.
	Making predictions	Doing science involves making predictions.
	Investigating	Doing science involves making sense of the world by investigating. // Young children doing science involves investigating ideas that go beyond their current knowledge
	Communicating / participating in science with others	Doing science involves listening // Children doing science involves discussing their ideas about scientific phenomena. // Doing science involves communication // Young children observe the reactions of others while doing science. // Doing science includes participating in a larger community. // Doing science with young children includes parent participation.
	Processes of science	Doing science is about process not just results. // Doing science is a process. // Doing science involves engaging in science practices. // Doing science with young children includes building a foundation of the methods of science. // Doing science involves learning skills of science.

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