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Informal Science Educators: Understanding Their Goals for Preschool-Aged Audiences

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Abstract

Informal science educators' (ISEs) work with young children has received limited attention in the literature. We investigated ISEs' goals for preschool-aged audiences (3- to 5-year-old children), methods they describe for achieving these goals, and how ISEs understand young children as *doing science* in their venues. We interviewed 35 ISEs working at informal science venues across the USA. Using thematic analysis, we generated codes and categories through iterative analysis of the interview data set. Our findings suggest ISEs most often described affective goals, conceptual learning goals, and a goal of increasing young children's awareness of nature and their world. ISEs frequently mentioned hands-on or active educational methods, creative experiences, and memorable experiences as ways they achieve their goals. Though science practices were rarely described as a goal for their preschool-aged audiences, ISEs believe young children are capable of participating in the practices of science and frequently described ways they provide opportunities for young children to participate in science practices, such as asking questions and collecting data. Our findings suggest a starting point for the field to understand how ISEs are working with and thinking about preschool-aged audiences, providing leverages for future professional development to support and strengthen ISEs' professional practice in engaging this audience in doing science.

Keywords Informal · Early childhood · Science practices

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A substantial body of literature has explored the many dimensions of science learning in informal settings, including studies of how families and groups engage within museums (e.g., Ash 2003; Palmquist and Crowley 2007) and how adults support children in learning (e.g., Ash 2003). However, the role of front-line professionals in informal science institutions has received scant attention in educational research. In particular, although limited research has explored the ways informal science educators (ISEs) develop identity in their jobs and how specific communities of ISEs work with their audiences (Plummer and Small 2013; Small and Plummer 2010; Tran and King 2007), our literature search finds no prior research examining ISEs work with young children's early science engagement in informal environments.

Yet, increasingly preschool-aged children (typically 3–5 years old) are an important audience for informal science institutions (Institute for Museums and Library Services 2013). Informal science institutions provide opportunities to support young children's early explorations of science in ways that will promote a broad range of possible science goals, including engagement in science practices (NRC 2009). We consider science practices as an active form of disciplinary engagement that allow us to make sense of science phenomena in the world. Participation in informal environments offers opportunities to develop an understanding of the tools and language of science as visitors interact with others around material representations that support their learning. And with the support, preschool-aged children are capable of engaging productively with others to use science practices, including asking questions, collecting and analyzing data, and constructing explanations (Callanan and Oakes 1992; Gelman et al. 2009).

Previous studies have not specifically considered ISE's work with early-childhood audiences. However, a few studies have investigated the identity, goals, and beliefs of the ISE community (Plummer and Small 2013; Small and Plummer 2010; Holliday and Lederman 2014; Pattison and Dierking 2013; Tran 2007, 2008). When engaged in programming, informal science educators may teach young children in ways that are similar to how classroom instruction is structured, such as the use of segmented lessons (Tran 2007). When their work with audiences is unstructured, the strategies used by ISEs include guiding, demonstrating, focusing attention, and modeling (Pattison and Dierking 2013). ISEs recognize that their work is often more *object-oriented*, specialized to a discipline, and engaged with audiences as brief rather than continuous interactions (Tran 2008).

ISEs have a range of goals for their audiences. Tran (2007) found that ISEs working with elementary students "taught their lessons with the intention to develop students' interests in returning to the museum and nurture students' intrinsic motivations to pursue science and learning" (p. 291)—rather than focusing on content-oriented goals. Pattison and Dierking's (2013) study of staff working in unstructured interactions suggests ISEs' attempt to introduce new goals for audiences' engagement often focusing on the scientific content. Small and Plummer (Plummer and Small 2013; Small andPlummer 2010) found that planetarium professionals' goals for audiences included both content-oriented goals and increasing interest.

Yet, gaps remain in our understanding of ISEs' goals for audiences and their ideas about engaging audiences in science. Specifically, these prior studies did not address ISEs' goals for preschool-aged audiences or their role in supporting audience's engagement in science practices. The present study begins to fill gaps in the literature in key ways. First, we characterized ISEs' goals for young children who visit their informal science venues and their methods for achieving those goals. Second, we considered ISEs conceptualization of what it means for young children to "do science" in the context of their informal environment. In doing so, we examined differences in how educators frame early science opportunities for young children, including early engagement in science practices. We were guided by the following research questions:

1. What are ISE practitioners' goals for their preschool-aged audiences?
2. What methods do ISEs describe for achieving these goals with preschool-aged audiences?
3. How do ISEs describe the ways they engage young children in "doing science"?

Answering these questions may position the field to provide targeted professional training for these educators.

Our study was shaped by a sociocultural theoretical framework in which we interpret learning as opportunities for shared repertoires of practice to be co-constructed by members of a community, through both their social interactions and their engagement with the physical environment (Lave and Wenger 1991; Rogoff 1994, 1995). As we take this lens on learning as a socially constructed experience, we use this theory to consider how science learning may be co-constructed by children, parents, and educators, as an emergent process rather than a static knowledge base (Siry et al. 2012). We view science as more than reasoning about content or following set procedures, but as a shared and co-developed practice of doing science among a community of scientists or learners of science (Lehrer and Schauble 2006; Manz 2016). This shapes the way we recognize young children's opportunities to learn science through how they enact the practice of doing science, interacting with others, thus allowing a shared science practice to emerge as a cultural phenomenon (Siry 2014). We draw attention to this perspective because it shaped the nature of our analysis, as we considered ISEs' goals and ways they describe engaging young children in doing science.

Informal Science Learning and Young Audiences

We reviewed how the research community views the potential of these venues as well as the potential for preschool-aged children to engage in science. *Learning Science in Informal Environments* (LSIE) (NRC 2009) describes productive ways informal educators may choose to engage their young audiences. LSIE's strands of science learning speak both to potential goals an individual ISE may hold for their audiences and may inform the nature of interactions within that setting. Strand 1 describes science learning as an opportunity to "experience excitement, interest, and motivation to learn" (p. 4) about science phenomena. Strand 2 suggests visitors develop conceptual knowledge and explanations in the informal environment. Strands 3, 4, and 5 identify science learning as an engagement with the practices of science, towards an understanding of science as a way of knowing, through engagement with others using a common scientific language. Strand 6 highlights the ways learners can come to identify with the scientific enterprise. While prior research considering ISEs' work with older audiences suggests ISEs attend to Strands 1 and 2 (Small and Plummer 2010; Tran 2007), limited research indicates how ISEs consider the remaining Strands in their work and how this is reflected in their work with their youngest audiences.

Young children are capable of engaging with these strands of science learning, given the opportunity and support. Metz (1995) contends that when provided opportunity and support, young children are not bound by concrete reasoning but rather have the potential to engage in scientific inquiry. Young children are intrinsically motivated to learn science (e.g., Patrick and

Mantzicopoulos 2015). Young children ask a wide range of questions about the natural world (Callanan and Jipson 2001; Callanan et al. 2018; Callanan and Oakes 1992), suggesting they are wondering about the world around them. Young children have been considered *scientists-in-waiting* because of their early disposition towards engaging in scientific reasoning and problem-solving (Gelman et al. 2009; NRC 2007, 2012). Because of young children's capacity to engage in science as a practice (e.g., Siry et al. 2012), one of our central interests in conducting this research was to explore the extent to which ISEs focused on these science practices as a goal for their audiences.

Our conceptual framework for science practices draws on reform-based notions of science as a way of understanding the world based on evidence, built on knowledge developed by others in the scientific community. We are informed by descriptions of science practices in *Learning Science in Informal Environments* (NRC 2009). LSIE describes engagement in the practices of science as a social process where science happens with groups of people working together to construct explanations for phenomena in the natural world. Through social interaction, participants in science "communicate to identify scientific problems, together analyze, and interpret evidence, to build explanations that account for the broadest set of observations; and to critique and improve on these accounts" (NRC 2009, p. 111). Further, as participation in science practice is a social system, it requires specialized language and the purposeful use of tools to inquiry about natural phenomena.

Research suggest ways in which young children's early scientific exploration can be supported and nurtured towards experiences that lead to their first experiences with science practices. Rennie and McClafferty (2002) suggest museums encourage young children to investigate through close observation of museum objects (e.g., looking, touching, manipulating) because of the novelty of the environment. Such a frame of mind may situate young children towards investigating new phenomena in order to generate new evidence-based claims about their world. Children's purposeful scientific observations and investigation increase when adults engage with children in the informal science environment. For example, Crowley and Galco (2001) found that when children engaged with a science exhibit, they were more likely to engage with scientific evidence with their parents than with peers or on their own. This may suggest educators could also play a role to increase children's opportunities to engage with evidence or aspects of science practices in the informal environment. Indeed, Plummer and Ricketts (2018) found that, through the facilitation of an ISE, many preschool-aged children were capable of co-constructing evidence-based explanations and modeling practices for astronomical phenomena during programs at a children's science museum.

Methodology

We used thematic analysis to guide this primarily qualitative study (Braun and Clarke 2006; Nowell et al. 2017) as thematic analysis is a commonly used approach for qualitative data (e.g., Moorhouse et al. 2019). Thematic analysis can use either inductive (*bottom-up*) or deductive (*top down*) approaches to generate themes. We used an inductive approach to generate themes about ISEs' goals, methods, and ways of engaging audiences in science that would be strongly linked to the data. In the case of exploring ISEs' goals and use of science practices with preschool-aged audiences, we were guided by our analytical framework drawn from the conceptual framework for science practices we described above. This deductive approach allowed us to identify how ISEs' work with audiences and align their descriptions of science practices with those found in the literature (e.g., NRC 2009, 2012).

Participants and Setting

We began selecting participants from ISEs who had previously responded to an online survey conducted as part of an earlier, unpublished study. We invited 33 professionals from that list ($N = 229$) to participate, selected to represent a diverse range of ISE settings (representing a cross-section of the types of institutions represented in the original survey) and past experience with 3- to 5-year-old children; 18 of those 33 professionals agreed to be interviewed. We used two methods to find additional participants. First, we contacted 14 additional ISE professionals working at institutions in places, though geographically dispersed across the USA, that would allow our team to visit and observe their practice for a later study; 10 out of 14 agreed to be interviewed. Second, we invited colleagues suggested by participants in each of the two groups who had already agreed to participate in the study; seven out of seven agreed to be interviewed. In total, these methods resulted in 35 participants interviewed for this study (6 men, 29 women).

Participants were drawn from 11 states across the USA working at nature centers and parks, science centers, children's museums, and natural history museums. Participants were in their current job on an average 6.7 years (SD = 7.2), ranging from less than 1 to 34 years. Participants' prior education included 37% with science degrees, 37% with education degrees, 9% with both education and science degrees, and 11% with other degrees (6% with no information). We also asked participants about prior experiences that help them with their current job: other informal science educator jobs (40%), classroom teachers (29%), planetarium educators (14%), and one laboratory scientist (3%). While not common, participants described professional development (PD) opportunities: PD workshops at conferences (14%), on-site PD (9%), and education coursework (9%). Four ISEs (11%) did not describe prior experiences.

We asked participants how frequently they work with 3-to-5-year-old children. Participants work with young children only during certain times of the year (e.g., during the summer) (20%), a few times a week (17%), everyday (14%), occasionally (9%), and were either not asked or their response was not clear (23%). The remaining ISEs (17%) described training/supervision early childhood educators in their venue.

Data Collection

All participants ($N = 35$) participated in one or two semi-structured interviews. The majority of participants ($n = 23$) were asked questions from our full interview protocol, audio-recorded over the phone for later transcription, lasting between 20 and 54 min. Questions addressed goals for 3-to-5-year-old audiences, how they achieve their goals, and ideas about how children do science and science practices.

The remaining participants ($n = 12$) were observed working with preschool-aged audiences for a separate study. Six of these participants were interviewed with the full interview protocol while all twelve of these participants were also interviewed after we observed their work with preschool-aged children using a revised version of the original protocol (observation follow-up interview). The relevant questions on the observation follow-up interview were nearly the same as with the full interview protocol; however, they were asked in the context of the program we observed. Both interview protocols are available as a supplemental file.

Analysis

Using a thematic analysis approach to analyze interview transcripts (Braun and Clarke 2006; Nowell et al. 2017), we began with open coding to identify potential codes within the three major areas of interest in this study: ISE practitioners' goals for their audience, how their goals are achieved, and ideas about engaging children in science. For each area of interest, the first and second authors iteratively reviewed groups of interviews and wrote out descriptive codes. These codes were compared and consolidated into shared language describing ideas, goals, practices, and beliefs expressed by participants. Those codes were used for the next subset of interviews, where the first and second authors repeated the process of separately reviewing the interviews and assigning existing codes and generating new codes where needed. After new codes were generated, we individually coded additional interviews then compared our coding again. We also reviewed and discussed previously coded interviews, in case newly added codes should have been applied to previously coded interviews. This process was repeated such that the coding was discussed by the first and second authors for all the remaining interviews.

The first and second authors then reviewed all codes within each area of interest to look for similar codes that could be grouped into categories. The first and second authors worked collaboratively to come into agreement on how all codes would be grouped into categories. For example, the goal codes to foster interest, to have fun (have a positive experience), to foster excitement, to foster curiosity, to get them to want to visit again were grouped into the category affective goals. The findings presented here focus primarily at the category level. Definitions of relevant categories are presented within the body of the findings. Descriptive statistics were generated to provide an estimation of the relative importance of each category within an area of interest for our participants, organized by our research questions. This allowed us to describe which themes emerged most frequently among participants and which were rarely discussed.

Findings

Findings are organized around our research questions. Due to the diversity of participants' responses and the large number of resultant categories, we highlight the most frequent responses and those that provide insight into our underlying interest in ISEs' use of science practices with young children. We highlight participants' frequent mention of affective goals as well as goals relating to content learning and awareness of the world. Participants often used active and/or hands-on methods to achieve these goals. And though science practices were rarely described as goals or methods by participants, nearly all participants were able to describe ways they use science practices in programming with preschool-aged audiences.

Goals for Preschool-Aged Audiences

ISEs were asked "What are your goals for your 3-5 year old audiences?" These goals were grouped into nine categories (Fig. 1). Most ISEs described goals across categories.

The most frequently described goals were in the affective category (23 out of 35 participants), referencing children's emotions, interest, or motivation to continue participating at the informal setting. Participants' goals included describing children as having fun, a positive

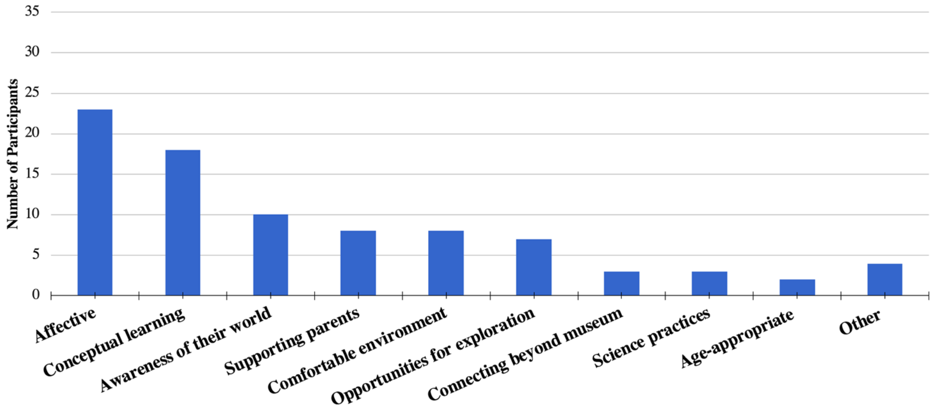

Fig. 1 ISE's goals for their preschool-aged audiences at informal science venues

experience, and fostering curiosity. Some participants' goals included repeat visits to their venue. Susan's[1] goals focused on fostering interest and excitement at her space-themed venue:

> To get them excited! In fact, that's truly our primary goal, overall, with most of our shows when it comes to school groups coming to the museum, not only educating but getting them excited and interested in doing further research. You only usually have around 30 to 40 minutes for each group. It's not enough time to really get into the science of it all.

Describing her goal as increasing interest or excitement was reflected across many participants.

The next most frequent goal was conceptual learning (18 participants), supporting children's learning of science concepts. Conceptual learning goals included learning general science concepts and new science vocabulary, but it also referred to opportunities to introduce children to new ideas and build a foundation for future learning. Lola described how her goals reflect learning general science concepts:

> A lot of the [planetarium] shows that we do tie into some of the work, the [State] Standards, for those age groups, so simple spelling things, simple colors, the motions of the Sun, phases of the Moon, that kind of thing, but on a really simple level.

In addition to expressing age-appropriate conceptual goals, educators also expressed their goals in more general terms such as "introduce them to different aspects that can't be provided (…) in the home or in day care, or pre-K" (Colleen) and "get a basic understanding and start building that foundation" (Lexa).

The third most frequently described goal by participants was awareness of their world (10 participants), which emphasized awareness of their surroundings and nature, empathy with nature, and identifying with nature. Misty described how children should empathize with nature:

> I think it's the appreciation and the empathy toward nature. The identification with nature. [...] The whole idea that for a child, what they see is their world. Their backyard is their world, that little hole that they dug is their world. So, if they can identify and empathize with that worm, and the worm has needs just like they have needs, they

[1] All names used in the paper are pseudonyms.

> realize that. It's an appreciation. It's that awe you're trying to get. It's not content, it's not that they can tell you that a worm is this type of an animal, or there is a head or there isn't a head. It's the, "Wow, this is an animal, this is alive, this is as special as I am."

Other participants in the awareness category described their goal as helping children see science all around them and giving children exposure to the outdoors.

The other categories included eight or fewer participants. Most of these goals reflecting the work of early childhood educators by addressing specific features of this age group: supporting parents, making the learning environment comfortable for young children, providing age-appropriate science experiences, and providing opportunities for exploration and creativity. A final category, connecting beyond the museum, mentioned by three participants, expressed how these participants seek to connect young visitors' experiences to ways they might engage with science beyond the informal institution.

Finally, goals relating to engagement in science practices were expressed by only three participants. We did not anticipate that participants would explicitly reference the term "science practices;" rather, we considered ways the participants talked about children doing science that might reflect normative views of doing science as characterized by reform-based documents (e.g., science as an investigative process, using evidence to understand and explain natural phenomena). Lindsey's science practices response emphasized making observations and recording data, as part of a scientific investigation:

> I would say our goals are really kind of introduction to the scientific ways of investigating things, so we've really tried a lot to focus on what are age-appropriate tools for making observations and recording what you see. Most of our things for that age groups are set up in centers in the classroom. The adults are really scaffolding the pieces of that process. We may have a big data chart up on the wall that the grown-ups are writing on but we'll make kids make a prediction about how far you'll be able to jump. Then the grown-ups will be writing the numbers on the chart and then the kids will jump. Then they'll be comparing that to how far a frog can jump or a T-Rex can jump.

Erica was the only respondent to explicitly mention science practices: "We are teaching them what it means to observe or predict. We are heavily incorporating the science practices." She went on to describe how her programs encourage children to be "little chemists, or astronomers, or gardeners" while also integrating her programs with play and creativity.

Achieving Their Goals

ISEs were prompted to describe how they achieve their goals as a way to provide insight into their methods of engaging preschool-aged audiences. Figure 2 includes categories assigned to five or more participants; educators often described methods within two or more categories.

Participants frequently described achieving their goals for children through hands-on or active methods (19 participants). These physically active methods were often combined with other ways ISEs achieved their goals, such as through designed programs (13 participants) which includes workshops, nature walks, or planetarium programs. Participants also described using both creative experiences (11 participants) and new and/or memorable experiences (5 participants) to achieve their goals. Creative experiences include songs, stories, crafts, and pretend play. Participants describing new and/or memorable experiences as a way to achieve

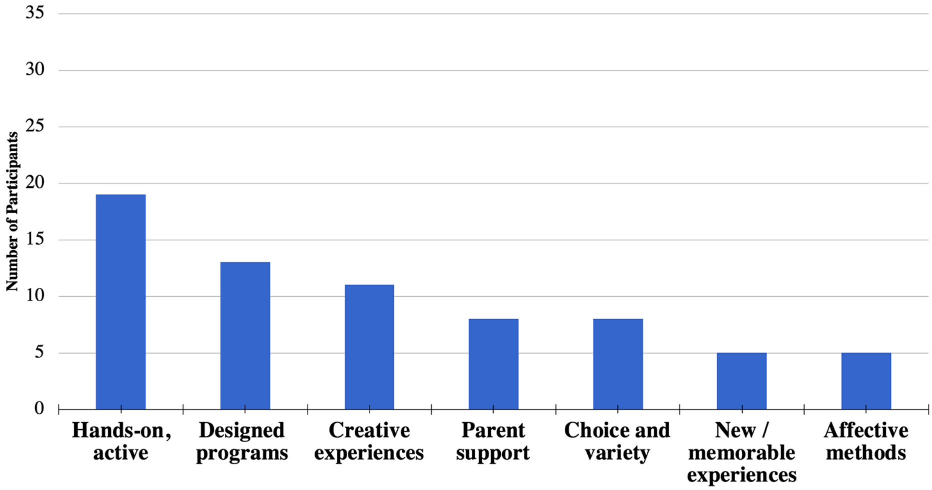

Fig. 2 ISE's descriptions of methods used to achieve their goals for preschool-aged audiences

their goals often used similar words, such as "memorable experiences" or experiences they are "not getting at home."

Mikayla's explanation of how she and her colleagues help children meet their goals includes these elements of hands-on, creative, and new experiences through a designed program:

> We tried to do things that they've probably not done in school, and especially at that younger age. (...) A lot of times science [in school] is still, surprisingly, it's still book and memorization and things like that. We do, like I said, we do read the stories, but then after that we do all sorts of hands on type stuff. [She described how they engage children with simulators of space missions.] Nothing like anything they've ever been in before. I think that's, just trying to base it around something that they haven't done before, it's something unique that we can offer. (...) We actually watch a launch in our mission control room. That right there in itself is very unique. They get to sit at the consoles, and we pretend like we're talking to NASA.

Mikayla's example highlights hands-on engagement using space mission simulators. Children have a new experience—something "unique"—where they engage in pretend play as they "talk to NASA" (creative)—set within a designed program Mikayla constructed for her audience.

Others describe reaching their goals by fostering interest and capitalizing on children's excitement (affective; five participants). April describes this perspective:

> We try to catch those teachable moments because, if the kids are excited about something, that's what they're going to remember. They're going to remember seeing that worm, touching it, looking at it, talking about it, holding it in their hands, and feeling it squirm. We try to be very hands-on and intimate and get down on their level and teach them what they want to know.

Other participants provided choice or a variety of experiences (eight participants). Lindsey described using stations designed to provide a balance of

> …things that kids can do on their own … paired with things that kids can dive a little bit deeper if they have a little more coaching from adults. Always a range of activities

> where we're just really into being inclusive and kind of helping kids find an "in" to whatever we're doing. Some kids are really into visual stuff and some are more tactile and some are really verbal and want to tell you a story.

Lindsay achieves her goals by offering a variety of activities, some at children's current level and some within their zone of proximal development when supported by others (Vygotsky 1978).

Finally, some participants meet their goals by supporting parents (eight participants). This might include offering activities for the parent and child to do together or encouraging parents to stay involved during a visit.

Engaging Preschool-Aged Audiences in "Doing Science"

One goal of our research was to investigate whether ISEs believe young children are capable of participating in science practices. Because we anticipated ISEs may be unfamiliar with the term "science practices," we asked "Can young children do science?" All 35 participants answered this question in the affirmative: young children can do science. We followed up by asking, "What does it mean for a young child to do science?" and "Are there ways that you think children are participating in doing science when they are at your venue?" Coded responses were grouped into the eight categories, shown in Fig. 3.

Science Practices The category in which most participants' responses were coded (32 participants) was science practices: a range of both specific and general ways of doing science that reflects normative views of science practices in the literature (e.g., NRC 2009, 2013). Responses in this category do not necessarily indicate that participants held a comprehensive understanding of how scientists engage in their work to answer questions when investigating phenomena or that the ISEs use these practices systematically with their audiences. Rather, responses often reflected descriptions of a specific scientific practice or a combination of a few practices at an age-appropriate level (e.g., observation or using tools). These responses were grouped into more detailed codes, as shown in Fig. 4.

The most frequently described science practice was collecting data (27 participants), which included making observations, using one's senses to observe, recording data, and using tools. For example, Misty described children engaged in collecting data by using their senses: "If you

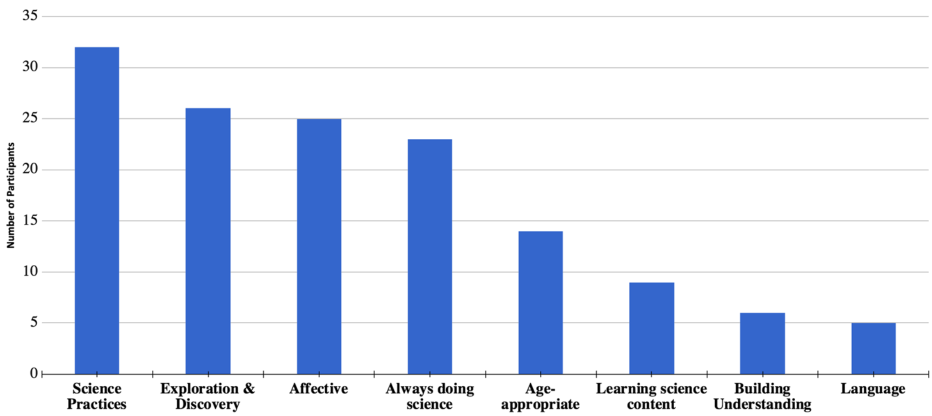

Fig. 3 ISEs' ideas about what it means for young children to "do science" ($N = 35$)

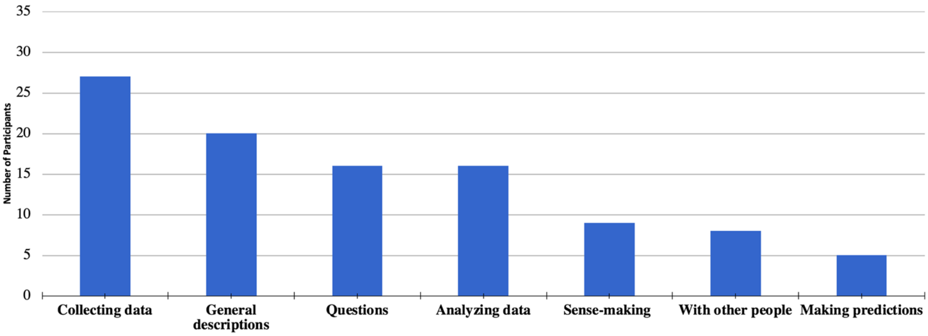

Fig. 4 ISEs' descriptions of preschool-aged children's use of science practices in informal venues

have a true scientist, they're always questioning what they see; they're always gathering data. Children are gathering data all the time. It's coming at them rapidly. They use their senses probably better than we adults do." Vivian focuses on making observations as ways young children engage in collecting data:

> I think that for preschool children, […] let's say that you are learning about the life cycle. For a preschooler you might just plant the seed and have them observe it; whereas older ages, as they plant the seed and as they are observing, you are talking about what do they see, what is happening to the plant the whole time. Whereas the preschoolers, you are just observing the different stages of the plant. It's really the types of things that they are learning but really, they are learning the same things but at their own level.

Participants approached collecting data in ways specific to the preschool audience.

Participants also described science practices for young children as analyzing data (16 participants), which included comparing and categorizing data as well as labeling and identifying patterns. Erica described children engaged in comparing and categorizing data:

> 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.

Many participants (16 participants) used asking questions to describe how young children do science. Lindsey connected asking questions to how children begin doing science, "I would say children at that age have a lot of questions and that's always where science begins, with your questions." Five participants described making predictions and hypothesizing as how young children do science. April discusses how children might generate a hypothesis to test: "They were doing the scientific process of experimenting and having a hypothesis of, "Oh, the fish is alive." Okay, let's test that hypothesis. They might not have known they were using the scientific process, but they were doing it." This idea of children doing science but not knowing that they are doing science was frequently described by ISEs.

Some participants (9 participants) described doing science in ways that included sense-making practices: those practices that help children develop a deeper understanding of the phenomenon they are investigating (Benedict-Chambers et al. 2017). Three aspects of sense-making emerged: constructing explanations, claims from evidence, and creating representations. Mikayla's description of engaging children in doing science includes sense-making, as children generate answers from data they have gathered as they classify objects as magnetic or not magnetic:

> We actually have a kind of a placemat where they put magnetic on one side and not magnetic on the other. Right there, they're making their predictions…. Instead of me telling them, once they've made their predictions, we discuss it all together and look at the predictions. Once they make those predictions, they actually get to check it themselves. That's pretty much the experiment part of it. Then, once they check it themselves, then we go over the correct answers and kind of put the data together.

This was an opportunity for young children to make claims when they "check it themselves" and "go over the correct answers" as they use evidence by putting "the data together."

General descriptions (20 participants) included experimenting, investigating, and references to processes of science but were grouped together because the responses provided limited detail. For example, Mikayla:

> But, yes, I think they can do small experiments. I think they can do the hands-on type things... They can do the exploring and I think that's the key for the young ones, is exploring. They don't necessarily have to do full-blown scientific experiments following the, you know...

We were unsure what Mikayla counted as "experiments" as her description lacked detail.

Finally, participants described young children doing science by communicating and participating in science with other people (10 participants). Ariel described how science is about children "wanting to investigate, wanting to know more, wanting to communicate their questions and discoveries with the people around them." This group of responses suggest some ISEs view young children doing science as part of a larger community of learners and scientists.

Additional Categories of "Doing Science" In addition to discussing science practices, participants provided additional ways young children do science (Fig. 3). Exploration and discovery (26 participants) is complementary to the normative view of science practices; participants provided few details about the nature of the practices children were engaged with while still suggesting this was a way children could learn about the natural world through their own actions. Exploration and discovery was used by some participants in conjunction with specific practices. Lacey's response reflects an open-ended process:

> They were actually engaged in open-ended explorations with a variety of materials. So, they were given materials, given just a few very basic parameters for safety precautions and things like that, and then it was up to them to discover and uncover the properties that they were seeing, and to try to use their own language.

We see this category fitting well with an overall approach that uses science practices but without enough detail to determine whether their views fit that conceptual framework.

Participants often indicated that young children are always doing science (23 participants), giving similar statements, such as "they're constantly doing it (Abbie)," "they do it all the time" (Jocelyn), and "they're born scientists (Lexa)." This suggests that participants recognize similarities in what it means to do science—learning about the world around us using evidence—with how young children make sense of the world.

Participants also connected doing science with affective descriptors (25 participants). ISEs spoke in terms of children's existing interest/curiosity and motivation, children's development of interest in science and related children doing science to having fun. Responses suggest participants were considering why we engage young children in doing science. Cindi described interest as central to what it means for young children to do science: "Their whole unadulterated tuning in is what science is. Of course, you can read that everywhere in the literature. But it's when you're with them, it's the full engagement of their interest." Jessie expressed the notion of doing science as fun or play for young children:

> Obviously, a scientist is probably doing science to prove a theory. A child is doing science pretty much just for fun to do it and maybe prove something, but they won't have it in their brain like that. They're just doing it for fun and some kind of end result.

Tony took this notion of play as science a step farther: "I think children do that very naturally. Traditionally it hasn't been called science. It's just been called play. At that age that play is then doing science. You can call it in a broad sense science." This notion of play as science may also reflect similar qualities as exploration and always doing science, expressed by other participants.

The last three categories relate to children doing science as ways of developing understanding of science content or language. Science content (nine participants) describes responses equating doing science with learning science content. Arden described doing science as science content when he described children putting "worms in these cups with soil and all sorts of trash, and they learned how they were sort of recycling, and they could actually see the worms in there. (...)." Arden went on to suggest that this "was pretty close to science, and they were kind of getting that the worms eat the garbage..." Building understanding (six participants) describes doing science as learning by making connections or building on prior knowledge. Tony gave an example of building on prior knowledge that also used the *science practice* of observation: "We try to focus very much on the observation. (...) Part of science is keeping record. Even at the young ages, anytime you're doing observing and trying to relate what you observe with something else or something you've observed previously." Finally, the language category (five participants) identified ways participants note the use of scientific language as part of doing science. Abbie discusses strategies for introducing new vocabulary in an activity discussing the Moon and how you can see the Moon during the day: "It's daytime, and you can see the Moon and the Sun in the sky at the same time. So, helping them just hear those words in context, and use those words." Other responses in this category also used children's own observations or personal language to introduce more scientific language or focused on the use of age-appropriate science language.

Discussion and Conclusions

ISEs in this study primarily highlighted affective and conceptual goals for their preschool-aged audiences. This focus is similar to goals found with studies of informal educators in other types of venues and with other audiences (Plummer and Small 2013; Small and Plummer 2010; Pattison and Dierking 2013; Tran 2007). ISEs frequently mentioned awareness of the natural world as a goal, which may be partly influenced by the number of participants from nature centers, parks, and planetariums whose educators resonate with engaging visitors in the natural world and night sky (Lavie Alon and Tal 2017; Small and Plummer 2010); engaging children in the natural environment has been taken up by preschool educators in formal settings as well (Tippins et al. 2015). Two other goals may be specific to this age group: comfort with the learning environment and providing support for parents. Support for parents, in particular, is well grounded in the extensive research on how families interact in museums and the ways this interaction can facilitate children's learning (see Munley 2012, for a review). Finally, few participants highlighted engagement with science practices as a goal; we will consider this further as we consider their ideas about how children do science in their venue.

One of the primary methods ISEs described for achieving their goals with preschool-aged audiences was through hands-on or active methods. This may reflect ISEs' belief that children learn science or develop interest in science through their own personal experiences with the world. Such an approach to early childhood education is well-supported in the literature; hands-on experiences are considered vital for preschool-aged children to learn science, though Gelman and Brenneman (2004) further point out the importance of "sensitive adult guidance" (p. 151). For some ISEs in this study, articulating a hands-on, active approach reflects their use of the exhibits in their museum or science center; many hands-on exhibits are designed for use by families with children (Mai & Ash 2012). Van Schijndel et al. (2010) go further to suggest that interactivity—how a visitor interacts with an exhibit—is an "indispensable part of young children's visit" to science museums (p. 795) and that children's actions, more than their verbal responses, provide more insight into the quality of their scientific reasoning.

Creative experiences were described by nearly one-third of the educators as a way of achieving goals with young audiences. The use of creative experiences, including play-based science experiences, suggests many ISEs may be aware of how play and creative experiences are important aspects of how children develop, cognitively and socially (Akman and Güçhan Özgül 2015). Many of the experiences, described by ISEs, engaged children's imagination through story and song. Fleer (2017) suggests the use of imaginary scientific situations, engaged through scientific narratives, has the potential to support young children in developing scientific learning and reasoning through play-based learning. Other studies support the ISEs' use of storybooks to engage children in learning science (e.g., Kelemen et al. 2014). This suggests that many of the diverse situations that engage young children in creative and imaginative experiences, created and advocated for by ISEs for preschool-aged audiences, have the potential to be productive opportunities for learning science.

Finally, we return to our finding that few participants explicitly identified science practices as a goal, in contrast to broader possibilities provided by informal science venues. *Learning Science in Informal Environments* (NRC 2009) describes a broad suite of ways informal science institutions can support visitors' science learning in ways that go beyond developing and supporting interest (affective goals) and supporting conceptual understanding. This suggests we have identified a gap between ISE's goals and a broader opportunity provided by these venues for engaging audiences in science as a way of reasoning from evidence.

Yet, when asked to describe their ideas about how preschool-aged children *do science* with them, nearly all ISEs described young children doing science at their venues in ways consistent with some aspects of science as practice. Though often limited to only describing children engaged with a few science practices, ISEs' widespread use of children's capacity to engage in science practices is promising for the field. In particular, a promising starting point was the frequent focus on engaging children in using scientific observation as this provides the foundation for further science practices and deeper engagement into scientific reasoning and domain-based learning (Gelman and Brenneman 2004; Lehrer and Schauble 2006). It suggests that ISEs recognize young children's capacity to take part in the processes we recognize as central to scientific reasoning and that many ISEs are engaging preschool-aged audiences in ways consistent with the multifaceted vision of science described in *Learning Science in Informal Settings* (NRC 2009). Prior research suggests ISEs have developed an understanding of many aspects of the nature of science (Holliday and Lederman 2014). Thus, our study adds to the literature demonstrating ISEs' potential in supporting audiences, including preschool-aged children, in the scientific enterprise.

In contrast to frequent descriptions of children engaged in a few science practices from our participants, we found few robust descriptions that reflected a coherent view of science-as-practice (Lehrer and Schauble 2006; Manz 2016; Siry et al. 2012). A few ISEs described the role of discourse or interaction with others, which points to a more nuanced notion of science as a practice developed through interaction with a community. However, we also considered that the ways in which ISEs envision children participating in community-oriented opportunities to generate evidence and make sense of their environment may not have been reflected in most of the participants' verbal descriptions of their own practice, due to the nature of the interview format. On the other hand, most of the ISEs' practice descriptions reflect the notion that children take up these practices for themselves rather than being directed by others. This is reflected both in how participants describe young children's science practices and the frequently indicated belief that children are "always doing science." The positive attitude towards children's capacity for science-as-practice could be a starting point to develop further support for children's engagement with these practices in informal settings.

In summary, many of the ISEs in our study view their role with preschool-aged children as one that aligns with the role espoused by many ISEs and institutions: inspiring audiences to want to learn more about the scientific world around them (Allen et al. 2008; NRC 2009). This view aligns well with their views about achieving their goals through engaging, active opportunities that often bring in creative and playful experiences. Such an approach may also be influenced by those ISEs with a particular focus or training in early childhood education as such approaches are highlighted as productive for this age group (Akman and Güçhan Özgül 2015). And while participants often described how they engage young children in ways consistent with the practices of science, these descriptions did not appear in their goals for preschool-aged children nor were practices described as a method ISEs consider to be the ways in which they can reach their goals. This disconnect may suggest ISEs miss opportunities to leverage children's own curiosity and wonderment about the natural world through experiences that guide children to answer their own questions about natural phenomena using the practices of science.

These findings point to ways future professional development (PD) could support ISEs while also leveraging the strengths exhibited by ISEs. As few ISEs articulated science practices as a goal, PD could engage ISEs in considering the benefits of science practices as a goal for young children or a method for achieving their goals. As many ISEs recognize that making observations reflects how young children do science, this could be leveraged in ways that help ISEs connect young visitors' experiences to new science phenomena. This could be further leveraged to help ISEs promote the social dimension of doing science, by encouraging opportunities for children to make sense of their observations together or with family members. This would take advantage of our finding that many ISEs want to support not only children but also their parents while at the same time promoting the idea that science practices are developed together with others. Activities and curricula developed for ISEs should consider ISEs' desire to support families' engagement in science and young children's comfort with the world around them, building on prior research on families engaged in science practices in informal settings (e.g., Small and Plummer 2013). Finally, PD and activities designed for ISEs to work with young children should continue to explore avenues to productively build in opportunities for creativity, play, and use of stories. Given the broad interest in these types of methods, PD and materials developed to work with young children in informal settings could help ISEs integrate these methods with young children's collaborative investigations of science phenomena.

Building on these recommendations for future PD for ISEs, future studies are needed that investigate methods of designing PD that supports ISEs work with young children and families in science practices and whether such PD leads to improved outcomes for both ISE professional practice and audiences. We also recommend that future research use video of ISEs engaging with preschool-aged audiences, and their families, to better understand how their descriptions of their work are carried out in practice. Such studies may clarify further the choices ISEs make to provide opportunities for children to do science-as-practice in ways ISEs are not able to fully articulate during their interviews.

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