Preschool-Age Children Engaged in Science Practices through Astronomy Experiences at a Museum

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This exploratory study begins to address how informal science venues can provide opportunities for preschool-aged children to engage in sense-making practices, specifically constructing explanations based on evidence. Data was gathered during a series of workshops on astronomy at a children's science museum. Findings support recommendations of the NSTA position statement for Early Childhood (2014) by showing that children are capable of engaging in scientific practices, demonstrating the important role adults play in helping children learn science, showing that young children develop science skills in informal settings, and pointing to the importance of experiential learning for young children. Findings also point to features of museum programs that support young children. First, children needed an opportunity with the phenomenon in order to have an opportunity to gather evidence to make a claim, such as through first-hand experiences, photographs, and models to engage children with astronomical phenomena. Second, children engaged in making claims based on evidence when an educator engaged them with scientific questions. Third, children's engagement in constructing explanations goes beyond just verbal responses to an educator. Children drew heavily on the affordances offered by materials at hand as well as their own gestures to help them communicate their explanations.

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Introduction

The goal of this research is to understand how to support preschool-age children in science practices through astronomy-based activities in museum settings and to examine the extent to which children take-up science practices in this context. Preschool-age audiences are a key demographic for informal science venues (Reach Advisors, 2010); further, there is increasing evidence for the importance of early educational experiences for children in shaping their future success (IMLS, 2013; Newcombe & Frick, 2010; Schweinhart et al., 2005). Thus, understanding this audience and how to support their engagement with science is critical for the field of informal science education and will have implications for other early childhood educators working towards engaging children in science.

Learning Science in Informal Environments (NRC, 2009) articulates six strands of science learning in informal settings; two of these strands focus on the practices of science in particular. Strand 3 describes learning science as generating scientific evidence, explanations, and arguments. Strand 5 describes learning science as participating in the practices of science, including specialized talk, disciplinary tool use, and use of representations. Prior research on children engaged in science practices has included studies of free-choice interaction with exhibits, often focusing on observing and manipulating variables (NRC, 2009). Rennie and McClafferty (2002) found that the nature of the exhibit design could support or hinder children's ability to engage in investigating its properties and using epistemic behaviors. Studies of parent-child interactions suggest that the explanations parents co-construct with their children are likely to be embedded in the current context and incomplete (Crowley & Jacobs, 2002; Crowley & Galco, 2001; Callanan & Jipson, 2001). However, little research has considered how museum programming supports children's engagement in scientific reasoning or science practices (NRC, 2009).

Further, existing research on early childhood engagement with astronomy has primarily focused on their conceptual understanding, such as what they know about the Earth's shape and why we have day and night (Kallery, 2011; Valanides, Gritsi, Kampeza, & Ravanis, 2000). Missing from the research literature are studies that further our understanding of children's earliest abilities to engage in scientific practices through astronomy contexts. Such science practices may include: asking questions, refining observational skills, interpreting observations, and engaging with scientific models and representations (e.g. Gelman et al., 2010). This study focuses on the range of ways children move towards developing evidence-based explanations about astronomical phenomena as we provide experiences that build on their natural capacity to engage in science practices (NRC, 2012).

Theoretical Framework

The framework used to interpret children's engagement and learning in a museum program draws on Greeno and Engstrom's (2014) situative perspective on learning in activity systems. Activity systems are a level of analysis above the individual learner – in this case a group of children, educators, and sometimes parents in a museum program. The situative perspective draws on multiple theories, also associated with general sociocultural theory, including situated learning (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), distributed cognition (Hutchins & Klausen, 1998), and cultural practices (Rogoff, 2003). Important to this notion of learning is that we make sense of the world through both our perceptions of and our interactions with the environment. Further, conceptual knowledge is embedded in the situations and contexts in which that knowledge was learned and used. The embodied cognition perspective adds further insight into how learning occurs by theorizing the role one's physical body plays (Glenberg, 1997). "Conceptual reasoning originates in physical interaction and becomes internalized as simulated actions…. We use artifacts to extend our perceptual motor and epistemic capacity. In so doing, we internalize physical and mental habits of interacting with the world via the artifacts' mediating structure. When these somatic, manipulatable, or cognitive artifacts fail to deliver desired effects, we consciously reflect on, recalibrate, or modify our models of engaging the world. That is, we learn" (Abrahamson & Lindgren, 2014,p. 362-363).

Finally, I draws on the perspective that engagement with and understanding of science is an emergent process that is generated by those participating together in "doing science" (Siry, Ziegler, & Max, 2012). As such, this implies that young children's engagement with science is "a collective process that draws on resources made available in interaction; which in turn produce further resources" (Siry, 2014, p. 299). This approach to understanding how children engage in science practices further suggests that we consider how their interactions involve more than just verbal language. Prior research on young children engaging in "doing science" has taken a multimodal approach that considers children's discourse and gesture use in the context of first- and second-hand investigations (Siry et al., 2012; Hapgood, Magnusson, & Palinscar, 2004).

This study was guided by the following research question: What characteristics of designed spaces and science-learning programs enable preschool-age children to construct evidence-based explanations during astronomy experiences at a museum setting?

Methods

The setting was a weekly 30-min program for preschool-age children at a small children's science museum. Each week museum educators implemented a different astronomy-themed activity, developed by a team of astronomy educators as part of a larger NSF-funded project on informal science for young children in astronomy. Participants included children ages 1-6 years, though the primary focus of this study were the 3-5 year olds who represented the largest portion of the participants. Participants included regular attendees and those who attended only one or two programs. The lead educator, Caroline[1], has a bachelors and masters degree in biology-related fields. She had several years experience as an informal science educator; however, this was primarily at the elementary through high school level.

Twelve workshops were audio and video recorded for coding. The author and an additional coder began the coding process using a framework analysis approach (Richie & Spencer, 1994) to deductively index the videos using our existing thematic framework. This allowed us to capture relevant segments of each workshop in which children were engaged in one or more science practices. Analysis continued as we refined our thematic framework of science practices based on considering each new case of children's engagement in the astronomy activities. In the process, we worked toward mapping the range and nature of children's engagement in astronomy practices during informal science experiences. Our analysis focused on multiple modes of communication and interaction, including verbal, gesture, and physical engagement with the materials.

The final phase of the analysis was an iterative process of analyzing video segments, guided by the following questions: What sequence of experiences led to children engaging in

[1] Pseudonyms are used for all participants.

evidence-based explanations? To what extent, and using what modalities, did children and educators take-up elements of evidence-based explanation building? This led to more detailed coding to identify instances that highlighted the range within science practices and the connections between science practices. The science as an emergent process framework (Siry et al., 2012) led to both close analysis of individual instances but also consideration of connections that looked across the extent of each workshop for how children and educators made connections and built their understanding of science practices over time.

Findings

Astronomy is often referred to as a descriptive or historical science rather than an experimental one. Thus one of the challenges in engaging young children in hands-on and minds-on investigations in the domain is finding methods that appropriately engage them with astronomical phenomena in ways that are true to the nature of astronomy. The second major challenge is that the phenomena of astronomy are by their very nature, being outside of the Earth itself, physically accessible to children. Further, most astronomical phenomena are not easily viewed during the daytime and during timescales available for a museum program. These challenges shaped the ways in which children had access to opportunities to engage in sense making practices in astronomy education.

Engaging with phenomena

Constructing explanations based on evidence requires opportunities for children to engage with phenomena in ways that would allow them to gather data that could later support claims. Thus, we examined common ways that the children's experience with astronomy was contextualized in these programs that led to making claims based on evidence. Three primary methods of engaging children with phenomena leading towards explanation building were used: direct experience with the phenomena, photographs/video, and models.

Direct experience with the phenomena: One of the methods that engaged children in an astronomical phenomenon, leading to constructing explanations, was through direct experience with the phenomena. As mentioned previously, this is challenging to do with astronomical phenomena. During "Moon Bear's Shadow," children investigated how the changing location of the Sun changes the length and direction of shadows. Understanding shadows is an important starting point for children before learning other astronomical phenomena such as eclipses and lunar phases; in the case of this workshop, children were learning about shadows in order to explore the Sun's apparent motion. During this workshop, Caroline read the children a story about a bear that went fishing but his shadow kept scaring the fish away. Later, she gathered the children around a table where each child had model of a pond, a bear figurine, and a flashlight to represent the Sun. Caroline presented the children with a series of challenge questions that led a group to recreate scenes from the book using their model and in the process, to learn more about how shadows formed.

Caroline: *Can you play with the light to make the bear's shadow longer or shorter?*
Rachel (4 years): *My shadow's smaller*.
Ella (5 years): *Mine's bigger*.
Caroline: *Remember when Bear went to sleep? Where was the Sun?* (Children unsure.)
Caroline: *Was it over here* (gestures to side) *or up here* (gestures above her head)?
Ella and Rachel: *Up* (gesturing with their arms to point over their heads).
Caroline: *So what happens when we put the flashlight up here and it shines down?*
Caroline helped guide the children towards shining the flashlights down like the Sun.

Caroline: *What happened to the shadow*?
Ella: *It's still there*.
Caroline: *Is it long or is it short though*?
Ella: *Short*.
Caroline: *And then it gets longer as you move the light down. Practice that*. (She physically guides some of the 3-year-olds hands to move their flashlights up then down.)
Ella: *Mine got longer* (She moves her flashlight from a high to a low angle as she says this).
Rachel: *It got bigger!* (Said while she is changing the angle of her flashlight.) *See look, there it is* (Rachel points to the shadow she made). *Bigger*.

Throughout their investigation with the flashlights, children made claims regarding shadows size and shape both verbally and through demonstration with their flashlights and models. They observed each others' actions, often mimicking what they saw. They educator also demonstrated and guided children's motions to help them make sense of the phenomena until they could construct their own explanations to the questions she posed.

Photographs and video: Multiple workshops engaged children with astronomical phenomena through the use of photographs and/or video. During a workshop called "Sky Windows," focused on what we see in the day and night skies, Caroline engaged children with the phenomenon by introducing images of the day and the night skies. Caroline began by asking a scientific question, *is this day or night?* The children observed the photographs, noticing features of the photographs based on their prior knowledge of objects in the day and night sky. This led the children to make simple claims (whether it was day or night) and back this up with evidence (what they noticed in the image that led them to make their claim). For example:

Caroline: *Let's talk about some of these skies* (holding up the photographs). *Tell me whether it is day or night. What do you guys think?* [Children: *Day*] *Day? What do you see in it?*
Alan (5 years): *Clouds, and buildings, telephone wires, and lots of trees.*
Caroline: *OK, so what about this one* (holds up a new photo)*?*
Alan: *Night, night, night!*
Rachel (4 years): *No, I see the Sun right there* (points to photograph)*!*
Caroline: *Oh, the Sun.*
Alan: *Oh, it is starting to get night.*
Caroline: *OK, so maybe it's on the cusp of where it's changing.*
Caroline: *What about this one* (new photograph)? *Is this day or night?*
Alan and Susie (3 years): *Day!*
Rachel: *Night! There's the Moon right there* (points to the Moon in the photograph).
Caroline: *Yeah, but look at how blue it is out. So this is actually the daytime.*
Rachel: *There's the Moon, right there* (again, points to the Moon in the photograph).
Caroline: *So sometimes - Alan you remember when you said sometimes you can see the Moon during the daytime? This is one of those times*.

Use of photographs provided children with direct experience with phenomena in a way that models an age-appropriate experience with how astronomers also use photographs to support their investigations. The photographs served to support collaborative exchanges between children and the educator about features they noticed and provided an opportunity to support claims with evidence. Later on in this workshop, the children made their own representations of the day and night sky. Rachel, who previous believed the Moon indicated it was a nighttime sky, put the Moon on her daytime representation.

Models and representations: Caroline also engaged children with astronomical phenomena through the use of scientific models and representations. Though the children used models, they were not used alongside primary evidence to support their explanations; rather, the children used the model to support their own reasoning about a known phenomenon. The "Moon Bear's Shadow" activity is an example of this, as the children were using the image of a scene with a pond, a plastic bear, and a flashlight as a model for a real sunny day. The children used the model to investigate how changes in the Sun's location explain changes the length and direction of shadows outside. Though they may have been able to make connections between the model and their own personal recollections of shadows outside, they were not asked directly to make connections between the two experiences.

In another activity, "Stars Near and Far," the educator engaged the children in exploring how and why the Sun and other stars appear to have different brightness in the sky by exploring their different distances. This exploration relied on children's prior knowledge of the Sun and stars' apparent brightness as presumably all had some first-hand experience observing the stars at night, even briefly. In one part of the activity, Caroline asked the children to first hold and observe two balls, yellow and orange, that were the same size; she asked them to imagine that each ball was a star. She then had one ball taken away and one kept close to the children, asking *Which ball appears larger?* Children indicated that the closer ball appeared larger. Caroline then said, *so maybe when we see those stars and the ones that are smaller, do you think they are closer or farther away than the Sun?* Children: *Farther*. Caroline: *Farther away.* Thus, the model was used to engage the children in reasoning with evidence – their observations of the model – about how celestial objects may appear small because of their distance. The children made a simple claim but this was guided through a series of observations with the model that supported their claim.

Modalities and Support for Constructing Evidence-Based Explanations

Examining those instances within the workshop that led to children constructing explanations also allowed us to analyze the modalities and collaborative nature of children's experiences. Specifically, we focused on a) who instigated the explanation building and b) what modalities did children engage in with their explanations? During the instances we observed, Caroline primarily drove the evidence-based explanation building. Often this was through the use of scientific questions that led children to make specific observations and construct claims based on those observations. For example, during "Moon Sand", children worked in small groups around tubs of sand during a free exploration of the surface of the Moon. The children had the opportunity to both recreate observations of features of the Moon and engage in play within this new environment. Caroline moved from group to group to focus their attention on craters on the Moon; they had previously discussed photographs of the Moon's surface and the children noticed the "bumpies" (craters) on the Moon. To focus their actions on explaining the craters observed in the photographs, she asked *Can you show me [how to make] a crater? What happens if that rock were to go in at an angle? Do you think it would be a different shape?* Later on, children were asked *How do you make a crater?* Children often responded with a combination of actions (demonstrating with a ball or rock) and verbally (e.g. Alan (5 years): *It is a rock that moves around in space and if it hits something it will go into the hole and then it will make a hole*).

Another way the educator guided children's explanations was through the design of the materials and the structure of the workshop. Caroline guided their opportunities to make observations and answer questions with claims by facilitating their engagement purposefully with appropriate content representations (Zembal-Saul, Blumenfeld, & Krajcik, 2000). For example, during Moon Bear's Shadow, Caroline led the children through a scenario in which children explored the relationship between the Sun's location in the sky and a shadow's length through a specific story about this phenomena and specific materials that modeled the actions of the story. During an activity on "Day and Night," Caroline engaged children in using small globes and an overhead lamp to model how one side of the Earth faces the Sun during day and while the other side is dark.

Children used both verbal and non-verbal modalities as they engaged in explanation construction. During "Moon Bear's Shadow," children pointed to shadows and their models as they explained their thinking. During "Day and Night Skies", children pointed to photographs to clarify the objects they were observing to support their claims. During "Moon Sand", children demonstrated their claims about how craters are formed using the materials provided. We considered children to be engaging in evidence-based explanation building when they answered a scientific question with a claim while engaging with the phenomena, such as in the modeling activity with Moon Bear's Shadow. Though they were not always able to verbalize their evidence, their demonstration with the materials revealed their claim as well as their evidence.

Conclusion

This was an exploratory study that begins to address how informal science venues can provide opportunities for preschool-aged children to engage in sense-making practices, specifically constructing explanations based on evidence, during a series of workshops on astronomy at a small children's science museum. Our findings support recommendations of the NSTA position statement for Early Childhood (2014) by showing that children are capable of engaging in scientific practices, demonstrating the important role adults play in helping children learn science, showing that young children develop science skills in informal settings, and pointing to the importance of experiential learning for young children.

Findings point to specific features of these types of museum programs that support young children. First, children needed an opportunity with the phenomenon in order to have an opportunity to gather evidence to make a claim. These workshops utilized first-hand experiences, photographs, and models to engage children with astronomical phenomena. Second, children engaged in making claims based on evidence when an educator engaged them with scientific questions. These questions provided opportunities for children to engage with an adult around scientific ideas while they explored astronomical phenomena mentally and physically. Adults play a central role in supporting young children's engagement in the practices of science (NSTA, 2014). Third, children's engagement in constructing explanations goes beyond just verbal responses to an educator. Instead, we observed children drawing heavily on the affordances offered by materials at hand as well as their own gestures to help them communicate their explanations. Thus, museum educators, curriculum designers, and researchers should consider the role embodiment plays in how children "do science" in museums.

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References

Abrahamson, D. & Lindgren, R. (2014). Embodiment and embodied design. In *Cambridge Handbook of the Learning Sciences,* second edition. New York: Cambridge University Press.
Callanan, M.A., and Jipson, J.L. (2001). Explanatory conversation and young children's developing scientific literacy. In K. Crowley, C.D. Schumm, and T. Okada (Eds.), Designing for science: Implications from everyday, classroom, and professional settings. Mahwah, NJ: Lawrence Erlbaum Associates.
Crowley, K., and Callanan, M.A. (1998). Identifying and supporting shared scientific reasoning in parent-child interactions. Journal of Museum Education, 23, 12-17.
Crowley, K., and Galco, J. (2001). Family conversations and the emergence of scientific literacy. In K. Crowley, C. Schunn, and T. Okada (Eds.), Designing for science: Implications from everyday, classroom, and professional science (pp. 393-413). Mahwah, NJ: Lawrence Erlbaum Associates.
Crowley, K., and Jacobs, M. (2002). Building islands of expertise in everyday family activity. In G. Leinhardt, K. Crowley, and K. Knutson (Eds.), Learning conversations in museums (pp. 333-356). Mahwah, NJ: Lawrence Erlbaum Associates.
Gelman et al. (2010). *Preschool Pathways to Science*. Baltimore, MD: Brookes Publishing.
Greeno, J.G. & Engestrom, Y. (2014). Learning in activity. In *Cambridge Handbook of the Learning Sciences,* second edition. New York: Cambridge University Press.
Hapgood et al. (2004). Teacher, text, and experience. *Journal of the Learning Sciences*, *13*(4), 455-505.
Institute for Museum-Library Services (IMLS). (2013). Growing Young Minds. Report
Kallery, M. (2011). Astronomical concepts and events awareness for young children. *International Journal of Science Education,* 33(3), 341-369.
NRC (2009). *Learning Science in Informal Environments.* National Academy Press, Washington, D.C.
NRC (2012). *A Framework for K-12 Science Education*. National Academy Press, Washington, D.C.
NSTA (2014). NSTA Position Statement: Early Childhood Science Education.
Newcombe, N. S., & Frick, A. (2010). Early education for spatial intelligence. *Mind, Brain, and Education*, *4*(3), 102-111.
Reach Advisors. (2010). Museum Audience Insight Blog. http://reachadvisors.typepad.com/
Richie, J. & Spencer, L. (1994). Qualitative data analysis for applied policy research, p. 173-194.
Schweinhart et al. (2005). *The High/Scope Perry Preschool study through age 40*. Ypsilanti Press.
Siry, C. (2014). Towards multidimensional approaches… *Cult Stud of Sci Ed*, 9, 297-304.
Siry et al. (2012). "Doing science" through discourse‐in‐interaction. *Science Education*, *96*(2), 311-326.
Valanides, N., Gritsi, F., Kampeza, M., & Ravanis, K. (2000). Changing Pre-school Children's Conceptions of the Day/Night Cycle Changer les Conceptions d'Enfants d'Age Prescolaire sur le Phenomene du Cercle'Jour-Nuit'Cambiar las Concepciones de los Ninos Preescolares en el Ciclo Dia/Noche. *International Journal of Early Years Education*, *8*(1), 27-39.
Zembal-Saul et al. (2000). Influence of guided cycles of planning, teaching, and reflection on prospective elementary teachers' science content representations. *Journal of Research in Science Teaching,* 37, 318-339.