# Preschool-Age Children Practicing Science: Intersections of Explanations, Modeling, and Gesture Use

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**Abstract:** Despite the importance reform efforts have placed on engaging students in science practices, limited research has considered the initial steps young children may take with evidence-based explanations and modeling practices. Following a theoretical perspective that science emerges as it is practiced, we analyzed video of astronomy programs for 3-to-5 year old children in a museum setting. Findings suggest that explanations co-constructed by children ranged in sophistication. Children's use of modeling practices supported their development of evidence-based explanations. We also found that children often used gestures to develop and communicate their explanations. Our findings demonstrate the initial ways young children's co-constructed, evidence-based explanations emerge through interactions with educators, peers, and their physical environment.

## Introduction

Young children have been referred to as "scientists-in-waiting" due to their notable capacity for scientific reasoning (Gelman et al., 2010). However, this is capacity may not be fully realized without support to develop their abilities. More research is needed that helps us understand the range of ways preschool-age children are capable of doing science (Siry, Ziegler, & Max, 2012). Prior research examines how young children develop an understanding of evidence (Monteira & Jiménez-Aleixandre, 2016) and how the practice of "doing science" emerges in children's discourse (Siry et al., 2012). Yet, limited research characterizes the ways preschool-age children develop an emergent use of evidence-based explanations or modeling practices. This study helps fill the gap by considering preschool-age children's initial steps, guided by the following question: *How do preschool-age children co-construct science explanations and engage in modeling practices?*

## Theoretical and conceptual frameworks for "Doing Science"

We focus on how children engage in argumentation from evidence towards constructing explanations and developing scientific models. We draw on sociocultural theory to interpret children's engagement and learning as situated in the environment (Brown, Collins, & Duguid, 1989) and developed through the interaction of members of a community (Rogoff, 1994). Our theoretical framework also considers science as an emergent process that is generated by those participating together in "doing science" (Siry et al., 2012). This suggests that young children develop understanding of science through interactions with their community, drawing on resources and producing new resources that further their engagement. This perspective on science learning suggests we consider how children's interactions involve more than just verbal language. Prior research on young children engaged in "doing science" has also taken a multimodal approach, considering children's discourse and gesture use in the context of science investigations (Siry et al., 2012). Further, studies of older students have considered both gestures and model use as critical to understanding how students convey their understanding of science phenomena (e.g. Kastens et al., 2008; Plummer et al., 2016).

We also define a conceptual framework for evidence-based practices of constructing explanations and modeling. McNeill, Berland, and Pelletier (2017) suggest that in order for children to develop evidence-based explanations in science, children's explanation should: a) address a question about a scientific phenomenon, b) provide evidence to support the explanation, and c) provide a how or why account for the occurrence of the phenomenon. In these explanations, children use evidence to support a claim - an answer to the question posed - about a science phenomenon; they use scientific principles to provide a mechanism for how or why the phenomenon occurs (McNeill et al., 2017). As we interpreted the sophistication of young children's explanations, we focused primarily on the degree to which they: 1) relied on the educator's questions about the phenomenon and 2) explicitly included evidence to support their claims. We left open in our coding process whether children would provide mechanistic accounts for the phenomenon, given their age and the complexity of such scientific reasoning. We also consider the extent to which children engaged in two types of modeling practices: 1) when children are *thinking about models,* they develop or revise models based on empirical evidence in order to better explain or predict a phenomenon; 2) when children are *thinking with models*, they use or apply models to help them make sense of a phenomenon they have observed (Passmore, Schwarz, & Mankowski, 2017).

 

## Methods

Using a design-based research approach, we worked with an informal science educator to make iterative improvements in the design and implementation of a set of astronomy programs for preschool-age children. The activities were initially selected based on early field-testing indicating their potential to engage young children in evidence-based astronomy explanations. We also selected activities that engaged children with astronomical phenomena through a range of different methods (models, photographs, and directly with phenomena). The four selected activities engaged children in investigating the shadows cast by the Sun, craters on the Moon, surface features of Mars, and the pattern of lunar phases. Each activity was implemented three times by the same early childhood educator, Nora (pseudonym), at a small children's science museum. The number of children in each workshop ranged from 4 to 25 (average = 12, SD = 5). Children were between 3 to 5 years old. Nora has been educating preschool-age children in formal settings for 40 years and at this museum for 2 years.

Each workshop was video recorded with two cameras to record multiple angles and/or multiple groups of children. Our coding process began using an analytic framework for science practices, developed using literature articulating science practices frameworks (e.g., McNeill et al., 2017; Passmore et al., 2017) and our own ongoing program of research on preschool-aged children's engagement in science practices in informal settings. We also defined gestures using existing classification schemes: *spatial pointing gestures* convey location and direction while *iconic gestures* indicate relationships between objects or spatial information (Alibali & Nathan, 2012; Plummer et al., 2016). One author coded each program to identify instances using these frameworks. The other author reviewed these instances followed by discussion leading to revision in the coding of each workshop timeline. Both authors reviewed all coding to correct for drift in code-use fidelity over time. We looked across the selection of evidence-based explanation codes and modeling codes to look for patterns in the ways children took-up these evidence-based practices through their experiences in this informal setting. And we analyzed how gesture use intersected with our interpretation of their use of these science practices.

## Findings

Patterns in the coding led us to three claims, relating to explanations, modeling, and gesture use, describing preschool-age children's emergent evidence-based practices. Each of these claims emerged through analysis across multiple workshops; we present exemplar episodes from *Creating Craters* and *Moon Phase Matching* to illustrate preschool-age children's emergent practices of "doing science" in museum-based programming.

- Claim 1: Children's emergent explanations varied in levels of sophistication depending on the degree of use of evidence and degree of support of educator.
- Claim 2: Children engaged in two types of emergent modeling practices: *thinking about models* and *thinking with models*.
- Claim 3: Children's emergent explanations and modeling practices were often dependent on their use of pointing gestures and/or iconic gestures as they developed and communicated those practices.

The *Creating Craters* workshop began with children discussing observations of lunar craters on a large banner. This was followed by an investigation of how craters are formed. Children worked in small groups to gather data on how craters are made using a model of the Moon's surface (a tub of sand) and impactors or asteroids (balls of different sizes/masses). Afterwards, children then drew representations of how craters are formed. In this segment, Nathan (5 years) explains his representation to Nora:

> Nathan: (Unintelligible) splashes. [*Gestures along his drawing showing "splashes" of sand.*]
>
> Nora: Splashes. How did the splashes get there?
>
> Nathan: I was standing [*Nathan passes the paper to Nora, and extends one hand above his head*] and I threw it down at it [*gestures in a quick, throwing motion down towards the ground*] and it knocked all the sand [*gestures out and away from himself*] went flying - [*gestures towards where he did his investigation*] it made splashes [*gestures back from to the drawing*]. And it got all over the teacher.
>
> Nora: It came down at great speed and it made a lot of splashes. What kind of crater did it make?
>
> Nathan: It made a really deep one. [*Gestures a circle around his crater drawing.*] All the way to the bottom. [*Starts with both hands above his head, then shoves them down on the word "bottom."*]
>
> Nora: All the way to the bottom of the bin. So what kind of impactor did you use?
>
> Nathan: A metal one.

Nathan generates his explanation with only a few prompting questions from Nora. His claim begins as he combines his drawing with verbal descriptions of descriptions of "splashes." Nathan's then uses pointing gestures to link the place where he conducted his investigation to his crater drawing, thus linking his evidence to his claim. He continued to use evidence - his investigation making craters - as he re-enacts, through iconic gestures, how he made a deep crater by throwing the projectile quickly. This allowed him to further develop his claim about how he made a deep crater with "splashes." It was Nathan's iconic gesture, and not his words, which indicated to Nora that the ball moved quickly - a concept she verbally stated after observing his gesture.

Nathan's development of a representation (his drawing of the crater) was an example of *thinking about models*, as it is based on the evidence he gathered through his investigation of variations in testing impactors made a difference in the size of craters. This is indicated though his description of how his representation shows the creation of "splashes" (the scientific term is *ejecta*) and the way he gestured to connect the physical location where he conducted his investigation with the paper showing his representation.

In the *Moon Phase Matching* workshop, children listened to "Papa Bring Me the Moon," then matched photos of the phases to a banner showing the lunar phases, constructing a representation of the Moon's cycle from Full to New then back to Full again. Nora led a discussion of the pattern after children organized the phases:

> Nora: The Moon looks big and round and then, just like in the story, it seems to get… [*Nora points to phases on the banner showing the part of the pattern she is indicating*.]
>
> Children: Smaller.
>
> Nora: Smaller.
>
> Children: Smaller, smaller, smaller -
>
> Nora: Until it seems to - [*Points to New Moon*.]
>
> Mae (4 years): Disappear! Another child: New!
>
> Nora: Disappear. And then back up in the sky its [*points along the phases*] it seems to get -
>
> Mae: Crescent. / Another child & Nora: Bigger.
>
> Children: Bigger, bigger, bigger - [*Nora points at phases leading up towards Full.*]
>
> Nora: Until it is a - (Children: Full) a full Moon again. [*Pointing at Full.*]

This is a less sophisticated example of children co-constructing an explanation than the previous episode as it is highly guided by the educator, and all of the evidence is "in-the-moment." In other words, children draw on evidence for their claim about the pattern of the lunar phases implicitly from the banner as they describe it getting smaller and bigger. This initial claim about the pattern was built on later in the workshop as children observed the Moon in a computer simulation and considered how it changes day after day. They used the evidence from the banner's representation to co-construct a new claim:

> Nora: We noticed the moon is getting bigger so we must be heading towards the -
>
> Children: Full moon.
>
> Nora: Then after full moon we'll head back and it will start to get -
>
> Mae: Smaller, smaller to new moon!

Here, the children are *thinking with models*; they have used a representation they developed by matching Moon phase photos to a banner showing the cycle of lunar phases, to support the construction of their claim. The representation supports the children in making sense of how, but not why, the pattern of phases occurs. The use of a representation, rather than a causal model, allowed children to co-construct an emergent explanation (one that lacked scientific reasoning).

In the previous segment, children did not use gestures while co-constructing explanations, but they were guided by Nora's gestures. Her use of pointing gestures supported their analysis of the representation. In other *Moon Phase Matching* workshops, we observed children using gestures to support their construction of explanations. This segment picks up after Nora responds to Nathan's idea about the Moon's appearance:

> Nora: … made it appear smaller, smaller, disappear [*pointing at New moon on the Moon phase banner*].
>
> Bryce (4 years): Smaller, smaller, smaller! [*He places his fingers as if holding something very small.*]
>
> Nora: And then appear, what does it appear to do? [*Nora is pointing, just beyond the New moon*.]

Bryce: And then it turns smaller, and smaller, like this [*shrinks his fingers down so that they are pinched together*] and then it disappears full up this place [*holds his hands above his head*].

Nora: OK, it's disappeared, and then what happens?

Nathan: It reappears [*uses both hands to open out in an expansive gesture*].

Both Bryce and Nathan use gestures to indicate how changing size is important their claims about the Moon.

## Conclusions and implications

Our findings suggest that preschool-age children have the capacity to engage with evidence-based practices as a form of "doing science," consistent with a trajectory towards more sophisticated use of these epistemic forms. Our analysis indicates that young children, with the support of their peers and educators, can engage in emergent forms of scientific explanations. Their simple claims were often guided by the educator, and the evidence was used either implicitly, such as making claims based on recent observations without verbal description, or they drew on data that they were currently observing, as indicated through verbal or gestured cues. Our findings extend research on how young learners begin to take up science practices as a way to understand their world through interactions with peers and the physical environment (Monteira & Jiménez-Alexandre, 2016; Siry et al., 2012).

Modeling practices and gesture use served as support for children as they co-constructed evidence-based explanations for astronomical phenomena. Children's use of modeling practices, both thinking with and thinking about models, was central to their engagement with evidence-based explanations. Models (and representations) provided opportunities for children to either refine their understanding of their evidence or produce evidence for their claims. Children used models to generate data and observe patterns which provided evidence for co-constructing claims, such as the representation used in *Moon Phase Matching*. Children also used evidence gathered from their own investigations to generate representations used to construct explanations for phenomena, such as during *Creating Craters*. Thus, children used models both as tools for thinking and tools for generating data (Passmore et al., 2017). Attending to children's gesture use was critical to understanding how they co-constructed explanations and engaged in modeling practices. Children used pointing gestures to attach evidence from their own personal investigations to claims and used iconic gestures to represent concepts central to their explanations. Gestures allowed children to go beyond what they might otherwise be able to express verbally, externalizing aspects of their developing knowledge (Alibali & Nathan, 2012).

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