Young Children's Ideas About Astronomy

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ABSTRACT

Young children express interest and understanding about science topics through everyday conversations with parents. Little is known about how much interest preschool-aged children show in astronomy. Using a diary report methodology, we asked parents in three communities in coastal California to keep track of conversations with their three to five-year-old children about nature. The communities varied in demographics, including one community with predominantly European-American families, one community with predominantly Latinx families, and one community with families from a variety of backgrounds. Overall, young children showed interest in astronomy through initiation and engagement in conversations about a variety of astronomical objects and events; this was consistent across gender, age, and community. Across all three communities, conversations about astronomy accounted for approximately 15% of the conversations about nature, ranking in the top three most frequent topics for each group. Children initiated the vast majority of conversations with their parents, including those about astronomy. Within astronomy, children were most interested in the sun, moon, stars, and day or night sky. Thus, while science educators may see astronomy as too complex for young children, children observe and comment on astronomical phenomena as part of their everyday life. Finding ways to support educators and parents in talking with children about these observations may productively build on this early astronomy interest and position children for greater understanding and engagement in this domain.

Keywords: Astronomy Interest; Parent-Child Conversation; Preschool Children; Science Education

O ver the past several decades, research in cognitive developmental psychology and in informal science learning demonstrates that preschool-aged children seek knowledge and express interest in a variety of science-related topics, including animals and other natural entities (Callanan & Oakes, 1992; Jipson, Labotka, Callanan & Gelman, 2018; Kelemen, Callanan, Casler & Perez-Granados, 2005; LoBue, Bloom Pickard, Sherman, Axford & DeLoache, 2013; Rigney & Callanan, 2011), as well as human-designed artifacts (Callanan & Oakes, 1992; Jipson & Gelman, 2007; Kelemen, et al. 2005). Further, not only are young children curious about science-related topics, but they also engage in aspects of causal and inferential reasoning that are fundamental for science learning (Cook, Goodman & Schulz, 2011; Legare, Gelman & Wellman, 2010; Schulz & Bonawitz, 2007). Taken together, these bodies of work suggest that efforts to engage children in science learning should begin before they enter formal school settings. Explorations of science at the preschool level have become more common in recent years, the focus is often on topics of interest to children, such as animals, and activities that can be explored interactively, such as object motion (Gelman, Brenneman, Macdonald & Roman, 2010). Educators often seem to assume that young children may be incapable of learning about science topics related to domains that are less open to hands-on discovery.

Assumptions about what science topics young children are capable of learning are rapidly shifting in light of new research evidence. Kelemen, Emmons, Seston Schillaci, and Ganea (2014), for example, demonstrated impressive learning about the mechanism of natural selection in children as young as five years using a storybook intervention (see Evans, Weiss, Lane & Palmquist, 2016). In another example, Ravanis, Christidou, and Hatzinikita (2013) successfully used metaphors about travel to advance preschool children's conceptual understanding of light, a topic that prior work demonstrates is difficult for children at this age (and older ages) to understand. Similarly, Ergazaki, Saltapida, and Zogza (2010) found that infusing activities about germs into the curriculum of a preschool classroom helped children reason in more sophisticated ways about these invisible-to-the-naked-eye biological agents.

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In addition to studies of children's learning of science content, other research shows impressive early learning of science practices within a variety of domains. For example, Lehrer and Schauble (2015) argue that with appropriate supports and experience, young elementary school-aged children can effectively engage in the complex science practice of modeling within knowledge-rich domains. In two different studies, first graders engaged in modeling that quickly moved from literal copies to more powerful and abstract representations – in one case modeling their own elbow (Penner, Giles, Lehrer & Schauble, 1997), and in the other case modeling outdoor decomposition of pumpkins by building compost columns in their classroom (Lehrer, Carpenter, Schauble & Putz, 2000). These illustrations show that making assumptions about young children's capability to understand and reason about scientific domains could result in underestimation and missed opportunities.

With regard to astronomy specifically, research in science education has shown that even for older children and adults some concepts can be quite challenging (Plummer, 2009; Vosniadou & Brewer, 1992). For example, in the classic documentary, *A Private Universe*, interviews with Harvard graduates revealed that they were not able to accurately explain what causes the phases of the moon (Schneps, 1989); empirical work supports claims that astronomy misconceptions are common even at the college level (e.g., Bailey, Prather, Johnson & Slater, 2009; Sadler et al. 2010). Considering this and other demonstrations of how challenging it can be to construct scientifically accurate astronomical understandings; one might argue that astronomical science is beyond the everyday experience of young children and too difficult for them to understand.

Reflecting assumptions about the difficulty of astronomy concepts, in the past, astronomy education was considered to be a topic to be explored in later elementary school and beyond. More recently, however, in the Next Generation Science Standards (NGSS), astronomy is first introduced as a topic in first grade. Notably, none of the five NGSS Earth and Space Science modules for kindergarten are about astronomy. Examination of children's interest in astronomy, even before they enter school, will provide information critical to determining when and how to initiate astronomy-related educational efforts with young learners.

Despite the complex nature of astronomical science, some astronomical entities and events are observable during the routines of everyday life, making astronomy a topic that could potentially compel children's interest, and about which children may be generating intuitive beliefs. For example, changes in the appearance and location of the sun, moon, and stars are part of the familiar everyday experience of children all around the world (Callanan & Oakes, 1992; Kelemen, Callanan, Casler, & Perez-Granados, 2005; Plummer, 2009; Valanides, Gristi, Kampeza & Ravanis, 2000). Recent research has shown that children do indeed construct intuitive theories about aspects of astronomy, and that these beliefs can be built upon to help children move toward more accurate understandings. For example, Plummer (2009) found that six to seven-year-old children were aware of the Sun's apparent motion but described it as straight up-and-down motion rather than movement across the sky. Using a simple intervention involving hand gestures in a planetarium setting, Plummer (2009) found significant improvement in children's correct descriptions of the sun's apparent movement. Plummer's (2009) work reveals not only that young children construct understandings of astronomical phenomena, but that they also can be supported to transform these initial ideas in ways that align more closely with scientific understandings. Thus, although the causal forces that underlie many astronomical events may be too complex for young children to understand, prior work suggests that children make observations of the sky. With better understanding of children's astronomical observations, we can inform the development of science curricula that build on their curiosity and promote sustained engagement with astronomy as they get older and more capable of constructing robust causal understandings (Hidi & Renninger, 2006 Alexander, Johnson & Kelley, 2012). Gauging the extent and content of young children's astronomy-related interests is an important step towards informing science education efforts. Such work may be particularly valuable in helping educators know when to introduce astronomy-related topics.

One approach to learning more about young children's science interests is to explore the topics they talk about within the context of family interactions. Conversations between children and parents, especially spontaneous conversations, can provide a rich context for gauging young children's early interests as well as their families' habits of talking about particular kinds of topics (Callanan & Jipson, 2001; Callanan & Valle, 2008; Haden, 2010). Research investigating parent-child conversations has shown that families vary in the topics they talk about (Callanan & Oakes, 1992; Kelemen et al. 2005), and in their tendency to elaborate on science topics (Crowley, Callanan, Tenenbaum & Allen,

2001; Haden, 2010; Jant, Haden, Uttal & Babcock, 2014; Jipson & Callanan, 2003), and to treat science topics as factual and fixed versus open to revision depending on evidence (Luce, Callanan & Smilovic, 2013; Valle, 2009). Families also vary in the styles of interaction they engage in, ranging from more parent-directed to more child-directed (Fung & Callanan, 2019; Medina & Sobel, 2019), and in the extent to which parents use different types of questions or statements in their talk to children (Ochs, 1988; Rogoff, 2003; Yu, Bonawitz & Shafto, 2019).

Research focused on children from non-dominant communities has shown variations in the ways that science-related topics are discussed within families. For example, Solis and Callanan (2016) studied Mexican-heritage parents from varied schooling experience engaging with their children in a sink-or-float game. Mexican-heritage parents with basic schooling experience were more likely to engage directly with unexpected evidence than were the parents with more extensive schooling. In another example, Marin and Bang (2018) studied Native American families on forest walks and characterized their use of knowledge-building practices that are grounded in Indigenous epistemologies: walking land, reading land, and storying land. Considering family conversations in different communities can provide valuable information about children's interest and engagement with science topics, as well as reveal variation in how they engage in talk and action around these topics.

One challenge in documenting children's early interest in science topics such as astronomy is to find settings in which such interests are expressed. Diary studies are a methodological technique by which parents keep track of conversations with their children over a period of a few weeks; this can provide researchers with data about children's articulation of their interest in particular topics (Callanan & Oakes, 1992). While this method relies on parents' reports of family conversations, which introduces potential bias, it is extremely valuable as an exploratory tool because it provides a solution to the challenge of being in the right place at the right time to observe spontaneous conversation.

In the present study, we asked parents of three to five-year-old children to keep track of "conversations about nature" for two weeks to allow us to gain insight into children's interest in astronomy topics, along with their interest in other nature-related topics. We investigated four simple questions. First, how often do three to five-year-old children spontaneously talk about astronomy in their everyday conversations with parents? Second, what are the specific types of astronomy topics that children discuss with their parents? Third, are conversations about astronomy primarily initiated by children or do parents take the lead in starting conversations about astronomy? Finally, is there evidence of variation in children's interest in astronomy, or in particular astronomy-related topics, depending on child gender and/or family background? To address these questions, we invited families from three communities to keep track of their conversations about nature with their children for two weeks. We compared diary reports across three groups of families in coastal California, including (A) a community of mostly European-American families with extensive formal schooling , (B) a community of Latinx families - most of whom immigrated from Mexico and had basic formal schooling experience, (C) and a more ethnically diverse community, with a majority of European-American families with extensive formal schooling. Considering the topics of these parent-child conversations from families of different backgrounds, both overall and within astronomy, allowed us to better understand the diversity and similarity in conversations across quite different families.

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METHOD

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Participants

Sixty-eight families participated in this study. Each family had a child between three and five years of age (M_{age} =53 months). Researchers recruited families from child care centers, parks, libraries and churches in three communities from coastal areas of California. In the first community, which we will refer to as Community A, we recruited 33 families with a child between three and five years (M_{age}=52 months, 19 girls). Self-reported ethnicity was 85% European-American or White (N=28), and 15% Mixed Ethnicity (N=5). Parents' average years of formal schooling was 16 years. In the second community, Community B, we recruited 16 families (M_{age}=56 months, six girls), 100% of whom self-identified as Latinx or Hispanic (N=16). Parents' average years of formal schooling in Community B was 8.5 years. Finally, in Community C, we recruited 19 families (M_{age}=53 months, 12 girls), whose self-reported ethnicity was 47% European-American or White (N=9), 26% Latinx or Hispanic (N=5), 10% African-American (N=2), and 16% mixed ethnicity (N=3). In Community C the average years of parental formal schooling was 15.5

years. An additional seven families, three from Community C and four from Community B, engaged in initial activities of the study but did not complete their participation in the diary study and, thus, are not considered in our analyses.

Materials and Procedure

Researchers invited families to participate in an initial session either in their home or in a lab on a university campus. Sixty-one families were interviewed in their homes, 7 families chose to come to a lab to participate. After learning about the study and providing informed consent, parents and children read two picture books together: *The Sun is My Favorite Star* by Frank Asch, a picture book about a child's interest in the sun, and *Wave* by Suzy Lee, a wordless picture book about a girl visiting the ocean. These books were chosen because they focused on children's interactions with the natural world, which was the main focus of the broader research project. Parents were then invited to document their "conversations about nature" with their child for the next two weeks. Researchers provided each family with a three-ring binder containing multiple copies of journal pages that prompted families to write down: (1) What idea or question about nature did your child talk about? (2) Who started this conversation? (3) How did this conversation start? (4) What was your family doing when this conversation started? (5) Is this a topic your child is often interested in discussing? and (6) Please describe as much as you can remember about this conversation, use direct quotes if possible. During the course of the two weeks, researchers periodically (approximately every three days) called families to ask whether they had any questions about the study, to provide opportunities for them to verbally share conversation details (which researchers then transcribed), and to encourage them to stay engaged in recording their nature conversations. After two weeks, researchers visited family homes to collect the journals and gave families a small gift (either a children's book or a gift card) to thank them for their participation. All materials were provided in both English and Spanish, and a native bilingual Spanish-English speaking researcher interacted with families who preferred to use Spanish. Nineteen families (14 in Community B and five in Community C) primarily spoke Spanish with their children and chose to submit the journal reports in Spanish; all remaining families submitted their journal reports in English. Native bilingual Spanish-English researchers translated the conversations that were completed in Spanish and a different native bilingual Spanish-English speaker checked the translation. Any disagreements between the two translators were discussed and resolved.

Coding

Topic coding. Researchers coded each conversation for the nature topics families reported discussing. The categories of topics were derived after examining a subset of the reported conversations in order to cover the range of topics discussed; the 9 topic categories are listed alphabetically in Table 1. Many conversations included the discussion of several topics. Thus, coders could code each conversation as containing more than one topic (e.g., a conversation report about an oil field and dinosaurs was coded as both animals and geology). To achieve interrater reliability, three researchers coded the same 20% of the total number of submitted conversation reports. All of the coders were native English speakers. In the case of the conversations that were in Spanish, the English-speaking coders coded the translated conversations. Agreement on topic reliability between each pair of coders exceeded 83% agreement and all Cohen's kappas exceeded .80, which is considered strong agreement (McHugh, 2012). Coders resolved disagreements on the reliability sample and proceeded to each independently code one-third of the remainder of the sample of journal reports.

Table 1. Coding Topics of Conversations about Nature

Topic	Examples
Animals	Conversations about dogs, bugs, dinosaurs, sharks
Astronomy	Conversations about moon, sun, stars, planets (including Earth as a planet)
Geology	Conversations about rocks, sand, other aspects of Earth's surface
Human Body	Conversations about human illness, injury, health
Physics	Conversations about other physics concepts such as gravity, energy conservation
Plants	Conversations about trees, flowers, vegetables
Psychology	Conversations about human mental or emotional states
Water	Conversations about natural bodies of water, such as oceans, tides, rivers, lakes, creeks (but not rain)
Weather	Conversations about rain, wind, fog, seasons
Other	Conversations about "Mother Nature" or about "things in nature" or other nature-related topics that do not fit any topic above

Astronomy sub-topic coding. For conversations that were astronomy-related, two native English speakers further coded these conversations into 9 sub-topics: sun, moon, stars, planets, earth, space travel, day/night, solar system. The two coders reached 88% agreement (Cohen's kappa=.85).

Initiation coding. In addition to identifying the topics of conversation, researchers coded each diary report for how the conversation began. Coding identified who initiated the conversation (parent, child, someone else in the setting), and whether the conversation began with a question (e.g., "Why do trees lose their leaves?") or a statement (e.g., "The wind makes the clouds move."). Two bilingual coders coded 20% of the total submitted conversations from Communities B and C, in either English or Spanish as appropriate. Their agreement was 84%, with a kappa of .77. Two native English speakers coded 20% of the total submitted conversations for Community A. Reliability was 88%, with a kappa of .74. In each case, the reliable coders then each coded half of the remaining conversations.

RESULTS

Our main research questions asked how often three to five-year-old children talked about astronomy with their parents during everyday activity, and what subtopics of astronomy they discussed. We also asked about who initiated the conversations. Throughout, we investigated whether our findings varied across diverse communities or across gender.

As background, we first considered the amount of nature-related talk that families reported. Across our communities, families submitted an average of 9 conversation reports (range=1-29). Each conversation report could include multiple topics; we coded an average of 11 nature-related topics per family (range=1-36). Within the three communities the mean number of conversation reports were respectively: Community A (M=11.15, SD=6.12), Community B (M=7.69, SD=3.86), and Community C (M=7.5, SD=3.48). The number of topics coded across communities were respectively: Community A (M=13, SD=7.4), Community B (M=8.5, SD=4.47), Community C (M=9.7, SD=4.5). Because there were often multiple topics within conversations, and families varied in the number of conversations reported, in our analyses we focus on proportion of topics coded.

How Often Did Young Children Talk About Astronomy?

We examined how often families reported talking about astronomy relative to other nature-related topics. We explored patterns in these nature-related conversations using a 9 (Topic: animals, astronomy, geology, human body, physics, plants, psychology, water, weather) x2 (Gender: boys, girls) x3 (Community: A, B, and C) mixed analysis of covariance (ANCOVA) with children's age in months as a covariate. To avoid violating the assumption of independence, we eliminated the tenth "Other" topic from the analysis. Gender and community were included in the model as between-subject variables and conversation topic was a repeated measure. The ANCOVA yielded no significant main effects for topic, gender, or community, and no significant effect of age. We did, however find a significant topic x community interaction, $F(16, 61)=2.02$, $p=.038$, $\eta^2 = .062$. Table 2 shows the relevant means and standard deviations.

Table 2. Mean Proportions (and Standard Deviations) of Coded Topics for Nature-related Conversations Across Three Communities

	Community A (Mostly European-American families, higher schooling)	Community B (Latinx families, mostly basic Schooling)	Community C (More diverse ethnic background, higher schooling)	Total Proportion
Animals	**.36** **(.19)**	**.30** **(.21)**	**.21** **(.17)**	**.29** **(.20)**
Astronomy	**.14** **(.13)**	**.19** **(.13)**	**.14** **(.13)**	**.16** **(.13)**
Geology	.06 (.08)	.06 (.09)	.03 (.08)	.05 (.08)
Human Body	.06 (.09)	.02 (.06)	.11 (.11)	.06 (.09)
Physics	.05 (.09)	.03 (.08)	.06 (.11)	.05 (.09)
Plants	**.15** **(.12)**	**.18** **(.18)**	**.22** **(.14)**	**.19** **(.14)**
Psychology	.004 (.02)	.03 (.06)	.01 (.03)	.02 (.04)
Natural Water	.04 (.06)	.003 (.02)	.07 (.09)	.04 (.06)
Weather	.11 (.11)	.17 (.25)	.12 (.11)	.13 (.15)
Other	.02 (.05)	.004 (.01)	.02 (.05)	.01 (.04)

Note: Bolded values reflect the top three highest means within each community and total overall

To further explore how topics varied by community, we conducted multiple pairwise comparisons, looking at differences across topics within our three communities. Following standard adjustments for multiple pairwise comparisons, we divided the conventional *p*-value of .05 by 108 (total number of comparisons). Using a new alpha level of *p*=.0005 as the criterion for significance, pairwise comparisons revealed several differences in the proportion of topics discussed within the three communities. Most importantly for our research questions, conversations about astronomy were among the top three highest proportions of topics in each community, as shown in Table 2.

Within Community A, a higher mean proportion of conversations included animal topics (*M*=.36) than any other topic (*p*=.0004); the two topics with the next highest mean proportions were plants (*M*=.15) and astronomy (*M*=.14), which did not significantly differ from each other (*p*=.002). Families discussed astronomy at significantly higher rates than they did natural water or psychology (both *p*<.0005). The proportion of astronomy topics was not significantly different from the proportion of conversations about plants, geology, weather, human body, or physics (all *p*>.002).

For Community B, the mean proportion of conversations about animals was again highest (*M* = .30), followed by astronomy (*M*=.19), and then plants (*M*=.18). In this community, however, conversations about animals, astronomy, and plants were not significantly different from one another. Astronomy conversation topics were discussed significantly more than natural water, human body, and psychology conversations (all *p*<.0005). Astronomy conversation topics did not differ in proportion from physics, weather, or geology conversations (all *p*>.0005).

For Community C, the mean proportion of conversational topics were plants (*M*=.22) and animals (*M*=.21). Astronomy conversations ranked third in the list (*M*=.14), and they were not significantly different from the proportion of topics about plants or animals. Astronomy conversations were proportionally higher than conversations about psychology (*p*<.0001). There were no significant differences in the proportion of topics about astronomy compared to the proportion of topics about plants, animals, the human body, natural water, geology, weather, or physics (all *p*>.0005).

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Overall, then, astronomy conversations occurred in each community, and while it was not the most discussed topic, astronomy was among the top three highest mean proportion of categories discussed.

What Astronomy Topics Were Discussed?

Because our research questions also focused on which aspects of astronomy children discussed with their families, we next investigated conversations with astronomy topics to see whether the astronomy subtopics varied across age, gender or community. Table 3 shows the mean proportions of astronomy topics coded into each subtopics category. For our analyses we chose to focus on astronomy subtopics with the four highest mean proportions. The mean proportion of astronomy conversation topics about the sun was highest ($M = .36$), followed by the mean proportion of topics about the day or night sky ($M=.20$), the stars ($M=.16$), and the moon ($M=.12$).

Focusing on the four most discussed astronomy subtopics, we conducted a 4 (Astronomy Subtopics: Sun, Moon, Stars, Day/Night) x2 (Gender: Boys, Girls) x3 (Community: A, B, and C) mixed ANCOVA covarying the age of the child in months. The proportion of each astronomy subtopic was the dependent measure. Gender and community were between-subjects factors, and astronomy subtopic was a repeated measure. The ANCOVA revealed a significant two-way interaction between topic and gender, $F(3, 129)=3.23$, $p=.025$, $\eta^2 = .07$), but no significant main effects or other interaction effects. Figure 1 presents the mean proportions by gender for the four sub-topics. To more closely investigate the significant interaction, we conducted pairwise comparisons examining differences in the mean proportions of astronomy subtopic codes by gender. The pairwise comparisons revealed a difference between boys and girls in mean proportion of talk about the sun, at $p=.017$; for boys .51 ($SD=.41$) of astronomy topics included the sun, whereas the mean for girls was .27 ($SD=.23$). To correct for the number of pairwise comparisons, however, our new criterion value was $p=.006$ (corrected $p = .05/8$). Thus, although the interaction was significant overall, this gender difference must be interpreted with caution.

**Table 3.** Mean Proportions (and Standard Deviations) of Astronomy Codes Containing Sub-topics

Sub-topic	Proportion
Sun	.36 (.33)
Moon	.12 (.20)
Stars	.16 (.24)
Planets	.04 (.12)
Earth	.10 (.18)
Space travel	.01 (.04)
Day and/or night sky	.20 (.26)
Solar system	.01 (.05)

One might wonder whether the high mean proportion of conversations about the sun might have been inflated because the families read a book about the sun in their initial visit. To investigate this possibility, we considered how many of the astronomy conversations referenced the book (*The Sun is My Favorite Star*). We found only two parent-reports that made direct reference to the book, and in only one of these did the parent explicitly mention the book to the child. One parent said that they discussed the book but gave no further details. The other parent commented in her journal that she asked her child if we can see any stars when it's not nighttime. She indicated to us that she was checking to see if her child remembered the book, but she did not seem to mention the book to her child. The small number of

explicit references to the book does not support the idea that families were heavily influenced by the book, however whether there may have been subtle influences is an open question.

Figure 1. Mean Proportion (And Standard Error) of Subtopics in Astronomy Conversations for Boys and Girls
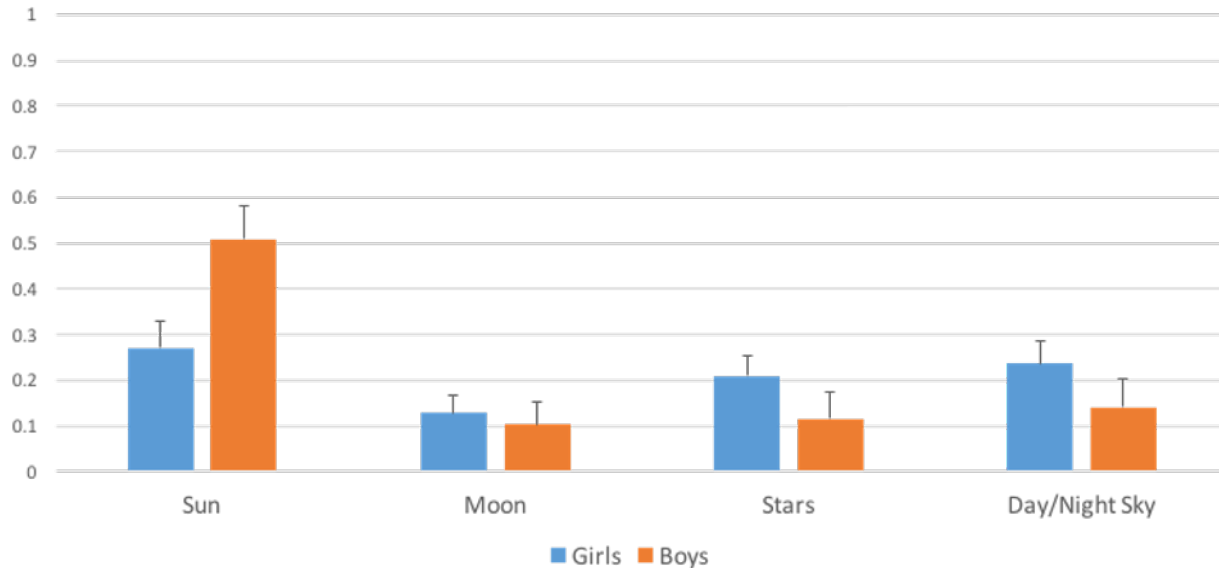
How Were Conversations Initiated?

We next asked about who initiated the conversations, first considering the entire set of conversations, and then focusing in on the astronomy conversations. Overall, children initiated an average of 75% of the conversations that parents reported to us. They were as likely to initiate conversations with questions as with statements. Approximately half of the child-initiated conversations began with questions (38% of the total conversations) and half with statements (37% of the total conversations).

The percentage of total child-initiated conversations was 73% in Community A, 81% in Community B, and 74% in Community C. To investigate possible differences based on children's age, gender, and community we conducted a 2 (gender) x3 (community) x2 (initiation type: question, statement) ANCOVA on percentage of child-initiated conversations, with initiation type (question vs statement) as a repeated measure, and children's age as a covariate. There were no significant main effects or interactions.

Next, considering only the astronomy conversations, we found that the average percentage of astronomy conversations that children initiated was again 75% (Community A: 79%, B: 71%, C: 73%), roughly evenly split between question and statement initiations. This was comparable to children's initiations for other topic categories, for example, children initiated 74% of animal conversations. Again, the ANCOVA for child-initiated astronomy conversations showed no significant effects of age, gender, community, or type of initiation (question versus statement).

Descriptive Examples of Child-Initiated Astronomy Conversations

Because these child-initiated conversations give us a window into children's thinking about astronomy, we elaborate here on a few examples. Children initiated some astronomy conversations with simple questions, such as "Why is the sun following us?" (asked by a four-year-old girl in Community C), "Why is the moon full?" (asked by a four-year-old girl from Community B), or "Why does it get dark at night?" (asked by a three-year-old girl in Community A). Other conversations began with statements, such as "It's almost a full moon" (stated by a three-year-old boy in

Community A). Some of the questions and statements were more unusual, and even sometimes profound. For example, a four-year-old girl from Community A asked, "What if the whole earth is in a deep, dark abyss?" a five-year-old boy from Community C asked "Why are the planets round instead of square?" and a five-year-old girl from Community B noticed the sun setting and told her mother that the sun was going to leave "so that it could shine other parts of the world and that's why the night is coming."

Even simple questions or statements sometimes led to conversations where children might begin to engage with important ideas about astronomy or about how astronomy relates to other topics. One example is when a three-year-old boy from Community B pointed to the stars and told his aunt, "Look, the stars." The aunt responded that the stars were shining, and the child asked, "And why do the stars shine?" His aunt answered, "because they have energy, they are very strong!" In another example, a five-year-old girl from Community B asked, "Why is there no sun when it rains?" which led to a conversation about how weather phenomena such as clouds interfere with our ability to perceive objects in the distant sky. In some conversations, children pondered unexpected observations, such as noticing the moon during the day in this example from a four-year-old girl in Community C:

Child: "What is that circle in the sky? That's not the sun."

Mother: "It's the moon"

Child: "But it's not nighttime?"

Mother: "The moon rises early, sometimes you can see it before it is dark."

Child: "Naughty moon, it needs more sleep, the sun is going to be mad at him."

This example also highlights how children in this age group often engage with fantasy at the same time that they reason about scientific information. This is a common phenomenon in young children's thinking. In another example, a four year old from Community B asked, "why does the moon not like the sun if they live in the same universe?" and the mother reports that she later proclaimed that "The moon fell in love with the sun and from their love the stars were born." These cases are intriguing because children seem to be making sophisticated observations about astronomical entities, yet interpret causality based on more familiar mechanisms. Whether they are playfully using these explanations as placeholders for phenomena they cannot yet explain, or earnestly engaging psychological interpretations to explain astronomy-related observations is an important direction for further research.

DISCUSSION

This study demonstrates that young children express interest in astronomical phenomena at a very young age, and that everyday conversations with family members may be a fruitful setting within which children begin to explore these interests. Our data emphasize that even by the age of three years, children were initiating conversations wherein they inquired or commented about the astronomical phenomena that they observed in the day and night sky or heard about from other sources. Parents also initiated such conversations with children. Thus, for both parents and children, astronomy-related phenomena appeared to be interesting and appropriate topics of conversation. Furthermore, and somewhat surprisingly, in all three communities, astronomy was among the top three nature-related topics discussed. This is particularly notable as the other two topics that received substantial attention from the families were animals and plants. Children's interest in the biological world, particularly animals, is well documented, and family conversations about living kinds serve as a rich source of information for children as they elaborate and revise understandings in this domain (e.g., Jipson et al. 2018; LoBue et al. 2013; Nielsen & Delude, 1989). In this work, we document that outside of the biological domain, astronomy was the most frequent topic discussed. Further, we show that the frequency of conversations about astronomy and children's roles in these conversations did not vary by age or gender, and that these patterns were consistent across the three communities. This suggests to us that family conversations are a valuable setting for supporting diverse children's early curiosity about the natural world in general, and specifically astronomy.

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Our finding that children spontaneously engage in astronomy-related conversations has implications for the types of experiences and materials parents and educators might offer young children. Children's conversations about astronomy focused on observations and questions about the sun, moon, and stars as their interest was piqued organically in the course of such everyday activities as driving in the car, looking out a window and walking in their neighborhoods. Previous research on children's and youths' learning shows that deeper understanding develops when learning is contextualized in ways that are personally meaningful rather than abstract (Doherty, Hilberg, Pinal & Tharp, 2003). While astronomical phenomena are embedded in complex causal mechanisms, our research shows that for young children astronomy is observational and part of their everyday lives. Children's initiation of conversations about astronomy demonstrates that they are motivated to share and explore their interests with others. Research on interest development suggests that capitalizing on children's situational interests as they arise in the course of everyday activity may be an entry point for building more sustained interest, and with it greater conceptual understandings. Hidi and Renninger (2006) propose a model of interest development in which they identify four phases of interest: triggered situational interest, maintained situational interest, emerging individual interest, and well-developed individual interest. This model suggests that intentional support of children's triggered situational interest in the area of astronomy inquiry may set children on a trajectory toward greater understanding, and perhaps encourage them to seek out additional astronomy-related learning experiences on their own initiative. Some children may even be motivated to construct "extremely intense interests" (DeLoache, Simcock & Macari, 2007) or "islands of expertise" (Crowley & Jacobs, 2002). Such well-developed interests in a topic are characterized as developing over a long period of time and result in rich and deep knowledge.

Open questions remain about how educators and facilitators may best support parents in encouraging their children's interest. Many studies document that parents contribute conceptually-relevant information as they talk with their young children about science (Callanan, Castañeda, Luce & Martin, 2017; Jant, et al. 2014; Jipson & Callanan, 2001). Although teachers, scientists, and museum educators often worry about the accuracy of parents' science explanations, some research suggests that, in fact, parents don't need to be experts to support their children's science interest and inquiry. Callanan et al. (2017) found that parents' talk about children's personal connections to the material was a better predictor of children's engagement with science content than was parents' focus on explanatory talk. Parents are experts about their own children, their interests and experiences, and this personal knowledge may be more important than expertise in the scientific domain they are discussing. Further, prior work suggests that part of supporting children's developing science interests may require adults to step back from adopting an instructive role and instead provide children with opportunities to demonstrate their knowledge through positioning themselves as experts (Palmquist & Crowley, 2007).

Another open question is how best to use hands-on resources to support astronomy-related interest and learning. Within the contexts of museum settings and classrooms, studies suggest that informal science activities that engage young children with STEM concepts and practices may help to promote more meaningful and enduring engagement with science (Greenfield et al. 2009; Gutwill & Allen, 2010). These activities may also increase the likelihood of children's sustained interest in such topics, which could relate to later academic motivation, interest, and performance. Prior work considers book-reading and storytelling as informal learning activities that offer ideas to children about the world that may serve as a springboard for further conversation and learning (Elley, 1989; Ganea, Pickard, & DeLoache, 2008; Hindmand, Skibbe & Foster; 2014; Solis, 2017). Research also suggests that storybooks can provide opportunities for fruitful conversation about science and other nature-related topics between parents and preschool-age children across diverse families (Kelemen et al. 2014; Shirefley, Castañeda, Rodriguez-Gutierrez, Callanan & Jipson, 2019).

This work yields opportunity for further investigation into children's early astronomy interest and engagement. Further work may seek to examine the catalyst of parent-child conversations about astronomy. For example, we noticed anecdotally in our data that some families' conversations seemed to be started from driving in the car, while others were started from some sort of media interaction (e.g. TV show, song, storybook). Future work may investigate the role of media on children's astronomy interests. From this, researchers may be able to use media as a context for catalysing children's interests and knowledge of astronomical concepts. Further work could also aim to gain a more accurate measure (e.g. interval sampling where parents report conversations every few hours) of how frequently these types of astronomical conversations occur within a family.

In sum, in order to create meaningful STEM activities and curriculum for children in early grades, it is crucial to first understand young children's interests and ideas about a topic prior to entering school (Gelman et al. 2010; Greenfield et al. 2009; Gutwill & Allen, 2010). Overall, these findings demonstrate that astronomy is a STEM topic about which very young children have personal connections and interests. Informal and formal science education settings should build on this early interest and engagement. Parents are potentially important partners for science educators, especially for astronomy where patterns can only be noticed if observations take place over time and throughout day and night. Educators can provide parents with tools to support these extended observations, potentially deepening children's interest and inquiry.

ACKNOWLEDGEMENTS

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