Exploring Children’s Conceptual Development: An Examination of How Children Learn Astronomy From Reported Access to Related Materials, Experiences, and Conversations to Initial Understandings

A Senior Project submitted in partial fulfillment of the requirements for the Bachelor of Science Degree in Child Development

by

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CHAPTER ONE

Introduction

This study explored children's conceptual development through the lens of preschool children's understanding of astronomy. I focused on astronomy as an avenue to further explore preschool children's conceptual development because of the large base of pre-existing research on how elementary-aged children learn astronomy concepts. Additionally, some astronomy-related phenomena can be observed (e.g., changes in the moon, movement of the sun), whereas learning about other astronomy-related phenomena (e.g., shape of the earth) relies on social transmission of information. The importance of both personal and social experiences in knowledge construction within astronomy makes it an ideal subject within which to explore children's conceptual development. In this project, I first explored how parents support children's astronomy learning, I then examined whether there is any connection between the support the child is given and their understanding of one astronomy-related concept, the shape of the earth. To embark on such an exploration, I first reviewed the current literature, and discovered that there is little pertaining to preschoolers, specifically.

Research on early astronomy learning explores elementary-aged children's understanding of earth shape and celestial motion. Vosniadou and Brewer (1992) identified seven variations in understandings of earth shape: sphere (scientifically correct), flattened sphere (people live on the flat areas on the top of the sphere), hollow sphere (people live on flat ground within the interior of a sphere), dual earth (there is one earth on which people live and one earth within space), disc earth
(earth is a flat disc on which people live), rectangular earth (earth is a flat rectangle on which people live), and mixed models (inconsistent view of earth that does not fit into any of the other models). That said, the ways in which children’s basic knowledge about earth shape is assessed can impact expressed level of understanding, with assessments involving solely close-ended questions resulting in more scientifically accurate reported understandings than assessments involving solely opened-ended questions (Vosniadou, Skopeliti, & Ikospentaki, 2004).

Similarly, several trajectories for how children understand celestial motion have been proposed. For example, one such trajectory involves children needing to understand the sun’s motion (continuous, in the sky during the day and not at night) in order to progress to understanding how the sun’s path changes across seasons. The finding that children may not have scientifically accurate understandings does not always align with current school curricula which seem to assume that children have this knowledge. As a result, children’s formal educational experiences in the domain of astronomy may not always be effective, as evidenced by Ivy League graduates’ tentative grasp on issues relating to celestial motion (Plummer & Krajcik, 2009, Sahiner & Schneps, 1987).

Several studies moved beyond describing children’s understandings to exploring how children learn astronomy. In several of these studies, researchers found that not all focused lessons targeting astronomy learning were effective (Hannust and Kikas, 2007, Shen & Jere, 2007). However, ones that involve teaching children concepts by having them use their own body to illustrate astronomical phenomena have been effective at supporting children in answering astronomy-
related questions correctly (Plummer, 2009). In studies investigating science learning more generally, children’s learning was supported by family interactions, most notably parent-child conversation dynamics such as explanation, open-ended questioning, and comparison (Fender & Crowley, 2007, Haden, 2010, Valle & Callanan, 2006). Whether and how these dynamics contribute to preschoolers’ astronomy-related learning specifically, is unknown. Further, some research has suggested that child interests may inform parent-child interactions (Alexander, Johnson, & Kelley, 2012). A desire to further explore how parents support preschool children’s science learning largely motivated the present study.

Within this study, 71 preschool and elementary children, and one parent of each child participated. I examined data previously collected, but never before explored, by Jipson (in preparation). Jipson gave parents either a questionnaire or interview aiming to measure how much exposure their child had to science and astronomy related experiences and materials. Additionally, she measured children’s understanding of earth shape using an interview adapted from Vosniadou and Brewer (1992). I used these data to investigate how much access children reportedly had to science and astronomy-related materials, experiences and conversations, and to determine to what extend reported access and children’s initial earth shape understanding are connected.

After analyzing the data, I found that preschoolers do have many opportunities to engage with science and astronomy. However, parents of preschoolers reported providing less access to science and astronomy related materials, experiences, and conversations than did parents of elementary-aged
children. The one exception was that parents of preschoolers reported having more access to science television than did parents of elementary-aged children. In addition to age, the experiences that children have may be shaped by the child’s gender. Overall, preschool boys had a greater incidence of exposure to science and astronomy related experiences and materials than preschool girls. Investigation of whether and how children’s general science and astronomy-specific experiences related to children’s understanding of earth shape demonstrated that the children that had never had a conversation about gravity or earth shaped displayed the least complex earth shape understandings, whereas children who did have these conversations displayed more complex, consistent earth shape understandings.

In sum, the present study provided some insight into children’s astronomy learning. A specific contribution of this work is in the information revealed about the preschool demographic. Not only do they have opportunities to learn about science and astronomy, but these opportunities may differ depending on their gender. Results align with current conversations about the importance of early childhood science education, as well as concerns about gender issues within the realm of science. The findings also raised questions about features of children’s conceptual development, namely, (1) What is the underlying cause behind gender differences in terms of access to materials and experiences, parent bias, child interest, or something else? and (2) What types of interactions best support children as they construct scientifically accurate understandings? In exploring these questions, it is important to remember that parent influence may not necessarily lie
solely within the opportunities parents provide, but also in how they help their
children navigate these experiences.
CHAPTER TWO

Literature Review

Piaget described children as “little scientists.” His view acknowledges that children have a natural curiosity, yet he also argued that children are too immature to grasp certain complex concepts. In contrast, Vygotsky believed that with scaffolding a child could attain sophisticated levels of understanding within reason for their developmental stage. Regardless, both agreed that children have a natural curiosity for the world around them and use active strategies to construct understandings of the world. As children learn about the world, they explore domains that adults recognize as “science.” Recent approaches to better understanding the nature of children’s developing scientific understandings suggest that children learn through both independent exploration and social interaction.

Children’s developing understanding of astronomy has attracted the interest of many researchers because learning of astronomy appears to rely on both firsthand observations (e.g., the moon appears to change shape) and information from others (e.g., the earth is round). As a result, it is an ideal domain to help inform understandings of children’s conceptual development. Although much research has explored elementary-aged children’s understanding of astronomy, less research has focused what contributes to preschool-age children’s understanding of astronomy. The purpose of this project was to contribute to the understanding of preschoolers’ astronomy learning by revisiting an existing data set with the goal of extending the existing research on children’s astronomy learning to the preschool demographic. By extending the research on children's astronomy learning to a younger age group,
understandings of children’s conceptual development can be expanded upon and potentially better understood.

*What Children Know about Astronomy-Related Topics*

Research on younger children’s thinking about astronomy focuses on identifying what children know about astronomy-related topics and how they structure knowledge in this domain. These questions have been explored primarily in relation to children’s developing understanding of the earth’s shape and their understanding of celestial motion.

*Understanding of the Earth’s shape.* Initial studies conducted on the topic of children’s understanding of the earth’s shape suggested that children construct mental models which, simply put, are mental representations of how things work. The mental model theory states that when children learn new concepts about a domain, these concepts increase the knowledge said individual has about the domain without changing the basic knowledge about the topic area (Morris, 2010). Therefore, children’s mental models are reinforced when they can successfully explain a phenomenon using an existing model. New phenomena can also be explained by model revisions, although such revisions are not always correct. Children create such models on the basis of both what they have been told as well as what they have observed.

Demonstrating support of the mental model theory in the domain of astronomy, Vosniadou and Brewer (1992) interviewed 60 elementary aged children from first, third, and fifth grade regarding their views on the earth’s shape. Upon examination of their responses, Vosniadou and Brewer suggested that children
construct mental models to understand the shape of the earth and these models have the ability to be inconsistent with scientific beliefs. Their findings suggest that children build mental models based on assumptions they make regarding the world around them based on observation and experiences (e.g., the earth looks flat), but this may be different from the information they receive socially (e.g., the earth is round). They provide evidence that there are a variety of different models that children may employ on their way to accepting the scientifically accurate, spherical model of the earth, which typically occurs by around age 10 or 11. Specifically, the models that Vosniadou and Brewer identified are the sphere (scientifically correct), flattened sphere (people live on the flat areas on the top of the sphere), hollow sphere (people live on flat ground within the interior of a sphere), dual earth (there is one earth on which people live and one earth within space), disc earth (earth is a flat disc on which people live), rectangular earth (earth is a flat rectangle on which people live), and mixed models (inconsistent view of earth that does not fit into any of the other models). Thus, children who do not already have an accurate mental model with which to explain basic astronomy may build a mental model that is inaccurate or overly simplistic in an attempt to resolve inconsistencies.

Vosniadou, Skopeliti, and Ikospentaki (2004) followed up on earlier work by Vosniadou & Brewer (1992) in order to address concerns that methodological approaches influenced initial reports of children’s earth shape understandings. They conducted a study in which first grade and third grade children were randomly assigned to complete either a forced choice questionnaire or open ended questionnaire containing questions about earth and moon shapes and processes.
These questionnaires were subsequently reviewed for internal consistency and scientific accuracy. The results revealed that children given the forced choice questionnaire tended to shift their answers in favor of the accurate spherical model of the earth despite initially responding that they believed the earth was shaped differently, while those completing the open ended questionnaire did not. This study raises a lot of questions in terms of how children can understand tasks, but also reveals that under certain circumstances, children may seem to accurately identify aspects of the earth’s tilt, rotation, and shape, when they otherwise would not be able to. Overall, children’s learning in the context of science-related topics is partially contingent on the support that children receive in terms of their interest in the topic, mastery of less complex scientific topics, and the types of questions the child is asked regarding the topic. Such a finding has implications for how we measure children’s understanding of earth shape.

Understanding of celestial motion. Plummer and Krajcik (2009) identified a learning progression related to topics such as how days passing and the phases of the moon can be explained by the earth’s rotation, tilt, and orbit. Although Plummer and Krajcik did not report any new data in describing their learning progressions, they drew heavily on Plummer’s (2009) earlier work which focused closely on elementary-aged children’s understanding of celestial motion. The research demonstrated many potential trajectories that children could take in understanding more and more complex astronomy concepts involving the earth, moon, and sun. In total, Plummer and Krajcik identified four possible learning trajectories for celestial motion, as described below:
Learning Trajectory 1: The sun’s path is a smooth arc across the sky that slowly changes in length and altitude across the seasons. (p. 774)

Learning Trajectory 2: The moon moves across the sky on a daily basis in a similar path to the sun, sometimes during the day and sometimes at night. (p. 775)

Learning Trajectory 3: The pattern of stars remains the same but appears to move across the sky nightly. The stars we can see after sunset change slowly across the seasons. (p. 776)

Learning Trajectory 4: The appearance of the moon changes slowly in a cycle that lasts about a month. (p. 777)

Plummer and Krajcik reasoned that it was difficult for children to grasp these concepts (e.g., the moon cycle) from the current methods of instruction. They point out that comparisons of the learning trajectories they identified to an elementary school curriculum reveals that the ways that children actually learn astronomy are different from how astronomy is currently taught in the schools.

Attempts to reveal whether and how formal education supports accurate celestial motion understandings have revealed that even young adults who have pedigreed educational backgrounds maintain misconceptions about astronomy. The video documentary, A Private Universe, demonstrates that many college graduates carry with them the same scientific misconceptions that they had in grade school (Sahiner & Schneps, 1987). In select interviews with Harvard graduates, the documentary revealed that even those with an Ivy League education express over simplified and erroneous explanations for astronomical phenomena, such as season
change. In fact, 21 of 23 randomly selected students and faculty of Harvard University revealed misconceptions regarding either seasonal change or moon phases.

*How Children Learn Astronomy*

These studies of children’s understanding of astronomy-related concepts have inspired additional explorations that explore how elementary aged children arrive at astronomy-related understandings. Children’s astronomy learning has been explored in a variety of contexts: designed curricular experience, informal conversations with others, and individuals’ own exploration.

With regard to curricular experiences, Hannust and Kikas (2007) tested kindergarteners and first graders in their baseline knowledge of astronomy. Children then participated in two 90-minute lessons. Within these lessons, the approach to teaching astronomy concepts adopted was based on a prior finding that suggested that the specific beliefs that children have must be addressed in order for children to forgo such beliefs for the scientifically accurate information. As a result, the lessons targeted three main misconceptions that children seem to have about astronomy. The topics covered included the contradiction between the earth appearing to be flat when we are on it and its actual spherical shape, the idea of people not being able to fall off the earth despite its spherical shape, and the potentially misleading use of the words “upside” and “downside” when referring to the earth. Each concept was addressed with both discussion and activities using materials such as magnets and spherical objects. As revealed in post-instruction interviews, Hannust and Kikas found that children’s knowledge about the earth was
largely fragmented and inconsistent in both pre-instruction and post-instruction interviews. Further, children in these age ranges had trouble even recalling accurate information post-instruction. Given these findings, it appears as though children have a difficult time constructing factually accurate, consistent models of astronomy phenomena, even after participating in focused lessons.

Shen and Jere (2007) also examined the impact of focused lessons on children’s astronomy-related understandings. They conducted a case study of whether and how a specific teaching model could produce positive learning outcomes. Specifically, Shen and Jere derived their results from an in-depth observation of how one teacher (among three teachers) chose to progress though a teaching model designed to physically engage the learner in astronomy-related concepts. They focused their observations in order to draw a conclusion to the following question: “How do manipulations and transformations of physical models contribute to modelers’ learning competence?” (p. 951). Based on their observation of this one teacher and her students, they deduced that beginning with basic physical models and slowly progressing to more complex, action oriented models resulted in the most beneficial learning environment. The basic models refer to those that can physically be used by the learner such as a paper model of how the sun moves across the sky. The action-oriented models refer to those that involve less formal structure and more creativity, such as having humans represent moon phases with the use of a Styrofoam ball and projector. Shen and Jere explain that these types of models, termed transformative modeling, entail using manipulatives to build upon prior knowledge. They argue that it can aid in conceptual
development, however participant observation was the only means used to support this hypothesis. When looked at together, these studies suggest there are different ways to teach astronomy-related concepts, all of which are inconclusive on a larger scale in terms of potential for successfully engaging children in constructing accurate astronomy-related understandings.

While much research suggests that young individuals lack accurate knowledge about astronomy concepts, and many studies demonstrate the difficulties in helping children advance their astronomy-related understandings, other work exploring how children can successfully acquire scientifically accurate information regarding astronomy is more optimistic. Plummer (2009) examined how children develop astronomy concepts in the context of a planetarium. The study included first and second grade students who participated in a live planetarium program regarding moon phases that included observations as well as kinesthetic learning. In this study, kinesthetic learning was defined as “students using their own motions of their own bodies to connect with the target concepts” (p. 196) and included learning techniques such as using one’s hand to trace the movement of the sun across the sky and standing up and moving one’s body as if one were the earth rotating around the sun. Following this session, students responded to questions about astronomy concepts. Researchers calculated scores based on kinesthetic and verbal responses. Results indicated that students were more accurately able to answer questions about celestial motion after the kinesthetic program than before the program. Thus, it seems that the kinesthetic format makes a differences in the potential for learning.
Beyond astronomy specifically, many studies that have explored science learning in other domains support the claim that conversational style and material presentation may impact child understanding. For example, Haden (2010) reviewed existing research on how science learning can be scaffolded by parent-child conversations in the context of a museum. She suggested that certain types of museum exhibits can encourage certain types of questions to be posed by parents; and that particular forms of conversations may be more likely than others to aid in science learning. Haden suggests that “conversations children have with their parents can both reflect and change what they understand about science” (p. 64). In a review of previous literature, Haden concluded that asking more open ended wh-questions may be a contributing factor in children’s sustained attention to science concepts.

In addition to open ended wh-questions, other types of speech have implications in children’s science learning. Valle and Callanan (2006) recruited 98 families with children ranging from ages four to nine attending a museum exhibit showing scientific concepts and subsequently video-taped and coded based on what type of speech they used, with a focus on similarity comparisons. It was noted that parents tended to make relational comparisons between exhibits as suggested by the museum signage. Additionally, when adults made similarity comparisons, children were also more likely to make similarity comparisons when discussing the scientific phenomena being communicated by the museum exhibit.

Fender and Crowley (2007) also examined the impact of particular forms of
parent-child conversation on children’s learning. In their study, children ranging in age from three to eight years visited a zoetrope exhibit at a museum either on their own or with a parent. Results demonstrated that children who explored the zoetrope with a parent, explored it more extensively. Further, children whose parents offered them explanations indicated a higher level of conceptual understanding in post-testing than did children whose parents did not explain. A second study including a similar demographic also involved children visiting the zoetrope exhibit under two conditions (Fender & Crowley, 2007). In the first condition, a child explored the zoetrope with a silent experimenter. In the second, the child observed the zoetrope with an experimenter who explained how the zoetrope worked and its intended function of creating animation. Through close examination of pre-test and post-tests about knowledge of the zoetrope, it was determined that children may encode experiences to reinforce existing thoughts or to introduce a new possible way of coding to the child. For example, the children in the condition in which an experimenter explained the function of the zoetrope, were more likely to encode it as a device that is intended to produce animation.

When looked at in sum, there is much research looking into how children’s science learning can be supported. The ways in which children conceptualize and encode scientific phenomena can be influenced by some techniques (e.g., conversational dynamics, kinesthetic experiences) whereas other approaches may be less effective (e.g., targeted intervention). However, research focusing specifically on how preschoolers conceptualize the same material, and how their environment can impact such learning remains limited. This is particularly true
within the domain of astronomy learning.

*What We Know About Preschoolers’ Astronomy Learning*

A limited number of studies have been published focusing on preschoolers and astronomy, specifically. In an effort to examine how children learn astronomy outside of formal interventions such as those in a classroom, planetarium or museum, Hannust and Kikas (2010) conducted a four-year long longitudinal study that engaged children who were aged 2 and 3 at the start of the study. The researchers asked children four open-ended questions aimed to assess their earth shape understanding, followed by a drawing task with the same goal. The assessment was designed based on the tasks developed by Vosniadou and Brewer (1992). Children participated in additional interviews occurring at one-year intervals. This study revealed that although children tended to answer more individual questions correctly as they aged, their answers did not appear to be consistent with a coherent mental model of the earth. Thus, leaving children to learn astronomy on their own via everyday experiences appears to be ineffective. While this study included preschoolers at onset, its focus was not in exploring they characterize earth shape, but rather how children’s knowledge of astronomy changes over time.

Additional studies specifically investigating preschoolers and their knowledge of astronomy are not available, however, there is research that focuses on preschoolers’ science learning more generally. Callanan and Oakes (1992) analyzed parent-recorded diary records for questions that their three to five year old children asked regarding how things worked and why things happen. Analysis
of the entries revealed that children typically are more interested in observable phenomena and parents tend to respond to their children’s questions with causal explanations. Such a study has implications for the field of astronomy, as it is a domain that can be observed and questioned, and one for which parents are likely to offer explanations that vary in scientific accuracy.

Furthering the research base in preschooler’s science learning, Alexander, Johnson, and Kelley (2012) revealed that preschoolers’ science learning occurs within a social context. In their longitudinal study, 4-year olds’ interests in science related topics were tracked for a three year long period. The study tracked these children’s opportunities for informal science learning based on a parent survey administered yearly and looked at the children’s interests in science themes by asking parents three questions relating to what children were interested in and what they preferred to do in free time. These researchers found that showing an early interest in science-related topics predicted later interest in science-related topics. Also, the more exposure to science-related topics early on, the more opportunities for science-related activity engagement later on. Access to science learning opportunities was determined by combining items on a questionnaire. Some of these items included watching a television program about science, conducting a science experiment, and consulting a science related book. This study points to the conclusion that child interests may play a significant role in the parents’ tendency to provide access to learning opportunities regarding said interests.
Direction of Current Project

Although there is research about preschool science learning, little has been published involving preschooler’s conceptualization of astronomy, specifically. Starting from a broad focus, and seeing what experiences, materials, and knowledge preschoolers have access to is a good starting place for future research. Jipson (in preparation) collected extensive data on preschool-aged children’s astronomy learning and exposure to astronomy-related experiences. She interviewed 32 preschoolers aged four to five and 32 older children aged six to eight with a questionnaire adapted from Vosniadou and Brewer regarding the earth’s shape. She conducted interviews both before and after focused activities that engaged children in consideration of concepts closely resembling those included on both the pre and post questionnaire. Children were also assigned to participate in a focused activity with either their mother or an experimenter, who did not provide the child with feedback regarding the activity. Parents also responded to questions documenting their children’s interest in and experience with astronomy concepts and experiences. These data allow for investigations of the extent to which parents support astronomy-related inquiry, as well as examination of the relationship between parents’ self-reported support for their child’s science learning and their child’s initial understanding of the earth’s shape.

This senior project capitalized on availability of Jipson’s data set. I explored the data in order to better understand preschoolers’ conceptual development within the domain of astronomy. In addition, I examined whether increased report of astronomy concepts in the parent survey portion of the study had any correlation to
children’s initial characterization of the earth’s shape. My goal was to learn whether parents who report that their child is more interested in astronomy concepts provide more opportunities for science or astronomy learning, and whether this could result in a more accurate view of the earth. This investigation serves as an initial step in interpreting the data collected by Jipson, potentially informs current research regarding children’s astronomy learning, and paves the way for more targeted research in this domain.
CHAPTER THREE

Method

This study focused on (re)examining data from Jipson’s (in preparation) existing data set in order to gain a fuller understanding of preschoolers’ interest in and access to astronomy-related materials and experiences, as well as to investigate how this may relate to knowledge about earth shape. As a result, my description of the methods are based on Jipson’s research materials and manuscript drafts and not on firsthand participation in the data collection process.

Participants

Seventy-one preschool and elementary children, and one parent of each child participated (age range: 4:1 to 5;4 and 6;1 to 8;0). The sample included 34 male children and 37 female children. Gender and age of participating parent were not noted. The preschool-aged subset was the focus of this study and included 39 children, 18 boys and 21 girls. Participants were primarily European-American and from the middle-class backgrounds. All participants were recruited through childcare centers and schools in and around Santa Cruz, CA.

Materials

Parent Questionnaire. The questionnaire (see Appendix A) consisted of 14 questions developed to assess children’s interest in science-related concepts and their experience with science-related activities. The questionnaire included both forced choice and open-ended items. For example, several items focused specifically on children’s experience with science-related books, science-related television shows, and science museums. In addition, several questions sought information
about children’s interest in and experience with astronomy-related concepts, specifically. Items included questions about children’s experiences visiting science museums, observatories, and planetariums, children’s experience with and interest in globes, telescopes, and maps, and children’s experience riding in airplanes. The questionnaire also asked for a parent report of parent-child conversations regarding the earth’s shape, gravity, and any other astronomy-related topics.

**Parent Interview.** The parent interview (see Appendix B) was similar to the questionnaire, but differed slightly in terms of content and in terms of method of administration. The parent interview consisted of 17 questions. It asked for the parent to report all of the same information as did the questionnaire with the exception of the item about parent-child conversations regarding the earth’s shape. Additionally, the parent questionnaire asked for a parent-report of parent-child conversations regarding the sun, the moon, seasonal change, and day-night cycle.

**Child interview.** Jipson (in preparation) describes the child interview protocol in the following manner:

The child interview consisted of a subset of items from a 207-item verbal questionnaire about astronomy developed for elementary school children by Vosniadou and Brewer (1987). These particular items focused specifically on the shape of the earth and have been frequently used in prior research to investigate children’s understanding of this topic. All items were asked verbally; however, in the third question the experimenter also showed children a simple black-and-white line drawing of a house on flat ground. Other materials consisted of blank paper and colored pencils which children used to draw pictures of the earth.

**Procedure**

**Parent Questionnaire/Interview.** The researcher randomly assigned parents to a condition in which they either filled out a parent questionnaire (N=43 overall, N
EXPLORING CHILDREN’S CONCEPTUAL DEVELOPMENT

=22 for preschool subset) or verbally answered interview questions (N=28 overall, N = 18 for preschool subset). The goal of these parent interviews/questionnaires was to gain information about children’s experiences with science-related concepts and experiences. Parents who participated in the interview did so while their child engaged in a focused activity on earth shape with an experimenter. Parents who filled out the questionnaire engaged in the focused activity on earth shape with their child and filled out the questionnaire afterwards. The content of the focused activity is not relevant to the current investigation; only the parent report is of interest to the current investigation.

Child Interview. All children participated in a structured interview with a focus on assessing their views on the shape of the earth. The interview was designed to replicate the protocol used by Vosniadou and Brewer (1992), with the exception of a modified coding strategy that allowed for more sensitivity to differences in children’s understandings due to the age of the participants. The interviews were conducted at each child’s childcare center. Jipson (in preparation) describes the child interview and coding procedure in the following manner:

Children were asked each of the interview items in a fixed order. Children who gave ambiguous or incomplete responses to any of the interview questions were asked to elaborate and/or clarify their remarks. In addition, children were provided with paper and a pencil, as some questions required children to supplement their written answers with illustrations. All interviews were videotaped for later coding. Interviews lasted approximately 5 to 10 minutes.

The modified coding strategy allowed for children’s responses to include as many as two acceptable deviations, or one unacceptable deviation (provided that there was an alternate, acceptable, way to interpret this apparent deviation). For example, many children responded to the question, "What is below the earth?" with answers such as "lava," "dirt," and "clay." In the original coding, such responses were considered to be unacceptable deviations to the
spherical model, as they suggested an understanding of the earth as supported by ground rather than floating in space. In the modified coding, such answers were thought of as potentially correct responses to a more local level interpretation of the question (e.g., what is below the \textit{ground}?). Therefore, if the rest of these children's responses were consistent with a spherical model, for example, their earth shape model was coded as a "Partial Sphere" (the word "partial" is used to indicate that the coding criteria differed from what would be obtained by the more rigid approach).

Although Jipson conducted these interviews both before and after a focused activity, only the pre-test is of interest in the current investigation.
CHAPTER FOUR

Results

Results are discussed in three sections. The first section provides descriptive information about children’s access to science-related materials, experiences, and conversations drawn from the parent questionnaire and parent interview. The second section looks at preschool children’s understanding of the earth’s shape. The third section examines the relationship between children’s science and astronomy-related experiences and their understanding of the shape of the earth.

Analysis of Parent Questionnaire/Interview

I combined the results from the parent questionnaire and parent interview to yield a larger sample size. I used data collected by Jipson (in preparation) from both the preschool and elementary age samples, although I gave specific attention to the data from the preschool sample.

When examining the data, I combined items to create an inclusive measure termed “Science Access” that combined scores on the following questions:

1) How often does you child watch televisions programs about science?

2) How often does your child read books about science?

3) To the best of your recollection, have you and your child even had any conversations about gravity?

4) Do you have any maps in your home?

5) Do you have a globe in your home?

6) Do you have a telescope in your home?

7) Has your child ever visited a planetarium?
8) Has your child ever visited an observatory?

9) Has your child ever visited a science museum?

I collapsed the response options and coded answers as 0 or 1, to either reflect some degree of exposure or no exposure at all. Thus, each child was given a numerical score for “Science Access” with a maximum score of nine.

The mean score, overall, for “Science Access” was 4.89. Broken down by age, mean scores on science access for preschool and elementary aged children were 4.44 and 5.44, respectively. In terms of gender, mean scores for boys and girls were 5.09 and 4.7, respectively. Within the preschool subset, mean scores for male and female children were 5.06 and 3.90, respectively. In the subset of elementary children, the mean “Science Access” score for female children was 5.75 whereas that of male children was 5.13.

In order to determine whether any of the differences with regard to “Science Access” were significant, a univariate analysis of variance was conducted to compare “Science Access” by both age and gender. Results indicated a significant main effect for age, \( F(1,67) = 9.84, p < .01 \). Elementary-aged children had more access to science learning opportunities than did preschool children. This main effect was accompanied by a significant interaction between age and gender, \( F(1,67) = 13.83, p < .01 \), indicating that gender differences were not the same for the two different age categories. A one-way ANOVA was used to test for gender differences regarding “Science Access” within the preschool subset, the group of interest to this study. Gender differences with regard to scores for “Science Access” differed
Table 1: “Science Acces” Item Analysis

<table>
<thead>
<tr>
<th>Item</th>
<th>Percentage of Participants Responding Affirmatively</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preschool</td>
</tr>
<tr>
<td>How often does your child watch television programs about science?</td>
<td>77.8</td>
</tr>
<tr>
<td>(answers reflect some exposure or none at all)</td>
<td></td>
</tr>
<tr>
<td>How often does your child read books about science?</td>
<td>83.3</td>
</tr>
<tr>
<td>(answers reflect some exposure or none at all)</td>
<td></td>
</tr>
<tr>
<td>To the best of your recollection, have you and your child even had</td>
<td>61.1</td>
</tr>
<tr>
<td>any conversations about gravity?</td>
<td></td>
</tr>
<tr>
<td>Do you have any maps in your home?</td>
<td>94.4</td>
</tr>
<tr>
<td>Do you have a globe in your home?</td>
<td>44.4</td>
</tr>
<tr>
<td>Do you have a telescope in your home?</td>
<td>43.6</td>
</tr>
<tr>
<td>Has your child even visited a planetarium?</td>
<td>22.2</td>
</tr>
<tr>
<td>Has your child even visited an observatory?</td>
<td>16.7</td>
</tr>
<tr>
<td>Has your child ever visited a science museum?</td>
<td>66.7</td>
</tr>
</tbody>
</table>

*Gray shading denotes significance

Figure 1: Preschool Subset Gender Analysis

Figure 2: Preschool/Elementary Age Analysis
significantly, $F(1, 37) = 7.33, p = .01$. Preschool boys had more opportunities to learn about science than did preschool girls.

To further explore “Science Access”, I broke this variable down into individual items. From here, I focused my analysis on gender differences within the preschool subset and age differences between the preschool and elementary subsets, as these differences were found to be significant in the prior analyses. Table 1 displays data from all items contributing to “Science Access.” Figure 1 displays data with a focus gender differences within the preschool subset. Figure 2 displays data with a focus age differences between preschool and elementary school children. To explore these data, I first focused on items that target science more generally, and then focused on items that specifically target exposure to astronomy-specific experiences, materials, and messages. Only significant findings are discussed in the following sections.

*Science-related items.* Several of the science related items that contributed to the measure “Science Access” were combined to create a measure termed “General Science Experiences”:

1) How often does you child watch televisions programs about science?

2) How often does your child read books about science?

3) Do you have any maps in your home?

4) Has your child ever visited a science museum?

Investigation of children’s experiences visiting informal science learning institutions revealed significant age-related differences. An examination of the percentage of parents who reported that their child had attended a science museum
differed between the preschool (56.4%) and elementary school (90.6%) subsets. There was a significant difference in the scores for preschoolers and elementary-age children in terms of exposure to a science museum, $t(63.1) = -3.57, p = 0.001$.

Questions targeting children’s access to science-related materials in the home, in particular, also revealed significant results. The measure targeting whether children had access to a map within the home within the preschool subset revealed that 94.4% of the male preschoolers in the study had maps in the home, compared to 61.9% of the female preschoolers in the study. This gender-related difference was significant, $t(29.5) = 2.67, p = 0.012$.

Exploring more socially transmitted science-related messages, 84.6% of parents within the preschool subset reported that their child watches television programs about science at least once a week, whereas 62.5% of parents within the elementary school subset reported that their child watches television about science at least once a week. These age-related differences in science-related TV viewing were significant, $t(56.1) = 2.11, p = 0.039$.

**Astronomy-specific items.** The astronomy-specific items that contributed to the measure “Science Access” were combined to create a new measure termed “Astronomy Experiences”:

1) To the best of your recollection, have you and your child even had any conversations about gravity?

2) Do you have a globe in your home?

3) Do you have a telescope in your home?

4) Has your child ever visited a planetarium?
5) Has your child ever visited an observatory?

Significant differences were found when looking at this measure as a whole. In order to determine what was significant within the measure “Astronomy Experiences,” a univariate analysis of variance was conducted to compare “Astronomy Experiences” by both age and gender. Results indicated a significant main effect for age, $F(1,67) = 9.17, p < .01$, with preschoolers having significantly lower scores on “Astronomy Experiences” than elementary aged children. This main effect was accompanied by a significant interaction between age and gender, $F(1,67) = 5.43, p < .05$, indicating that gender differences were not the same for the two different age categories. An independent sample t-test was used to test for gender differences regarding “Astronomy Experiences” within the preschool subset: the group of interest to this study and significance was determined, $t(37)=2.32, p = 0.026$. This means that preschool boys had significantly higher scores on the measure of “Astronomy Experiences” than did girls. These findings stand out as there were not gender or age related significant findings within the “General Science Experiences” measure.

On the individual item level, significant differences were found as well. Investigation of children’s experiences visiting informal science learning institutions revealed that within the preschool subset, 7.7% of parents reported that their child had visited an observatory. This percentage includes 16.67% of the male preschoolers and 0% of female preschoolers involved in the study. Findings for reported visitation of an observatory among preschoolers in regard to gender was marginally significant, $t(17)=1.84, p = .083$. 
The two additional items that t-test analyses revealed to be significant within the “Astronomy Experiences” measures targeted children’s access to astronomy related materials in the home. Gender-related analyses within the preschool subsets revealed that 38.9% of boys had access to a telescope in the home whereas only 9.5% of girls in the study did. This finding was significant, t(26.9)=2.71, p = 0.039. Age related analyses regarding access to a globe in the home revealed that 43.6% of preschoolers reported having a globe in their home, whereas 71.9% of elementary school children reported having a globe in their home. These age-related differences on the measure of map access were significant, t(56.1)=2.11, p = 0.039.

Features of Children’s Understanding of Earth Shape

My analysis of earth shape understanding focused solely on the preschool-aged subset. Prior to my involvements with these data, coding of earth shape understandings targeted the following possibilities: rectangular, disc, mixed, dual earth, partial hollow sphere, hollow sphere, flattened sphere, and spherical. I further collapsed across codes to categorize earth shape understandings in the following manner:

<table>
<thead>
<tr>
<th>New Category</th>
<th>Previous Categories Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>Rectangular, Disc</td>
</tr>
<tr>
<td>Mixed</td>
<td>Mixed</td>
</tr>
<tr>
<td>Hybrid</td>
<td>2 Earth Model</td>
</tr>
<tr>
<td></td>
<td>• Dual Earth</td>
</tr>
<tr>
<td></td>
<td>1 Earth Model</td>
</tr>
<tr>
<td></td>
<td>• Partial Hollow Sphere</td>
</tr>
<tr>
<td></td>
<td>• Hollow Sphere</td>
</tr>
<tr>
<td></td>
<td>• Flattened Sphere</td>
</tr>
</tbody>
</table>
Nine of the preschoolers did not have data on earth shape understanding, therefore, are not included in this portion of the analysis. The distribution of remaining preschoolers’ earth shape understanding is provided in the two left hand columns of Table 2 with the earth shape understandings listed in in order of increasing complexity. With that:

**Table 2: Earth Shape Understanding Distribution and Mean Scores for Science Access**

<table>
<thead>
<tr>
<th>Earth Shape Understanding</th>
<th>Number of Children with this Earth Shape Understanding</th>
<th>Mean Score for Science Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Mixed</td>
<td>16</td>
<td>4.19</td>
</tr>
<tr>
<td>Hybrid</td>
<td>11</td>
<td>4.18</td>
</tr>
<tr>
<td>• 2 Earths</td>
<td>(8)</td>
<td>(4.5)</td>
</tr>
<tr>
<td>• 1 Earth</td>
<td>(3)</td>
<td>(3.33)</td>
</tr>
<tr>
<td>Accurate</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

*Connections Between Parent-Report and Preschooler’s Earth Shape Understanding*

Mean scores for “Science Access” for each of the earth shape understanding categories are listed in the third column of Table 2. As Table 2 shows, the children categorized as having the “accurate” earth shape understanding also possess the greatest mean score for “Science Access.” In contrast, the least complex earth shape understanding category (flat) is not associated with the lowest mean score for “Science Access.” The lowest mean score for “Science Access” occurs within the “1 earth” category, which is considered the second most complex category of earth shape understanding. Based on these comparisons, it can be determined that scores for science access do not necessarily indicate level of complexity or accuracy in
earth shape understanding. When looking at how “Astronomy Experiences,” specifically, compare to earth shape understandings, on item stood out. None of the children who were characterized as having a “flat” understanding of earth shape (N=2) were reported to have ever discussed gravity with a parent. In contrast, all of the children who were characterized as having an “accurate” understanding of earth shape (N =2) were reported to have discussed gravity with a parent. A similar trend exists in parents’ report of having discussed earth shape with their child. This sample, however, consisted of only the 17 children whose parents filled out the questionnaire and had data collected about their understanding of the earth’s shape and for this reason it was not included in the measure “Astronomy Experiences.” Among these children, all children who were characterized as having a “hybrid” or “accurate” understanding (6 and 2, respectively) were reported to have discussed earth shape with a parent. Conversely, the one child who was characterized as having a “flat” understanding of earth shape was not reported to have had said conversation.
CHAPTER FIVE

Discussion

The present study aimed to extend work on children's conceptual development within the domain of astronomy by: (1) examining science-related opportunities that preschool and elementary-aged children reportedly have access to, and (2) exploring how this access to science-related learning opportunities relates to preschool children's understanding of earth shape.

Children's Access to Science-Related Opportunities

This study makes several contributions to the existing literature on children's access to science-related opportunities. At least some of the parents, overall, report that they are taking their children to science museums, planetariums, and observatories, that they have access to maps, globes, telescopes, science books, and science television, and that they have discussions with their child regarding gravity. However, these parents may be providing their children with differential experiences depending on gender and age.

The data suggests that girls and boys have differential access to science-related opportunities. I identified that boys have greater access to science-related opportunities. Such a finding leaves more questions than answers. To find answers, alternative research can be looked into. A study by Alexander, Johnson, and Kelley (2012) found that from the ages 4-7, boys were more likely than girls to be reported to have an interest in science by their parents. Given this, it is still unclear why it is that boys have a greater reported interest and, as the current study finds, more access to science-related opportunities. A radio broadcast on NPR on May 7, 2013
entitled “Young Girls May Get More ‘Teaching Time’ from Parents Than Boys Do” sheds some light on this topic by discussing a study by Michael Baker and Kevin Milligan that has not yet been published (Vedantam, 2013). Baker and Milligan looked at how parents spend time with their children by conducting surveys in the United States, Canada, and Britain. There was a disparity in terms of the amount of time parents interacted with preschool age boys versus girls in certain activities, such as reading and teaching numbers. Baker and Milligan found that while parents do spend the same amount of time with boy and girls, girls spent more time with parents engaging in these types of teaching activities. Baker proposed that the disparity exists based on feedback that the parent receives from the child and, in turn, causes the parent to respond to the child differently (e.g. A boy is more wiggly when reading, so the parent engages with their son in a way that is more action-oriented). However, this model does not fully explain the data from the current study as some of the statistically significant findings reported involved access to materials in the home. Future investigation is needed to determine what really accounts for the apparent gender differences in the opportunities that parents report providing to their children.

Aside from gender-related differences, the data also suggest age-related differences in exposure to science-related opportunities. The data reveals that younger children have significantly more access to science television and significantly less access to other science-related materials and experiences, globes and science museums specifically. Since age-related differential access exists, it cannot be argued that those strategies that have been shown to be effective at
teaching elementary age children will yield the same results with the preschool age group. For example, Plummer’s (2009) finding that kinesthetic learning techniques aided children in answering questions about celestial motion correctly might have a different level of effectiveness with the preschool age group. Additionally, the finding by Hannust and Kikas (2007) that dispelling major misconceptions that children have regarding earth shape does not necessarily result in greater child understanding might have different implications with a younger age group. Further investigation is needed to discover what is effective in helping preschool-aged children develop accurate beliefs about science and astronomy.

*Earth Shape Understanding and Science Access*

A question posed by the present study concerned the extent to which parental report of exposure to science and astronomy-related materials and experiences impacts preschoolers’ understanding of earth’s shape. Although some findings were noted, the present study was largely inconclusive on this matter due to small sample size. The data suggests that having discussed gravity with a parent is connected to a more cohesive and complex understanding of earth shape. Similarly, having discussed earth shape with a parent was connected to a more cohesive and complex understanding of earth shape. The more impressive relationship was that those children who had not reportedly had conversations about earth shape and/or gravity displayed the least accurate understanding of earth shape. The data revealed begs the question: what conversations result in a more accurate understanding of earth shape for the child? No such research currently exists. However, studies show that children do hold misconceptions about
science concepts. Pine, Messer, and St. John (2001) explored mental models in a study in which classroom teachers in 81 schools responded to questionnaires to help determine the naïve models children hold about science concepts. The types of questions asked on the questionnaires included questions regarding misconceptions children have about science concepts, questions regarding the previous knowledge that students have regarding science concepts, and questions about the experimental method. Pine et al. (2001) determined that children come into science lessons with previous knowledge regarding the topics that they are learning, however this knowledge includes many overgeneralizations and misconceptions. One avenue for future research is to address how these overgeneralizations and misconceptions can be dispelled and replaced with accurate knowledge. The current study minimally explored how conversation topics between parents and children can address these overgeneralizations and misconceptions. A more in depth exploration into what features of these conversations result in more accurate scientific understanding could be beneficial to the field.

In total, the results of the present study have extended the research on children’s astronomy learning to the preschool domain. They have also presented several issues for future investigation. Specifically, the study has led to more questions that came about as a result of an investigation of how children learn astronomy, but focus much more generally on children’s conceptual development. Two such questions are: (1) What is the underlying cause behind gender differences in terms of access to materials and experiences? and (2) What types of interactions best support children as they construct scientifically accurate understandings?
Looking at these questions would lead to a fuller understanding of children's conceptual development.
References


APPENDIX A: Parent Questionnaire

We would like some information from you about what experiences your child has had with concepts related to astronomy. Please answer the questions below as well as you can.

1. Is your child (please circle one):
   a. an only child     
   b. the oldest sibling
   c. a middle sibling
   d. the youngest sibling

2. How often does your child watch television programs about science? (please check one)
   - [ ] never
   - [x] 1-3 times a week
   - [ ] 4-6 times a week
   - [ ] over 6 times a week

   If so, what programs does he/she watch?
   Amazing Animals, Bill Nye the Science Guy, Magic School Bus, other Misc.

3. How often does your child read books about science? (please check one)
   - [x] never
   - [ ] 1-3 times a week
   - [ ] 4-6 times a week
   - [ ] over 6 times a week

   If so, what kinds of books does he/she enjoy (e.g., dinosaurs, outer space, gardening)?
   Outer Space, Human Body, Weather, Animals

4. To the best of your recollection, have you and your child ever had any conversations about the shape of the earth?
   [ ] YES  [ ] NO

   If yes, can you describe any aspects of those conversations?
   General discussion— he likes the planets & rockets. I don’t know if we specifically said “the earth is round.”

   Did any of these conversations take place in the last week?
   Yes, and we talked about the North & South poles, the Equator (we’ve been reading a book about Penguins & the S. pole)
5. To the best of your recollection, have you and your child ever had any conversations about gravity?

- YES  
- NO

If yes, can you describe any aspects of those conversations?

We saw a show about it on "The Magic Schoolbus" I talked about the fact that gravity keeps us on the earth. Did any of these conversations take place in the past week?

- YES, a brief one after his first meeting with the sun, but in space on the moon we float.

6. To the best of your recollection, have you and your child ever had any conversations about any other topics related to astronomy?

- YES  
- NO

If yes, can you describe any aspects of those conversations?

We talk about the moon, moon changes, the planets & our seasons, spaceships, & space travel. Did any of these conversations take place in the past week?

- Yes — when we were reading the "Penguin" book

7. Do you have any maps in your home? YES  

- NO

If yes, how often does your child seem to demonstrate interest in these maps?

- OFTEN  
- OCCASIONALLY  
- NEVER

8. Do you have a globe in your home? YES  

- NO

If yes, how often does your child seem to demonstrate interest in the globe?

- OFTEN  
- OCCASIONALLY  
- NEVER

9. Do you have a telescope in your home? YES  

- NO

If yes, how often does your child seem to demonstrate interest in the telescope?

- OFTEN  
- OCCASIONALLY  
- NEVER
10. Please check all the places that your child has visited:
   - planetarium
   - observatory
   - science museum

11. Has your child ever flown on an airplane? YES  NO
    If yes, what is the farthest destination that they have visited by airplane?
    New York
    Do you recall commenting on the way the earth looks from above? YES NO
    If yes, what kinds of things did you talk about?
    Just talked about how small everything looks from the plane.

12. What other parts of the country has your child lived in?
    None

13. Does your child attend a child care program? YES  NO
    If yes, please list any activities included in the program that may contribute to your child’s understanding of astronomy. For example, are there maps? globes? constellation charts?
    Nothing specific

14. Please list any other experiences your child has had that might have provided him/her with additional information on concepts related to the earth’s shape.
    Other books, books about shapes, he likes the planets & space.

Thank you very much for participating in our study!
APPENDIX B: Parent Interview

We would like some information from you about what experiences your child has had with concepts related to astronomy. Please answer the questions below as well as you can.

1. Is your child (please circle one):
   a. an only child
   b. the oldest sibling
   c. a middle sibling
   d. the youngest sibling

2. How often does your child watch television programs about science? (please check one)
   never
   ___ 3 times a week
   ___ 4-6 times a week
   ___ over 6 times a week

   If so, what programs does he/she watch?
   [Handwritten: animal planet]

3. How often does your child read books about science? (please check one)
   ___ never
   ___ 1-3 times a week
   ___ 4-6 times a week
   ___ over 6 times a week

   If so, what kinds of books does he/she enjoy (e.g., dinosaurs, outer space, gardening)?

4. To the best of your recollection, have you and your child ever had any conversations about the sun?
   [Handwritten: YES]

   If yes, can you describe any aspects of those conversations?
   [Handwritten: [illegible]]

   Did any of these conversations take place in the past week?
   NO
5. To the best of your recollection, have you and your child ever had any conversations about gravity?

\[ \begin{array}{c}
\text{YES} \\
\text{NO}
\end{array} \]

If \text{yes}, can you describe any aspects of those conversations?

Did any of these conversations take place in the past week?

6. To the best of your recollection, have you and your child ever had any conversations about the moon?

\[ \begin{array}{c}
\text{YES} \\
\text{NO}
\end{array} \]

If \text{yes}, can you describe any aspects of those conversations?

Did any of these conversations take place in the past week?

7. To the best of your recollection, have you and your child ever had any conversations about seasonal changes?

\[ \begin{array}{c}
\text{YES} \\
\text{NO}
\end{array} \]

If \text{yes}, can you describe any aspects of those conversations?

Did any of these conversations take place in the past week?
8. To the best of your recollection, have you and your child ever had any conversations about the day-night cycle?

   YES   NO

   If yes, can you describe any aspects of those conversations?

   Did any of these conversations take place in the past week?

   NO

9. Do you have any maps in your home?   YES   NO

   If yes, how often does your child seem to demonstrate interest in these maps?

   OFTEN   OCCASIONALLY   NEVER

10. Do you have a globe in your home? YES   NO

    If yes, how often does your child seem to demonstrate interest in the globe?

    OFTEN   OCCASIONALLY   NEVER

11. Do you have a telescope in your home? YES   NO

    If yes, how often does your child seem to demonstrate interest in the telescope?

    OFTEN   OCCASIONALLY   NEVER

    He has looked through one.

12. Please check all the places that your child has visited:
    - planetarium
    - observatory
    - Exploratorium
    - science museum

13. Has your child ever flown on an airplane? YES   NO

    If yes, what is the farthest destination that they have visited by airplane?

    3,000 (mawu)

    Do you recall commenting on the way the earth looks from above? YES   NO

    If yes, what kinds of things did you talk about?

    Little stuff is lightning
14. Has your child ever traveled across time zones? **YES** NO
   
   If yes, do you recall having any conversations about the time change? **NO**
   
   Maui | east coast

15. What other parts of the country has your child lived in? **SC, CA**

16. To the best of your knowledge, has your child's childcare program ever included a unit on astronomy? **YES** NO **Probably**
   
   If yes, please list any activities included in the program that may contribute to your child's understanding of astronomy. For example, are there maps? globes? constellation charts?

15. Please list any other experiences your child has had that might have provided him/her with additional information on concepts related to the earth's shape.

   **NO**

Thank you very much for participating in our study!