PARENT-CHILD SHARED BOOK READING: CHILDREN'S LEARNING OF NATURAL SELECTION FROM A DIGITAL BOOK

A Dissertation

Presented to

The Faculty of the School of Education and Human Development

University of Virginia

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

---

by

Shoronda Erica Matthews, M.A.

June 2022

ABSTRACT

Research on shared parent-child book reading finds that it can provide support to children's learning in the areas of language and literacy development (Chow et al., 2008; Lever & Sénéchal, 2011; Parish-Morris et al., 2013). Children show the capacity for science learning when reading with a researcher or teacher (Altun, 2019; Daubert et al., 2020; Ganea et al., 2011; Kelemen et al., 2014), but limited work has examined whether shared book reading experiences with parents can impact children's learning of science concepts. Questioning, such as pedagogical questioning, and children's utterances are a part of these reading experiences that research finds to relate to children's learning (Blewitt et al., 2009; Daubert et al., 2020; Legare, 2014; Lombrozo, 2006; Wellman, 2011; Yu et al., 2018; Yu et al., 2019). In this dissertation I examine whether 1) parent-child digital book reading is associated with children's learning about natural selection, 2) parents' pedagogical questions during shared book reading are associated with children's learning about natural selection, 3) parents' pedagogical questions during shared book reading are associated with children' utterances, 4) children's utterances during shared book reading are associated with children's learning about natural selection and 5) children's utterances mediated the association between parent pedagogical questions and children's learning of natural selection. Twenty-five parent-child dyads with children ages seven and eight (M = 7.64, SD = 0.49) participated in the study, which was conducted over Zoom and took place in one 45-60 minute session. Dyads read a children's science book about natural selection and parents were encouraged to ask their child questions while reading, with children completing pre-test and post-test measures of natural selection understanding.

Children made gains in their understanding of natural selection after reading with a parent, with a significant change in children's scores from pre-to post-test measures. However, parent questions and child utterances were not related to learning. Results also show that the associations between parents' pedagogical questions and children's utterances were significant. Taken together, these results reveal that children can learn science concepts when reading with a parent. It also indicates that children talk more in a science learning task through book reading when pedagogical questions are asked by their parent. The lack of association between parent questions and child utterances with science learning suggests that there may be other factors related to parents' questions and children's utterances outside of quantity that better support children's learning.

Department of Education Leadership, Foundations, and Policy
School of Education and Human Development
University of Virginia
Charlottesville, Virginia

APPROVAL OF THE DISSERTATION

This dissertation, ("Parent-child shared book reading: Children's learning of natural selection from a digital book"), has been approved by the Graduate Faculty of the School of Education and Human Development in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

_____
Dr. Jamie J. Jirout (Chair)

_____
Dr. Vivian C. Wong

_____
Dr. Colby Hall

_____
Dr. Jessica E. Whittaker

_____Date

DEDICATION

To my parents who immigrated from Guyana and sacrificed so much so that my sister and I could pursue our dreams. To my little sister who has provided me with so much laughter throughout this entire journey. I love you all so much.

ACKNOWLEDGEMENTS

Completing this Ph.D. has been a long journey and I am so grateful for the support I have received from so many individuals.

First, I want to thank my parents for providing unconditional support and love throughout this entire experience. Anytime I doubted myself you both would remind me that I can achieve anything I put my mind to.

To my little sister, thank you for all of your support, love, and laughter. Thank you for all the times that you made sure I didn't put my work first over my mental health.

To all of my aunts, uncles, cousins, godparents and extended family, thank you for your unwavering support and love.

To my friends from college, thank you for all the late-night phone calls, memes, and just being there for me always.

To my friends, EP-ADS family, and cohort from UVA, thank you for all of the support throughout this program. When I first came to UVA, I never thought that I would leave with lifelong friends. I'm so happy to have all of you in my life. Thank you for all the times you all forced me out of my comfortable zone, late night laughs, and introducing me to different wine flavors.

To my advisor Dr. Jamie Jirout, I would have been lost without you. Thank you for helping me become the researcher I am today. Thank you for caring about me as person and always making sure that I was okay health wise throughout this program.

To my committee, Dr. Vivian Wong, Dr. Colby Hall, and Dr. Jessica Whittaker, thank you for all the feedback and support you have provided me throughout this dissertation journey.

To my mentor, Dr. Katrina Debnam, thank you for everything. Thank you for keeping me sane and being the person, I can come to when I needed to get things off my chest. Without your support and tons of advice, I would not have been able to end my time at UVA on a positive note.

Thank you to the Virginia Education Science Training (VEST) Predoctoral Program, for supporting my research and development as a researcher.

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305B200005 to the University of Virginia. The opinions expressed are those of the author and do not represent views of the Institute or the U.S. Department of Education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION: DISSERTATION OVERVIEW

Overview of the Literature

Young children engage with many different activities that support their learning on a daily basis. In the frameworks of constructivism and sociocultural theory, children are considered active participants in their learning because they are constructing their own knowledge (Piaget, 1970; Schunk, 2019; Vygotsky, 1978). When children are constructing their knowledge by integrating new and preexisting knowledge, they are engaging in a meaning making process (Cooper 2007; Narayan et al., 2013). Social interactions and experiences with others can scaffold and guide children through the process of making meaning (Schunk, 2019; Vygotsky, 1978). One type of interaction that children benefit from when learning and engaging in different activities is parent-child interactions, which can be observed during book reading, an activity where parents can play a direct role in guiding their children's learning.

Much work has examined parent-child shared book reading experiences as they relate to literacy skills, but more limited work has examined how these reading experiences relate to children's science learning specifically. Prior research on children's ability to learn from books shows that children as young as four-years-old can engage with and learn science concepts from a picture storybook read to them by an adult (Altun, 2019; Ganea et al., 2011; Kelemen et al., 2014). Early science exposure and knowledge plays an important role in that child's later academic success (Eshach & Fried, 2005).

Likewise, early book reading with a parent is predictive of a child's later reading and language success (de Jong & Bus, 2002; Hood et al., 2008; Parish-Morris et al., 2013; Strouse & Ganea, 2017). When reading with their child, parents play an important role in scaffolding the child's learning through story-related dialogue and question asking (de Jong and Bus, 2002; Parish-Morris et al., 2013). Dialogic reading, which is interactive reading of a picture book with an adult, is found to support the development of young children's language and literacy (Hemmeter & Kaiser, 1994; Mol et al., 2008). To use this method, parents can encourage verbal exchanges through question prompts and have the child play an active role during the reading experience (Flynn, 2011; Towson et al., 2017; U.S. Department of Education, 2007).

This study explored two components of parent-child interactions related to dialogic reading that might support children learning: questioning and child utterances. Questioning is an effective strategy that research finds to be beneficial to children's reading experiences. Specifically, children's own question asking can support their learning and cognitive development (Chouinard et al., 2007), as can parent question asking. One type of question that parents can use to scaffold their child's learning is by asking pedagogical questions, in which the parent asks a question but knows the answer, with the goal in asking the question to elicit learning from the child (Jean et al., 2019; Yu et al., 2018; Yu et al., 2019). Research finds that pedagogical questions and question-asking in general support various learning and literacy outcomes such as story retelling and memory, causal learning, comprehension, vocabulary, word learning, and language

skills (Blewitt et al., 2009; Daubert et al., 2020; Fletcher et al., 2008; Kang et al., 2009; Leech et al., 2013; Rowe et al., 2017; Strouse et al., 2013; Walsh & Blewitt, 2006). Parent questions relate to more child talk, and children's self-explanations can aid learning, thus, parent questions during reading might be associated with more child utterances and explanations, which could support their learning of science content in books (Benjamin et al., 2010; Jant et al., 2014; Legare et al., 2009; Legare & Lombrozo, 2014).

One line of research that has shown consistent learning effects from reading science books is that of Kelemen and colleagues, whose research demonstrates that children's understanding of natural selection improves from hearing science books read by a researcher or teacher (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). This dissertation extends this work done by Kelemen and colleagues by examining whether learning from a science storybook can occur when reading with a parent rather than with a researcher. In prior studies, traditional physical print books were used when examining children's learning. In this study, participants instead read a digital book version of Kelemen and colleagues' (2014) natural selection book over a computer screen. An additional goal of this work is to explore whether there is an association between parent pedagogical questioning, child's utterances, and children's science learning from a storybook.

Aims of the Current Study and Methods Overview

The current work has two aims:

Aim 1: This work tests whether there is an association between parents' digital reading of a science book and children's learning about natural selection. The prior research shows consistent positive influences of reading this book on learning; however, the reading was done between researcher-child dyads or in a teacher-led classroom (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). It is much more common for young children to read with a parent than a researcher (Scholastic, 2019); for this reason, the first research question explores whether children still learn as they did in prior studies when reading this book in digital form with a parent.

Aim 2: I explore factors related to parent-child interactions that might relate to children's learning from reading the science book: parent pedagogical questions and child utterances. Specifically, research question 2 tests whether there is an association between the pedagogical questions asked by parents when reading and children's science learning from a storybook. Research question 3 tests whether there an association between frequency of parents' pedagogical questions asked and frequency of child utterances made. Research question 4 tests whether there is an association between child utterances made while reading and their science learning from a storybook. The final question tests to see if child utterances mediate the relationship between parent pedagogical questions and children's science learning.

Methods Overview

Parent-child dyads read a digital children's science book with a focus on natural selection called "*How the Piloses Evolved Skinny Noses"* created by Dr. Deborah Kelemen and colleagues at the Child Cognition Lab at Boston University (2014). When giving directions about the book reading session, all parent participants received directions encouraging them to ask questions. They were informed that these questions could be about things in the book, like words, pictures, or content, or about whatever thoughts they or their child may be thinking about. Before starting the shared book reading session, the child participant completed a pre-test measure to assess what they know about natural selection. After the reading session the child participant completed two post-test measures assessing their knowledge about natural selection and generalization of what was learned from the story.

Research Questions of Interest and Hypotheses

Research Question 1: Are gains in children's understanding about natural selection associated with a shared parent-child digital book reading about natural selection?

- Hypothesis: Children's understanding of natural selection will improve after shared digital book reading with a parent.
- For this question, a repeated-measures ANCOVA was used to explore whether there is a difference in children's scores from pre-test to post-tests, controlling for age and gender. Significant positive change in scores would show that children's

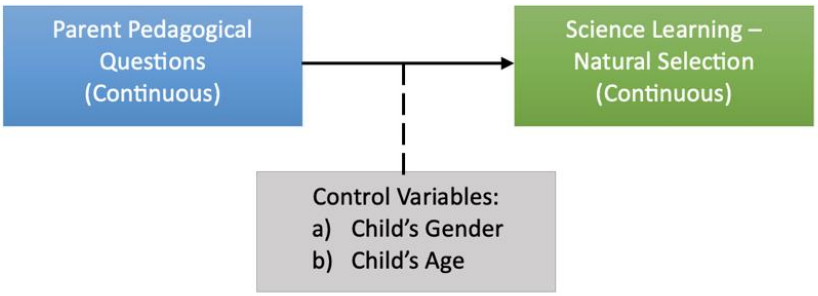
learning of a complex concept like natural selection can occur within the context of shared parent-child digital book reading.

Research Question 2: Is there an association between parent pedagogical questioning during a digital book reading and gains in children's understanding about natural selection?

- Hypothesis: The number of parent pedagogical questions will positively relate to children's learning from a storybook.
- This question is asked to test if variability in parents' pedagogical questions predicts variability in children's learning of natural selection. The repeated-measures ANCOVA test from RQ1 was used to explore and answer this question by including the total number of parent pedagogical questions as a covariate. An interaction between parent pedagogical questions and test time would suggest that the frequency of a parent's pedagogical question asking relates to their child's learning of natural selection (See Figure 1-1).

Figure 1-1:

Model of Research Question of Interest 2

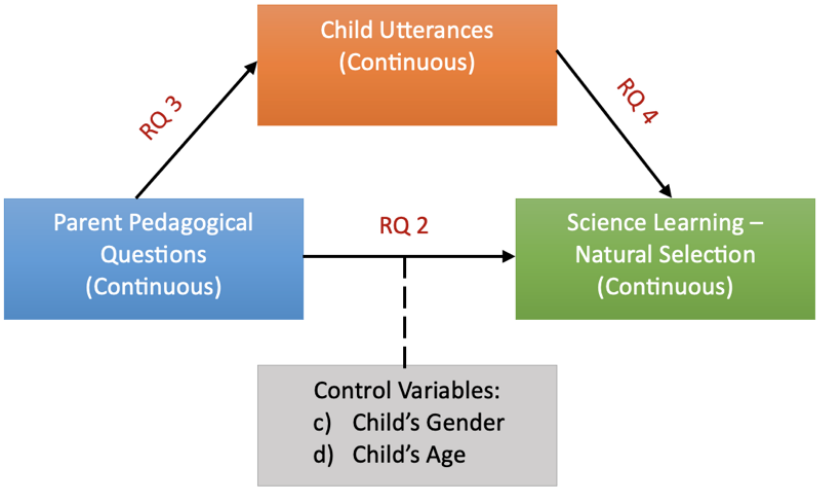


Research Question 3: Does frequency of parent pedagogical questioning relate to frequency in child utterances?

- Hypothesis: More frequent parent pedagogical questions during shared book reading will relate to more frequency in child utterances.
- The purpose of this question is to explore further how parents' pedagogical questions support children's learning. One possibility is that the pedagogical questions asked by parents may get children to talk more about the content covered in the book. A linear regression test is used to explore and answer this question. If the hypothesis is supported, it would mean that more parent pedagogical questions relate to greater verbal engagement from the child. This verbal engagement can be thought of as a way in which the child is actively engaging with the shared book reading task. So, greater instances of children's utterances should be seen with more parent pedagogical questions.

Figure 1-2:

Mediation Model Consisting of Research Questions of Interest 3, 4, and 5



Research Question 4: Is there an association between child utterances during parent reading of a digital storybook and gains in children's understanding about natural selection?

- Hypothesis: The number of child utterances will positively relate to their science learning from a storybook.
- The repeated-measures ANCOVA test from RQ1 was used to explore and answer this question by including the total number of child utterances as a covariate. If an interaction between child utterances and test time is found to be significant this would suggest that the pattern of change in natural selection understanding from

pretest to posttest differs with the number of children's utterances made while reading.

Research Question 5: Do child utterances mediate the relation between parent's pedagogical question asking and gains in children's understanding about natural selection?

- Hypothesis: The number of children's utterances will mediate the relation between the number of parents' pedagogical questions asked and children's science learning.
- The purpose of this question is to explore whether children's utterances can explain the association between parents' pedagogical questions and children's science learning. Structural equation modeling is used to explore and answer this question. If a mediation is found that would mean that the number of children's utterances partially mediates the association between the number of parent's pedagogical questions asked and children's science learning (See Figure 1-2).

Additional Planned Analyses – Exploratory Questions

The research questions of interests for this study focus mainly on analyzing parents' pedagogical questions during shared book reading, but research shows that parents' question asking in general can aid a child's learning on various learning and literacy outcomes (Blewitt et al., 2009; Kang et al., 2009; Leech et al., 2013; Rowe et al., 2017; Walsh & Blewitt, 2006). For this reason, the exploratory questions of this study focus on parents' non-pedagogical questions and how they relate to the book reading task

and the topic of natural selection. The major difference between pedagogical questions and non-pedagogical questions is that for pedagogical questions the parent knows the answer to the question, their child assumes they know the answer, and their intention in asking the question is to elicit learning by providing their child an opportunity to do so (Yu et al., 2019). If an association is found between non-pedagogical questions and children's science learning it would suggest that it may not be necessary for parents to know the answer to their questions and/or that their child assumes they know for questions to support learning.

- Exploratory Question 1: What proportion of questions asked by parents are non-pedagogical questions?
- Exploratory Question 2: Is there an association between parent non-pedagogical questions as they relate to the story and children's science learning?

Organization of Dissertation Document

The rest of this dissertation is organized as follows: Chapter 2 reviews the conceptual framework of the study and prior literature on science learning from books, book reading experiences with parents, parent-child interactions during book reading, question asking, and child utterances. Chapter 3 describes the study's research design and methodology. It also explains in greater detail the pre- and post-test measures and the parent-child book reading session. Chapter 4 presents my results and whether my hypotheses were confirmed. Finally, Chapter 5 includes a discussion of the results in the context of how it relates to prior literature and what further research can be done.

Appendices A-D includes the protocols and materials that were used for data collection, additional analyses, and the IRB approval.

Chapter 2

LITERATURE REVIEW

I begin this chapter by first describing the conceptual framework for the dissertation which includes constructivism and sociocultural theory, before describing the relevant literature. This conceptual discussion of learning is followed by a discussion of empirical research on science learning and how this can be supported by books. Because my dissertation explores parent's pedagogical questions and whether they can support children's learning in the context of parent-child shared book reading and whether children's utterances mediated the association between parent questions and children's learning of natural selection, I review the literature on children's science learning from books, book reading with parents, parent-child interactions during shared book reading, question asking and parent pedagogical question asking, and child's utterances and speech during book reading.

Conceptual framework

The learning theories of constructivism and sociocultural theory provide the theoretical context for this study. Constructivism has been shaped by the work of Jean Piaget and Lev Vygotsky. In this framework, an individual, the learner, is an active participant who constructs the knowledge they are learning. This knowledge can be thought of as the schemas or representations an individual has about what they are learning. These representations are later used by the individual to make hypotheses about situations they are in or to create expectations (Akpan & Kennedy, 2020; Piaget, 1970;

Schunk, 2019; Vygotsky, 1978). When a learner encounters new knowledge that contradicts their current schemas, they can decide to evaluate and modify their schemas (Narayan et al., 2013). This can be thought of as part of the process of learning because the learner constructs knowledge through the integration of new and preexisting knowledge and engages in a meaning-making process (Cooper 2007; Narayan et al., 2013). The process of learning can also occur when the learner discovers new ideas, connections between preexisting schemas, and the basic principles of a topic of focus (Bruner, 1967; Narayan et al., 2013; Schunk, 2019; Vygotsky, 1978). This discovery can occur through manipulation of materials and/or social interactions (Schunk, 2019; Vygotsky, 1978).

Students' learning can be spurred through the manipulation of materials, which demonstrates the importance of cultural tools as stressed by Vygotsky in his sociocultural theory (Vygotsky, 1978). Some examples of cultural tools include books, media, language, and writing (Code & Zaparyniuk, 2009). These tools can be explained as "something that can be used in the service of something else" (Lauricella et al., 2014, p. 18). In other words, tools can be used to make meaning of both social interactions and other occurrences in one's external environment (Vygotsky, 1978). In this dissertation, I explore the social tool of a science book designed to support young children's developing understanding of natural selection (Kelemen et al., 2014). When this type of advanced materials or tools are delivered at a level just above a child's current ability to be successful independently, but within a level possible to achieve with support, tools can be

quite effective in helping to advance a child's cognition because of the scaffolding support they provide within the child's zone of proximal development (ZPD) (Lauricella et al., 2014; Vygotsky, 1978; Wood et al., 1976).

Wood et al. (1976) expanded upon the concept of scaffolding by describing it as a process that occurs over a series of steps as it pertains to problem solving. The different components of this process are generalizable across contexts. The first step of this process is recruiting the child's interest in the task at hand and having the child adhere to any requirements for the task. The second involves simplifying the task which allows the child to figure out whether they can achieve any of the requirements for the task. Step three involves the adult maintaining the child's attention on the task, while also encouraging them to take risks when they are successful at completing the simpler parts of the task (Wood et al., 1976). The fourth step is when the adult emphasizes to the child any relevant information or features of the task. This step could be thought of as the step where cues are given to help the child learn from the task. The fifth step primarily involves the adult helping the child control any frustrations they may have while completing a particular task. In the final step, the adult provides and demonstrates the solution to the task, which can be described as modelling (Wood et al., 1976).

Sociocultural theory suggests that parents can use storybooks as cultural tools to help scaffold their child's learning. A story can be used to help explain different lessons, moral values, societal rules, and other complex concepts (Bowman et al., 2014; Nicholas, 2020). Stories can also be used to help children understand the emotions they are having

in specific situations or future experiences they will encounter, such as going to school for the first time (Parish-Morris et al., 2013). Stories then, in conjunction with story-related parent-child dialogue, can aid in the meaning making process that children go through when making sense of their external surroundings, social interactions, and identify gaps in their knowledge they need to fill (Narayan et al., 2013). These early reading experiences can be thought of as opportunities for parents to introduce their child to new topics and ideas within their zone of proximal development (Bowman et al., 2014). The current study explores parents' use of a storybook as a scaffold for children's science learning, and whether pedagogical questions asked and child utterances made during parent-child shared book reading can support children's understanding and learning of the science concept of natural selection presented in the book.

Children's science learning from books

Prior work on book reading indicates that it is possible for young children to learn from books, though much of this work has examined shared book reading as it relates to children's learning of literacy skills, rather than science content knowledge (Hood et al., 2008; Krcmar & Cingel, 2014; Parish-Morris et al., 2013; Strouse & Ganea, 2017). Several studies, though, have shown that children also have the capacity to learn and understand science concepts from book reading. In these studies, book reading occurred during interactions with a researcher, rather than with a parent (Altun, 2019; Daubert et al., 2020; Ganea et al., 2011; Kelemen et al., 2014).

This current study expands this prior work by examining whether science learning can occur when a parent is the one reading the story. It specifically explores the associations between a parent's questions and children's science learning when reading science books. Furthermore, this study aims to understand whether children can learn a science concept through parent-child digital storybook reading. This is important to consider because early science exposure and knowledge plays a role in a child's later academic success (Eshach & Fried, 2005).

In one example of children's learning from science books, Ganea et al. (2011), in two between-subject experimental studies found that children as young as four were able to learn new biological facts about color camouflaging in animals from books, and to transfer what they learned from the book to real animals. In both experiments, children read a story developed by the researchers that explained why a predator would or would not be able to find a camouflage animal. For half of the children the experimenter read a factual story while with the other half they read an intentional story (Ganea et al., 2011). The factual story included neutral factual language, while the intentional story covered the same facts but included personified animals with names and intentions and desires. Learning and transfer were then assessed by having 104 children (total sample size between the two experiments) look at pictures of animals and explain which of the animals would more likely fall prey to a predatory bird. The authors found that regardless of which story condition a child was in they were able to correctly choose which animal

would fall prey to a predatory bird, indicating that children learned from reading the books (Ganea et al., 2011).

Altun (2019) in a within subject quasi-experimental study with 34 preschoolers compared preschoolers' learning and understanding of the concept of the lunar cycle. Participants read two books and were tested after reading each book. One book was created by the author and included both real images and accurate facts, while the other one was a fictional children's book already in publication that had illustrations with no facts (Altun, 2019). The author found that most of the child participants, after reading the fictional book, had a non-scientific understanding of the moon. This understanding shifted to a more scientific understanding after the children read the book that included real images and accurate facts, again indicating that books can support children's science learning, but also suggesting that the content of the book matters (Altun, 2019).

What Ganea et al. (2011) and Altun (2019) have in common are their findings that show that children who read stories that include factual language and information will be able to gain an understanding of different science concepts. Altun's (2019) study gives a warning that children will have less scientific understanding when reading fictional stories that do not provide facts on the science concepts covered in the story. Based on this prior work, this dissertation uses a storybook that presents factual information on natural selection through a story about how a fictional animal species adapted over time. Using the book used in this dissertation study and similar books developed by the researchers, Kelemen and colleagues explored how to teach children about natural

selection through storybooks across several studies (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). To help children learn about natural selection from books, Kelemen and colleagues created several children's books to describe adaptation by natural selection, including accurate and comprehensive mechanistic descriptions throughout the entire book, realistic pictures, and a factual narrative on a fictional animal species (Emmons et al., 2017; Kelemen et al., 2014). On each page a new adaptation fact is provided and causally connected to one another (Kelemen et al., 2014). In a test of the originally developed book's efficacy for science learning of natural selection the authors tested whether 95 five- to eight-year-old children (total sample size between two experiments) could learn about natural selection through storytelling using picture books (Kelemen et al., 2014). A revised version of the storybook used in the first experiment was used in the second; in both studies children within each sample read the same storybook, and there was no control group. The results for these two experiments found that five- to eight-year-olds were able to learn the population-based logic of natural selection, and older children ages seven and eight were able to generalize the information to new animals after reading the books with a researcher. The authors also found that this learning endured three months later when a follow-up was done after one of the experiments (Kelemen et al., 2014). The current study expands upon Kelemen and colleagues' work (2014) by exploring whether there is an association between a parent's digital reading of a science book and children's

learning about natural selection, and, whether parent's questions, specifically pedagogical questions, and child utterances can support this learning.

The published natural selection book by Kelemen that I use in this dissertation was used in subsequent studies that continue to provide support to children's ability to learn complex science concepts, like natural selection, from storybooks (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). These studies have expanded the initial research to show that children are capable of near and far transfer of the information they learn and their misconceptions about natural selection at least in the short term are reduced after reading, and also that they learn when read the book by a teacher. It is still unknown whether similar learning will be observed when the book is read by a parent rather than a researcher, and when using a digital rather than physical storybook.

Learning from Book Reading Experiences with Parents

Early Book Reading Experiences with Parents

During early childhood, book reading between parents and children is a common activity, with 55% of children between the ages of zero to five and 45% of children ages six to eight experiencing their parents reading aloud to them nearly 5 days a week (Scholastic, 2019). These early shared experiences with parents involve dialogic experiences specifically and are important and predictive of a child's later reading and language success (de Jong & Bus, 2002; Hood et al., 2008; Krcmar & Cingel, 2014; Parish-Morris et al., 2013; Strouse & Ganea, 2017). Parents play an important role in

facilitating their child's understanding of a story by engaging the child in discussions about the story, explaining events in the story, and relating the events of the story to the child's own life (de Jong and Bus, 2002; Parish-Morris et al., 2013). For example, parents facilitate understanding and discussion about a book by using distancing prompts, which encourage the child to relate the story to their life (Parish-Morris et al., 2013). An example of this is a parent asking a question such as, "Would you be nervous like Daniel Tiger if you had to visit a new doctor?" Utterances like this help create a more interactive reading experience for the child where they help their parent "tell the story" while also making connections between their life and the story (Parish-Morris et al., 2013).

Research on the quality of book reading experiences with parents and adults find that these experiences impact factors such as story comprehension, emergent literacy and reading skills, and children's interest in books and reading (Bingham 2007; Reese & Cox, 1999; Sonnenschein & Munsterman, 2002). For example, Sonnenschein and Munsterman (2002) observed parent-child interactions during book reading in 30, five-year-old children interacting with their mothers. The affective quality of interactions was assessed as a composite of physical contact with the child, reading expression, reader's and child's appearance of involvement, and reader's sensitivity to child's engagement. The researchers found that the affective quality of parent-child interactions was predictive of children's motivations to engage in reading, measured by children's responses to a 20-item forced choice questionnaire on children's motivation for reading (Sonnenschein & Munsterman, 2002). In both within-subject and between-subject experimental studies,

early book reading experiences with parents or another adult were associated with children using more words, speaking longer sentences, scoring higher on vocabulary tests, improving in expressive language skills, and developing attention, memory, and learning (Chow et al., 2008; Lever & Sénéchal, 2011; Parish-Morris et al., 2013; Richter & Courage, 2017; Wasik & Bond, 2001). Additionally, linking the child's past and future experiences in life to the story correlates with the child's print knowledge and emerging literacy skills (Parris-Morris et al, 2013).

Reading with Parents Supports Children's Learning

Research finds that reading with parents can support children's learning and understanding of various concepts. For example, Aram et al. (2013) in their experimental study with 58 parent-child dyads with four-to-five-year-olds examined the efficacy of an intervention that was designed to help promote the referencing of storybook plots and socio-cognitive themes (i.e., character emotions, beliefs, thoughts, and intentions) by parent-child pairs. Parents in their experimental study received guidance on how to read to their child. This guidance led to an increase in children's ability to relate the story to their own experiences. They also were able to have better discourse with their parents about the socio-cognitive themes presented in the books that they read. These discussions were supportive of children's developing understanding of socio-cognitive themes (Aram et al., 2013).

Another example, in an experimental study, Leech et al. (2020) studied children's learning in 60 four-to-five-year-olds who read a storybook with their parent about electric

circuits that contained either mechanistic or non-mechanistic explanations. Better learning outcomes on a comprehension post-test was found only when children had more mechanistic discourse with their parent during and after reading the storybook (Leech et al., 2020). Leech et al. (2020) study shows support to the idea of parents helping to facilitate their child's understanding through the use of discussions when reading.

These studies summarized above show how interacting with parents when reading benefits children's ability to learn from books, and specifically how these interactions are language-based, suggesting the importance of both parent and children's language input. However, it is important to also understand how parent-child interactions can support children's learning. Parents can facilitate this learning through scaffolding.

Parent-Child Shared Book Reading

Scaffolding and Parent-child interactions during book reading

There are various forms of scaffolding that parents can use with their children. Wood et al. (1976) touched upon a few of them when describing scaffolding as a process that adults go through when guiding children's learning. Some forms of scaffolding include providing feedback and reinforcement, modeling a preferred behavior, creating an environment that eases the child's ability to complete a task, and maintaining the child's attention on the item or task that the parent wants them to focus on (Ugur et al., 2011; Wood et al., 1976). Parents can also provide cues, such as pointing to and looking in the direction of the item they want the child to shift their focus to, using certain vocal tones, and by asking questions (Ugur et al., 2011). The scaffolding and cues parents

provide to their children can be applied during various activities, including during shared book reading.

During book reading, scaffolding and cues can be used during shared reading by parents in several different ways. For example, a parent may point to a specific sentence in the story to emphasize it because it will play an important role in helping the child comprehend what's about to happen next in the story. The parent may also scaffold the child's learning by asking them to relate something in their personal life to what occurs in the story. If the parent is having trouble keeping the child's attention to the story, they may ask questions for the purpose of seeing if the child is comprehending the story so far or to get the child thinking about what may happen next (Parish-Morris et al., 2013; Towson et al., 2017). Reading interactions that involve reciprocal dialogue are labelled dialogic reading and are a common way that scaffolding during shared book reading has been studied, especially in regard to associations with literacy outcomes.

The benefits that parent-child interactions during reading have on children's learning of and gains in literacy skills are thought to be influenced by different factors like children's attitudes towards reading, individual literacy skill differences, and how often the child is read to (Robbins & Ehri, 1994; Scarborough & Dobrich, 1994), but overall findings on the association between parent-child interactions and the development of children's language and literacy skills show mixed results. Scarborough and Dobrich (1994) reviewed and synthesized 31 studies that examined the influence of parent-child read aloud experiences on the development of language and literacy skills. For some of

the studies reviewed, the authors reported effect sizes that were moderately positive. However, based on the variability of the results and methods used in the reviewed studies, the strength of the association between parent-child reading interactions and children's development of language and literacy skills was inconclusive across studies (Scarborough & Dobrich, 1994). Possible explanations suggested for the variability found in the results were limitations in statistical power of the reviewed studies and variations in how parent-child reading, and children's language and literacy skills were measured. Most of the studies reviewed were correlational studies (N = 20), and their results suggest that the outcome variables (i.e., achievement scores, emergent literacy skills, and oral language abilities) were poorly predicted by the qualitative aspects of parent-child reading as compared to frequency of shared reading. In contrast, intervention studies demonstrated that high-quality parent-child reading was associated with improvement in child language and literacy skills. This review showed that the connection between parent-child read-aloud experiences and children's language and literacy development is nuanced because there may be different interactions of shared reading that have not been considered, such as gender beliefs parents and children hold towards reading. Scarborough and Dobrich (1994) recommended that more work be done on examining methods and other aspects of parent-child shared reading that are beneficial.

Dialogic reading

One method that research finds beneficial to parent-child dyads' reading experiences is dialogic reading (Hemmeter & Kaiser, 1994; Mol et al., 2008; Mol et al.,

2009; Towson et al., 2017). Dialogic reading is defined as "an interactive shared picture book reading practice designed to enhance young children's language and literacy skills. During the shared reading practice, the adult and the child switch roles so that the child learns to become the storyteller with the assistance of the adult who functions as an active listener and questioner" (U.S. Department of Education, 2007, p. 1). This differs from the parent-child read aloud experience as studied by Scarborough and Dobrich (1994) where the parent is the main storyteller and the child role is to mostly listen. The child is not the most active participant in the read aloud experience as compared to the dialogic method, where conversational responses from the child are more encouraged (Ezell & Justice, 2005).

Mol et al. (2009) in a meta-analysis reviewed 31 quasi-experimental studies to examine the dialogic reading method and its effects on children's language and literacy development. They found that dialogic reading led to growth in children's oral language, print knowledge, and expressive vocabulary skills (Mol et al., 2009). Similar results for vocabulary and language growth were found in Whitehurst et al.'s (1998) experimental study. Using 29 children participants ranging between the ages of twenty-one and thirty-five months old, Whitehurst et al. (1998) examined whether maternal picture book reading would have a direct impact on children's language acquisition. The experimental group received a 4-week treatment program that provided them with assignments instructing them to alter the frequency and timing of different aspects of their child-directed speech while reading. Parents in the control group were instructed to read as they

normally would. The authors found that children in the experimental group scored significantly higher than those in the control group on the post-test measures for vocabulary and language. They also had a higher frequency of phrases and a higher mean length of utterances (Whitehurst et al., 1998).

The vocabulary and language growth found by Mol et al. (2009) and Whitehurst et al (1998) can be attributed to the fact that dialogic reading involves when an "adult uses specific question prompts to encourage children to talk during book reading" (Towson et al., 2017, p. 132). By encouraging children to engage in verbal exchanges during reading, parents can be deliberate in how they are scaffolding their child learning (Flynn, 2011; Whitehurst et al., 1998). Although the use of this method is found to be beneficial to children, observational studies suggest that parents do not spontaneously use dialogic reading methods (Britto et al, 2006; Silvén et al 2003).

The research on the dialogic method provides support and understanding about how shared parent-child experiences can be effective in leading to children having learning gains in language and literacy. It is likely that similar gains to those observed in children's language and literacy development from dialogic reading would be present in other domains, such as science learning. This current study explored whether reading that involved dialogue between a parent and a child can support children's gains in science understanding of natural selection. Parents were not explicitly instructed or trained to use dialogic reading approaches as defined above, but they were asked to read the story as they would typically read to their child, and to ask questions often, which might have

created interactions that included features of dialogic reading, and could potentially improve children's understanding of natural selection.

Parent-child interactions and Science learning

Parent-child interactions and/or dialogue can boost the benefits of early science exposure and knowledge for children's science learning (Benjamin et al., 2010; Haden et al., 2010; Tare et al., 2011). For example, children learn more about science concepts when their parents engage them in elaborative conversations during parent-child interactions in museums (Benjamin et al., 2010; Callanan et., 2017; Haden et al., 2010; Jant et al., 2014; Tare et al., 2011).

Benjamin et al. (2010), in a factorial experimental design study with 121 four- to-eight-year-old children and parents randomly assigned dyads to one of five conditions in which they received either building instructions, conversation instructions, both types of instructions (building + conversation), no instructions, or a presentation on models of buildings and conversations but without instruction. Results showed dyads who received conversation instruction asked more *wh*-questions, made more associations that linked any aspect of the exhibit to their prior knowledge or past experiences, and engaged in more joint talk as compared to those who received building instruction alone or no instruction at all (Benjamin et al., 2010).

Similar results were found by Jant et al. (2014) who in an experimental study with 78 three- to-six-year-old children and parents randomly assigned dyads to conditions where they either received conversation cards that included elaborative questions (*wh*-

questions), a set of physical objects, the conversation cards and the set of physical objects, or did not receive either the cards or objects. These conditions were assigned before the dyads visited two natural history exhibits. Like the dyads in the conversation instruction condition in Benjamin et al.'s (2010) study the dyads in Jant et al.'s (2014) study who received the conversation cards experienced more elaborative talk and joint nonverbal activities. Those who received the conversation cards transferred more information and made connections between exhibits. The same way dyads in the conversation instruction condition in Benjamin et al.'s (2010) study made connections between aspects of the exhibit and their prior knowledge or past experiences.

This research on parent-child interactions in museums tells us that parents have the ability to guide their children's science learning. It also tells us that when parents are given remainders or cues to engage with their child in the learning activities, they are doing together, children are able to learn more from the experience and engage with science on a deeper level versus on a surface level. Informed by this prior work, the current study provides parents with directions that encourage them to ask questions while reading to their child before the shared reading activity. A cue parents are given while reading is a question mark that can be found on some of the pages in the story to remind them to ask their child a question. Furthermore, the findings reported in studies summarized in this section support the literature on children's science learning from books showing that young children are quite capable of understanding, engaging with, and learning science concepts when given the opportunity.

Recent work done by Shirefley et al. (2020) supports this point further. In their experimental study, which examined within-cultural group family conversations about science concepts when reading a storybook, children from 65 families had the option of completing the study either at their homes or in a lab where they were video recorded. Parent-child pairs read a published age-appropriate storybook about the sun; the book provided them opportunities to talk about science and the story (Shirefley et al., 2020). Recordings were coded for amount of text read by the parent, parents' extra-textual talk, and parents' elaborative talk. Parents' elaborative talk was coded into the categories of science, fantasy, personal connections, describing, labeling, the book as an object, and other forms of extra-textual talk. Importantly, the researchers included samples of both European-American families and Latin American families and found that both cultural backgrounds had similar patterns of elaborative discussion about the science concepts in the book (Shirefley et al., 2020).

The research work discussed above provides support to the idea that science learning can occur within parent-child interactions and even book reading. These studies suggest that children might even learn from a digital book with parents during joint reading, but this hasn't yet been tested empirically. This study will try to address this gap and provide further support to the literature on parent-child interactions and the benefit it can have for children's science learning.

Components of parent-child interactions

Question asking

Research finds question asking to be valuable to a child's reading experience with their parent. During reading interactions and more general parent-child interactions, questions can support children's learning and cognitive development (Chouinard et al., 2007). Chouinard and colleagues (2007) consider question asking as a mechanism for cognitive development. Research examining children's question asking shows that asking questions allows children to actively collect information from others and explore and target the information they need to fill gaps in their knowledge (Chouinard et al., 2007; Jean et al., 2019; Ronfard et al., 2018; Yu et al., 2019). When asking questions, children are also relying on the adults around them to scaffold their learning and exploration on topics of interest and/or problems that they are trying to solve (Jean et al., 2019). Children's learning is not only aided by their own question-asking, but it is also aided when parents ask questions. This study focuses on parents' questions, because they can be used both as a tool for scaffolding and as a tool for helping children to actively participate in their learning experiences.

Parent (adult) question asking and pedagogical questions

Parents engage in question asking with their children as early as 5 months old (Bornstein et al., 1992). By asking questions parents can guide their child's thoughts and help scaffold learning by engaging children within their zone of proximal development (Anderson et al., 2012). Much work has been done to examine the association between

question asking and different learning and literacy outcomes for children, such as vocabulary, word learning and comprehension, story retelling and memory, language skills, and causal learning (Blewitt et al., 2009; Daubert et al., 2020; Fletcher et al., 2008; Kang et al., 2009; Leech et al., 2013; Rowe et al., 2017; Strouse et al., 2013; Walsh & Blewitt, 2006). A lot of this work has been done with children between the ages of two and five years old and has found that questions can facilitate growth in language and literacy outcomes.

For example, Walsh and Blewitt's (2006) experimental study with 35 three-year-old children examined question asking and preschoolers' acquisition of novel words during shared storybook reading sessions. Children were randomly assigned to one of the three storybook reading question conditions: vocabulary eliciting questions, non-eliciting questions, and no questions (Walsh & Blewitt, 2006). An experimenter read three storybooks to the children repeatedly over four reading sessions and in the final session tested children for comprehension and production of novel words presented to them in the stories. Children in the vocabulary eliciting questions and non-eliciting questions conditions were asked six questions per story which were interspersed throughout the reading sessions. The authors found that children in the conditions where questions were asked experienced an increase in their novel word comprehension (Walsh & Blewitt, 2006). This study showed how questions in general could be used to scaffold children's learning.

There are different types of questions parents can ask to aid their children's learning, but parents who ask their children questions with the intent of teaching are using what researchers call pedagogical questions (Jean et al., 2019; Yu et al., 2018; Yu et al., 2019). What makes pedagogical questions different from other types of questions (i.e., information seeking or rhetorical questions), is the fact that the person asking the question knows the answer to it and their goal in asking their question is to elicit learning (Jean et al., 2019; Yu et al., 2018; Yu et al., 2019). An example of this would be if the parent and child are doing an at-home science experiment and the parent instead of just telling the child what will occur asks a question such as, "What do you think will happen next?" By asking pedagogical questions the parent is giving their child the space to think about and explore more deeply the topic they are learning about (Jean et al., 2019; Yu et al., 2018). The child is sensitive to the parent's intention that the goal is to learn.

Not only are children sensitive to the intention of pedagogical questions asked of them but they are also sensitive to the pedagogical cues they receive from their parents and other adults that signal an intention to provide the child with information that will be beneficial to them (Butler & Markman, 2014; Yu et al., 2019). Types of pedagogical cues include eye contact, joint attention, and child-directed speech (Butler & Markman, 2014; Csibra & Gergely, 2009; Yu et al., 2018). As children get older, they continue to use these cues while also considering the knowledge state of the individual asking them the question (Yu et al., 2019).

Jean et al. (2019) in an experimental study with 100 four-to-six-year-old children examined whether pedagogical questions empowered children's perseverance when working on a difficult problem-solving task with a machine. They found that children in the condition where they were asked a pedagogical question (e.g., *"what happens if you change these sliders?"*) before interacting with the machine attempted more hypothesis-test interventions to try solving the problem of making the machine work compared to those in conditions that included direct instruction, overheard naïve questions, or overheard pedagogical questions (Jean et al., 2019). When examining exploration, children who heard a pedagogical question attempted more hypothesis-test interventions and the number of unique actions done during the play time with the machine. Although this study did not examine pedagogical question asking in parents, it provides support to the notion that a knowledgeable adult's pedagogical questions can encourage exploration and perseverance in solving a problem. Jean and colleagues (2019) found that in the context of problem solving, pedagogical questions are supportive of exploration, which is consistent with broader research showing the effectiveness of questions in supporting learning.

Recent work by Daubert et al. (2020) examined pedagogical questions and preschoolers' memory and learning from psychosomatic storybooks. Their experimental study with 73 preschoolers examined whether children could learn about cause and effect from storybooks and specifically the tricky concept of psychosomatic reasoning which involves understanding that psychological causes can affect physical outcomes (Daubert

et al., 2020). A psychosomatic example would be feeling stress or frustrated, with these feelings then causing a headache. The authors examined how swapping instructional language with pedagogical questions in psychosomatic storybooks improved preschoolers' memory and learning. Preschoolers were randomly assigned to one of three storybook conditions where they were read books that had either direct instruction, pedagogical question, or control content. The authors found that children in the condition that read storybooks that included pedagogical questions in them had improved psychosomatic understanding (Daubert et al., 2020). Although parent pedagogical questions asking is not examined, this study and Jant et al.'s (2019) study show that children are sensitive to the intention and goal conveyed by the pedagogical question which is for them to learn (Jean et al., 2019).

Building off this work, this study investigates whether pedagogical questions asked by parents support children's learning of a science concept in the context of shared parent-child reading. The goal of pedagogical questions is to elicit learning when paired with a children's science book written with the intent to teach, so questioning should lead to children making gains in their understanding of the science concept covered in the story.

Child Utterances

The literature on parents' questions shows that they are one component of parent-child interactions that are supportive of children's learning. Parents' questions and speech have been found to also encourage more child talk or dialogue between parent and child.

Benjamin et al. (2010) and Jant et al. (2014) in their work examining parent-child interactions in museums found that children participated in more joint and elaborative talk with their parents when asked more open-ended questions (i.e., where, why, what, and how) and when connections are made between the exhibit and the child's prior knowledge. Further, the literature on children's explanations or self-explanations shows that these utterances can aid children's learning, especially their science and causal learning (Legare, 2014; Legare & Lombrozo, 2014; Lombrozo, 2006; Wellman, 2011). For example, Legare et al. (2009) found that children's scientific reasoning about a biological phenomena was aided when they had to provide explanations to vignettes on the phenomena. Legare and Lombrozo (2014) found that children's self-explanations, when doing a problem-solving task involving a gear machine, supported their learning of causal mechanisms. What this literature helps to show is that child explanations and utterances can be helpful in understanding children's thinking and meaning-making process.

In this dissertation, I am examining whether there is an association between parents' questions asked while reading and children's utterances. Specifically, I am exploring whether the frequency of parents pedagogical questions will relate to the frequency of child utterances but in the context of shared parent-child reading. As discussed above, parents' questions and speech led to more utterances and explanations by children, suggesting that child utterances should relate to parent pedagogical questions. I am also examining whether there is an association between children's

utterances and their science learning of natural selection. If children's learning can be aided by their self-explanations, then children's utterances while reading a book on natural selection with their parents should contribute to children's learning and understanding of natural selection. Because the prior literature suggests that children's learning might benefit from their self-explanation, which could be prompted by parents' questions, I am also exploring whether children's utterances will mediate the association between parent questions and children's science learning of natural selection.

The gaps being addressed and why studying this topic matters

What gaps in the literature are being addressed?

Past research has largely examined shared parent-child book reading as it relates to children's literacy development, but limited work has been done examining how parent-child shared book reading experiences impact children's learning of and engagement with science concepts. This study seeks to explore this gap further and extend prior work in several ways. First, it expands upon Kelemen and colleagues work (2014) by having parents be the reader as opposed to a researcher and using a digital book. Parents should not differ from researchers when reading the storybook. This is because the story was written with the intention of helping children learn through the inclusion of accurate and comprehensive mechanistic descriptions about adaptation by natural selection (Emmons et al., 2017; Kelemen et al., 2014). Previous studies presented the books in a physical format, in this study I am presenting the exact same story but in a digital format on a computer screen. Specifically, photos of the book and its pages were

taken and animated in a PowerPoint program to make it appear like pages were turning. The bulk of research suggests that there are no differences between digital and physical print formats in the context of parent-child engagement while reading (Law et al., 2018).

Why does studying parent-child shared book reading matter?

The benefits that parent-child shared reading experiences have on young children's development cannot be minimized. These experiences provide children multiple opportunities to be intellectually challenged, to pinpoint and close any information gaps they may have, to help them process information, and make connections between what they know and what they are learning. Furthermore, these shared parent-child experiences can provide the child with the opportunity, when done right, to be an active learner. Children can become active learners when their parents can guide their learning and understanding within the child's zone of proximal development. It is important to study these experiences because they can have an influence on children's later academic success as children begin and move through formal schooling (Eshach & Fried, 2005). Thus, the aims of this study are to extend the literature discussed here in two ways: 1) by examining whether children's science learning can still occur in the context of parent-child shared book reading with a digital book and 2) by examining whether parents' pedagogical questions and children's utterances can support children's learning of the science concept of natural selection.

Current Study

The most general research question of interest for this dissertation is: do children learn from reading a storybook about natural selection with their parents? I expected children's natural selection understanding to improve after shared digital book reading with a parent. This hypothesis is based on the findings of prior research that found positive influences on children's learning of natural selection when reading a storybook on the topic in researcher-child dyads and teacher-led classrooms (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). Learning should also occur with parents because of the use of a storybook that been written with the intention to teach a complex science concept (Kelemen et al., 2014). Furthermore, learning outcomes in terms of literacy and language development were found for children in the context of parent-child shared reading experiences (Chow & McBride-Change, 2003; Chow et al., 2008; Lever & Sénéchal, 2011; Parish-Morris et al., 2013; Richter & Courage, 2017; Wasik & Bond, 2001).

Since for the first question, I expected variability in learning based on the prior work, my subsequent research questions explore how elements of the reading experiences might support learning. One such element being explored is pedagogical questions. My second research question of interest is: is there an association between parent pedagogical questioning during digital book reading and gains in children's understanding about natural selection? I expected parent pedagogical questions to associate with children's learning from a storybook on natural selection. This hypothesis is based on the literature

which find that pedagogical question can be used by parents to scaffold their child's learning because the intention and goal of asking these questions is to elicit learning (Jean et al., 2019; Yu et al., 2018; Yu et al., 2019). Children's causal learning and exploration and perseverance in problem solving were found to be supported by pedagogical questions (Daubert et al., 2020; Jean et al, 2017).

Expanding on the focus of my second research question of interest, I'm also interested in understanding how parents' pedagogical questions support children's learning. My third research question of interest asks: does more frequent parent pedagogical questioning relate to more frequency in child utterances? I expected more frequent parent pedagogical questioning during shared book reading to relate to more frequency in child utterances. This hypothesis is based on findings that showed that more elaborative and/or joint talk between parent and child occurs when parents included more questions in their discussions during learning experiences with their child (Benjamin et al, 2010; Jant et al., 2014).My fourth research question of interest expands on the third question by asking: is there an association between child utterances during parent reading of a digital storybook and gains in children's understanding about natural selection. I expected child utterances to relate to their science learning from a storybook. This hypothesis is based on prior literature findings that show that children's self-explanations can aid their science and causal learning (Legare, 2014; Legare & Lombrozo, 2014; Lombrozo, 2006; Wellman, 2011).

My final research question asks: do child utterances mediate the relation between parent's pedagogical question asking and gains in children's understanding about natural selection? This question is a mediation model that is based upon all the literature covered in research questions two, three, and four. The purpose in asking this question was to examine whether children's utterances can explain the association between parents' pedagogical questions and children's science learning. I expected that children's utterances would partially mediate the relation between parents' pedagogical questions and children's learning of natural selection.

Chapter 3

METHODOLOGY

Recruitment and Participants

Twenty-five parent-child dyads with children ages 7-8 (M = 7.64, SD = .49; 15 boys) are included in this dissertation study. Race and ethnicity information for child participants was collected; 60% were White, 12% were Black, 8% were Asian, and 20% were two or more races. For ethnicity, 88% were non-Hispanic and 12% were Hispanic. Parents were recruited for online participation via a list of families who signed up to participate in studies on cognitive development through the Cognitive Development Society Digest listserv, websites designed to connect interested families with researchers, such as Children Helping Science, the participant database used in the Research in Education and Learning Lab (REAL) at the University of Virginia, and on social media accounts such as Twitter and Facebook. Parents who signed up to participate received a link to a Qualtrics form to collect consent via email prior to the scheduled date of their reading session with their child. They were also asked before the session began to use a laptop or desktop computer for the study.

Data collection took place remotely using the web application Zoom due to COVID-19. All parent-child dyads received two $10 Amazon gift card codes, which is enough to purchase a hard copy of the science e-book they read during the session or something else of their choice. Data collection for the dissertation began mid-February 2022 and continued with a planned stop of either April 1, 2022, or until a sample size of

at least 24 dyads was reached (this was achieved at the end of April 2022). Recruitment and study procedures have been approved by the University of Virginia's Institutional Review Board (Protocol #4705).

Materials and Procedures

All materials and measures were adapted from prior research to be such that all study activities could be conducted in a single session via Zoom. Parents were provided a consent document and an online questionnaire via Qualtrics that included basic demographic questions prior to their study session appointment. Participation in the study took place in one 45–60-minute session. The experimenter obtained both written and verbal consent for video recording and answered any questions from the parents before beginning the study. After receiving consent, the experimenter conducted a set of technological checks with the parent to ensure that their Zoom screen was in full screen mode, the parent and child could not see their own video, and that the sound was working properly. Parent-child dyads then played a warm-up game with the researcher to help the child and parent get comfortable and build a rapport with the experimenter. Afterwards, the child completed a short pre-test. Dyads then read a digital science storybook together, with all parent participants given directions encouraging them to ask questions. After the shared storybook reading time, children completed two post-test measures.

The technology checks were designed and made publicly available by the Stanford Social Learning Lab and the warm-up activity was designed by the Research in

Education and Learning Lab (REAL) at the University of Virginia. Scripts for all materials and measures are included in Appendices A and B.

Warm-up Task

This task was adapted from the REAL lab at the University of Virginia and includes a "I spy"-style game played by parent and child with the researcher. The purpose of this task is to help children feel comfortable in the context and build rapport between the experimenter and the parent-child dyad. The experimenter explained to the parent and child that they have a quick game that they both can participate in. The experimenter then shared their screen and presented an image that has a set of items sporadically placed (Figure 3-1). The experimenter gave directions for the game and had the parent go first in selecting an object in the picture and giving a hint about it to help their child find the object, with the child being allowed to ask questions for more hints as needed to figure out what the object is. The parent started the game by saying a statement like, "I spy with my little eye an object that is red and can be found on shirts. Can you find the object that is red and can be found on shirts?" The parent then gave their child some time to guess. If the child guessed incorrectly, the parent had their child guess again and repeated the hint given to them earlier. Once the child guessed correctly, they then performed the same task and had their parent guess the object. After doing the task with their parent, they performed the same task with the experimenter. In my lab's prior experience running studies on Zoom, this game is effective in helping children become oriented to the Zoom

screen and direct their attention to the materials and provide support for them to feel comfortable verbally interacting with the researcher over Zoom.

Figure 3-1:

Warm-up task: "I spy"-style game

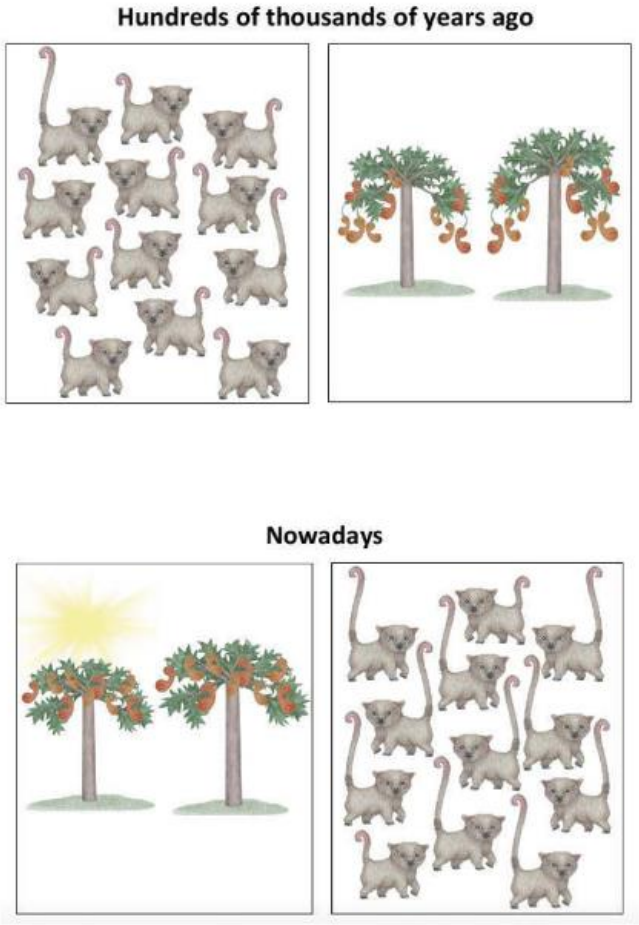
Pre-test task

The pre-test task and the post-test tasks were all adapted from Kelemen et al. (2014). After conducting the warm-up task, the experimenter tells the child that they have another activity just for them to complete. This activity was the pre-test task. The child was asked if they would like to proceed, and their parent was asked not to intervene or help their child during this task. The purpose of the pre-test task was to get a sense of what the child knows about natural selection. The child was presented with two sets of images of a novel animal species not covered in the storybook they read with their parent or in the post-test tasks. The first set of images showed what the species and their

environment looked like hundreds of thousands of years ago, while the other set of images showed what the species and their environment look like nowadays (Figure 3-2).

Figure 3-2:

Pre-test Task



The experimenter first displayed the images and gave a brief explanation about the species. The child is given an explanation like the one below:

"Here we have a group of tardons. I want to tell you more about them! This is what the group of tardons looked like many hundreds of years ago. Many had stumpier tails and a small number had stretchier tails. This is where the tardons lived and what they ate, the orange melons, many hundreds of years ago. But then the weather became very hot and sunny all of the time, and now the melons mostly grow on the tops of trees. So, this is where tardons live and what they eat, the orange melons, now. And this is what the group of tardons looks like now. They mostly all have stretchier tails. Now I have some questions about the tardons that I would like for you to answer. I will keep the pictures up on the screen so you can use them to help you."

Once the brief explanation was given, the child was asked a set of ten questions (six closed-ended and four opened-ended) all related to natural selection based on the species presented to them. With the closed-ended questions the child was given two answer choices to choose from (Figure 3-3) and then asked to explain their choice, while for the open-ended questions the child viewed the set of images shown to them when given the brief explanation of the fictional species. The child, for example, was asked something like "Nowadays will a tardon with a stumpy tail probably be healthy and live for a long time? Why?" When the child completed the pre-test task they were told "Thank you for giving your response!" All ten questions can be found in Appendix A.

Figure 3-3:

Presentation of closed-ended questions' answer choices

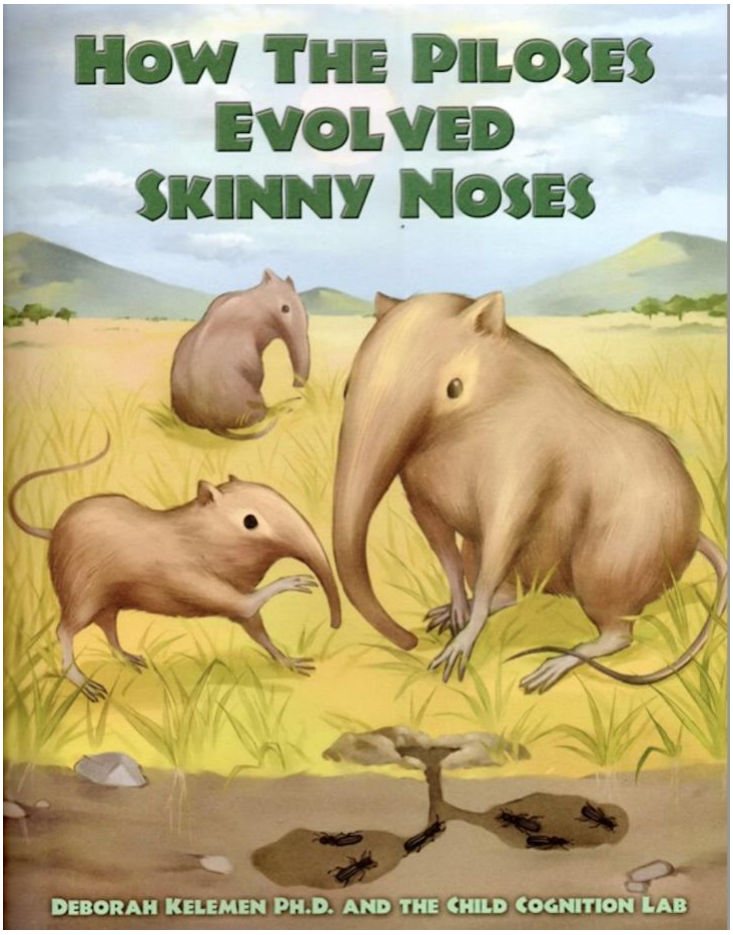
Book reading session

Once the child completed the pre-test task, the experimenter gives directions for the shared storybook reading session. All parent-child dyads read the science picture children storybook titled "*How the Piloses Evolved Skinny Noses?*" created by Dr. Deborah Kelemen and colleagues at the Child Cognition Lab at Boston University (2017). The 23-page picture storybook on natural selection uses realistic pictures and a factual narrative with nonteleological, nonintentional language to answer the question

presented at the beginning of the story, "*How the Piloses Evolved Skinny Noses?*" (Kelemen & the Child Cognition Lab, 2017; Figure 3-4). The story describes how piloses, a fictional anteater species, adapted over time as rising temperatures cause their food source of insects to move from above ground to deep thin underground tunnels (Kelemen & the Child Cognition Lab, 2017; Ronfard et al., 2021). This change led the piloses with the infrequent trait of long skinny noses to be better able to catch insects compared to the piloses with wider noses who were more numerous in the population. This resulted in the piloses with long skinny noses living longer, being healthier, and reproducing more than the piloses with wider noses. The story then explains how this process repeats itself over multiple generations leading to those with long skinny noses to be more numerous than the piloses with wider trunks (Kelemen & the Child Cognition Lab, 2017; Ronfard et al., 2021).

Figure 3-4:

Storybook: How the Piloses Evolved Skinny Noses



The storybook was adapted to a digital version for the current study using PowerPoint. Pictures of the pages in the physical version of the story were embedded into PowerPoint slides so that each page in the digital version looks as close as possible to each page in the physical version. Animated transitions gave the parent-child dyads the chance to click through the pages in a way that simulates physical page turning.

Parent-child dyads all received the same directions encouraging them to ask questions. The direction they heard was:

"You and your parent [mom/dad] will now get a chance to read together. Before you both begin, here are some directions. Mom/Dad please read the story to [child name] and try to ask them questions while reading. These questions could be about things in the book, like words, pictures, or content, or about what you or your child may be thinking about. For example, you might ask something like "How do you think the animals get their food?" or "Which animals have more babies?". You can ask your child as many questions as you'd like, but please try to ask a question at least every four or so pages. A Question Mark will be shown in the corner of some pages to help remind you to ask your child a question. If you forget that's okay. I will now share my screen with you and allow you to turn the pages of the digital book. I'll be working on some other items of mine while you are reading. When you finish reading you can get my attention by saying, "Hello, we have completed the story," and I'll return to do an activity with [child name]. Do either of you have any questions?"

A technological check was performed to make sure that parents had access to the storybook and could click through the pages. In this check, parents clicked through a set of practice pages and not the story itself. To make the parent-child dyad feel more comfortable the experimenter lets them know that while the dyad is reading, they will be working on some other items with their camera off and their microphone muted. The experimenter then lets the parent know that if there are any technology problems or if

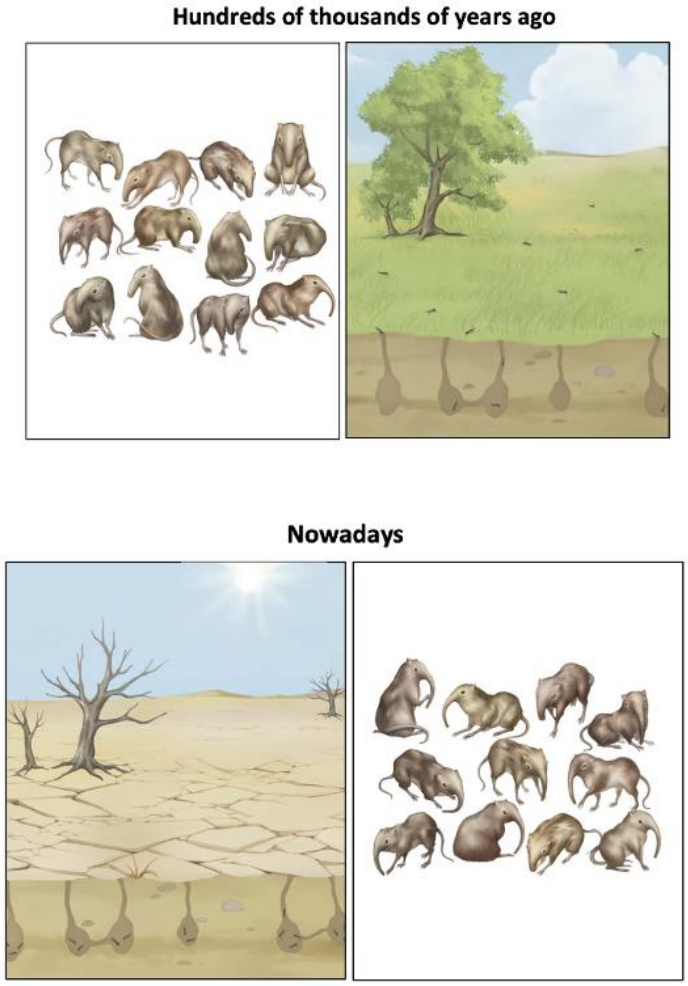
they need help in clicking through the story they will be there to help. The experimenter also informed the dyad that once they are finished reading the storybook, they can get the experimenter's attention by verbally saying they have completed reading the story.

Post-test tasks

The post-test tasks occurred after the shared book reading session when the experimenter was notified by the parent or child that their reading session was complete. The experimenter then let the child know that before the study session ends, they have two final activities for the child to complete. Like the pre-test, parents were asked not to intervene or help their child during these tasks. The experimenter then asks the child if they are ready to begin. Once the child agreed to continue the experimenter shared their screen and showed a similar set of images to what was shown in the pre-test. However, in this first post-test task, the child was shown a set of images related to the piloses that they just read about in the story (Figure 3-5). The purpose of this first post-test task was to examine whether children understand the specific natural selection process explained in the story that was read to them by their parent. The experimenter gave a brief explanation about the piloses. Once the explanation was given the child was asked a set of ten questions all related to natural selection as it relates to the piloses.

Figure 3-5:

Post-test Task 1

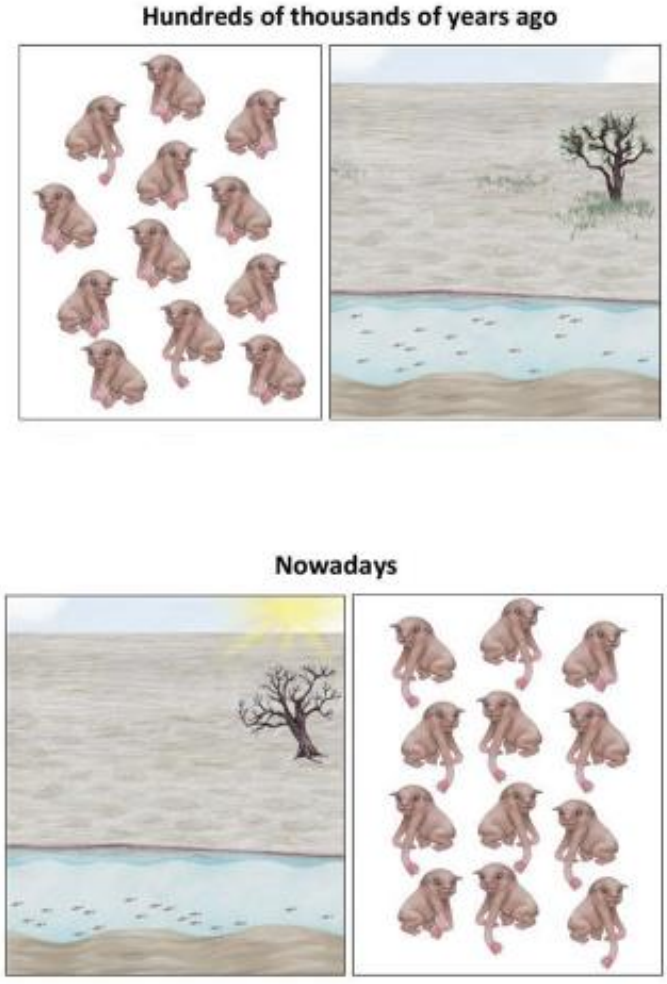


The second post-test task only differed from the pre-test in the species that was presented to the child and the features of the animal and environment that changed over time. The purpose of this second post-test task was to examine whether the child can generalize what they learned about in the storybook to a novel species they have not seen

in either the storybook or pre-test task. Just like before a set of images of the species was shown to the child and they received a brief explanation about this novel species (Figure 3-6). They were then asked to answer ten natural selection questions related to this novel species.

Figure 3-6:

Post-test Task 2



The Study's Variables of Interest

Children's science learning of natural selection. Children's science learning of natural selection was measured using their responses to the 10 questions on the different tests, which were coded in two ways. The first scored children on an ordinal scale using a conceptual checklist and conservative coding rubric created by Kelemen and colleagues (2014) that considers both children's closed- and open-ended responses in the pre-test and post-test measures to classify the level of children's understanding of natural selection. Close-ended questions were used to evaluate children's knowledge of isolated facts relevant to natural selection. Children answered these questions by pointing to one of two pictures and justifying their response. To be given credit for correct responses, children must provide *both* the correct choice and a correct justification. If two or more of the justifications were incorrect, a child could not be scored above a level 0 understanding; if they were all correct, a child scored at least at a level 1. From there, open-ended questions were used to examine children's ability to self-generate causal explanations of adaptation that also integrate knowledge of the isolated facts. Responses were coded for understanding of several concepts, including causal references to differential survival (level 2), differential reproduction in one generation (level 3), and differential reproduction in multiple generations (level 4).

Each child received three ordinal level scores, one for pre-test, one for the post-test measure of comprehension, and one for the post-test measure of generalization. A score of Level 0 indicated that the child's close-ended responses did not demonstrate

enough factual knowledge of the isolated facts. Level 1 was assigned if the child's close-ended responses demonstrated sufficient knowledge on isolated facts for five or more close-ended questions but show that that child was unable to accurately connect the facts into a self-generated response about population-based change in the open-ended questions (Kelemen et al., 2014). Level 2, 3, and 4 were assigned if children demonstrated both enough factual knowledge in their closed-ended responses to five or more closed-ended questions and described the accurate population-based mechanism in their open-ended responses. These levels differ though in the degree of population-based logic given in the child's response. Level 2 was assigned if the child's open-ended response accurately described adaptation as a result of differential survival due to differential access to food (Kelemen et al., 2014). Level 3 was assigned if the child showed understanding of natural selection in one generation. So, their open-ended response needed to causally connect differential survival and differential reproduction in one generation. Finally, Level 4 was assigned if children extended a Level 3 response by also discussing differential reproduction over multiple generations (Kelemen et al., 2014).

The use of this ordinal scale requires for analyses using ordinal logistic regressions. Since this study is intended to be exploratory and is underpowered for doing ordinal logistic regressions, a second scoring was used. Using accuracy on the 10 questions (including the justification accuracy for the closed ended questions), sum scores were calculated to indicate children's science understanding of natural selection

for exploring dissertation's research questions. Appendix C provides the power test to determine how many participants would be needed to detect change and results from analysis using ordinal logistic regressions with the sample of 25 participants collected in this study.

To select an alternative scoring method for the ten questions, I checked the alpha (internal reliability) for the justification accuracy scores of the six closed ended items that are first asked at pre (a = 0.58) and post-test (comprehension measure a = 0.56; generalization a = 0.56) and the full set of ten questions for pre (a = 0.76) and post-test (comprehension measure a = 0.70; generalization a = 0.63). Based on the higher reliability using the full scale, this method was chosen to indicate children's natural selection understanding for the pre- and post-test measures with each child having three sum scores. Descriptive information for the measures based on the sum scores were examined to ensure similar properties (i.e., means and standard deviations).

Parents' Pedagogical Questions. Parents' pedagogical questions were measured by the total number of questions asked that are coded as pedagogical questions based on the coding scheme by Yu et al. (2019). A parent's pedagogical question was defined as a question asked with the intent of teaching and the parent knows the answer to the question they are asking (Jean et al., 2019; Yu et al., 2018; Yu et al., 2019). For example, "Why did the thinner [trunk] ones survive?" would be coded as a pedagogical question, because there is an intention to teach about a general concept or object while "What did

you say?" would not be coded as a pedagogical question because it is asking the child to clarify what he or she said.

Parents' Non-Pedagogical Questions. To answer my exploratory questions, parents' non-pedagogical questions are also measured, but they are measured by the total number of questions asked that are coded as parent's non-pedagogical questions as they relate to the book reading task and the topic of natural selection. In other words, these were questions asked that were related to the topic of natural selection and/or the book, but weren't considered pedagogical. Yu et al.'s (2019) coding scheme was used to help distinguish between non-pedagogical questions and pedagogical questions.

Child Utterances. Child utterances are measured by the total number of utterances made by children as they relate to the book reading task and the topic of natural selection. An utterance is defined as independent clauses, dependent clauses, and/or questions made by the child that can be clearly recognized as a single unit of communication (Hunt, 1965; Loban, 1976). Unattached fragments were not counted as their own independent utterance unit (Hunt, 1965; Loban, 1976).

Coding. Data collectors were trained and provided with a guide for transcribing and coding parent's questions and child's utterances. Consensus coding was done with each collector's coding being coded by another research assistant to see if the same conclusions were reached. When I coded children's science learning from the pre- and post-test measures, another research assistant who was not involved in collecting the data,

also coded for science learning with excellent reliability (ICC = .96). Discussions were had for any disagreements to reach consensus.

Analysis. I provide descriptive data for all variables measured, and a correlation test was conducted to determine whether these variables differed by age (7 vs. 8 years old) or gender (boys vs. girls). Repeated-measures ANCOVAs were used in tests of natural selection understanding. Sum scores across the ten questions asked from the pre- and post-test measures were used in the analyses in order to compare children's scores. I controlled for gender since gender differences observed in prior studies on language and parent-child interactions show girls as having greater language abilities (Andersson et al., 2011; Eriksson et al., 2012; Wallentin, 2008). I also controlled for age since studies on cognitive abilities and working memory have found age-related differences (Schiff & Vakil, 2015; Swanson, 1996). Since I do not have exact ages for the child participant, age was included as a categorical variable in all analyses (i.e., 7 or 8 years old).

Repeated-measures ANCOVAs were implemented to test the associations between children's science learning of natural selection and parent pedagogical questions and child utterances for research questions 1, 2, and 4. Sum scores for children's science learning of natural selection were analyzed as a within-subject variable, and parent questions, child utterances, age and gender were analyzed as between-subject variables. A linear regression model was used to test the association between parent pedagogical questions and child utterances for research question 3. For the final research question, a mediation was implemented in STATA 17 using structural equation modeling to test

whether children's utterances mediated the association between parent pedagogical questions and children's learning of natural selection (StataCorp, 2021).

Chapter 4

RESULTS

Descriptive Statistics

All parent-child dyads completed the study session. Table 4-1 displays the descriptive statistics for the variables of age, pre-test sum scores, post-test comprehension measure sum score, post-test generalization measure sum score, parent questions (total number), parent pedagogical questions, parent non-pedagogical questions, and child utterances. Table 4-2 displays the correlation results showing that age and gender were not highly correlated with any of my variables of interests. Table 4-3 displays the results of independent *t*-tests of differences between boys and girls.

Table 4-1

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	25	7.64	.49	7	8
Pre-test Sum Scores	25	3.48	2.365	0	8
Post-test Comprehension Sum Scores	25	8.68	1.52	5	10
Post-test Generalization Sum Scores	25	8.56	1.635	4	10
Parent Questions (Total Number)	25	30.92	15.367	6	61
Parent Pedagogical Questions	25	16.04	9.312	3	31
Parent Non-pedagogical Questions	25	14.88	8.776	0	30
Child Utterances	25	52.04	25.634	7	111

Table 4-2

Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Age	1.000								
(2) Gender	-0.238	1.000							
(3) Pre-test Sum Scores	0.191	0.218	1.000						
(4) Post-test Comprehension Sum Scores	0.007	-0.263	0.450	1.000					
(5) Post-test Generalization Sum Scores	0.158	-0.489	0.445	0.545	1.000				
(6) Parent Questions (Total Number)	0.029	-0.082	-0.428	-0.187	-0.249	1.000			
(7) Parent Pedagogical Questions	-0.115	-0.156	-0.438	-0.134	-0.204	0.859	1.000		
(8) Parent Non-pedagogical Questions	0.174	0.021	-0.284	-0.184	-0.219	0.840	0.443	1.000	
(9) Child Utterances	0.024	0.103	-0.184	0.013	-0.108	0.760	0.566	0.731	1.000

Table 4-3

Results of Independent t-tests of Gender Differences

	Boys		Girls		*t*-value	*df*	*p* – value
	M	*SE*	*M*	*SE*			
Age	7.73	.12	7.5	.17	1.18	23	.25
Pre-test Sum Scores	3.07	.50	4.1	.91	-1.07	23	.29
Post-test Comprehension Sum Scores	9	.31	8.2	.59	1.31	23	.20
Post-test Generalization Sum Scores	9.2	.22	7.6	.65	2.69	23	.01
Parent Questions (Total Number)	31.93	3.97	29.4	5.08	.40	23	.70
Parent Pedagogical Questions	17.2	2.45	14.3	2.93	0.76	23	.46
Parent Non-pedagogical Questions	14.73	2.15	15.1	3.12	-.10	23	.92
Child Utterances	49.93	7.31	55.2	6.99	-.50	23	.63

Note. Two-sided *p*-values reported.

Research Question 1: Are gains in children's understanding about natural selection associated with shared parent-child digital book reading about natural selection?

A repeated-measures ANCOVA was used to test whether children's natural selection understanding improved from before parent-child digital book reading (pre-test) to after (post-tests). To test the association, the sum scores for children's science learning of natural selection were included as a within-subject dependent repeated measure variable to assess the difference between the pre- and post-test measures. Age (7 or 8) and gender were included as between-subject variables. A significant main effect of

children's sum scores differing across pre- and the two post-test was observed, $F(2, 42) = 122.64$, $p < .001$, $\eta_p^2 = .85$. The pairwise comparison of pre-test to the post-test measures was significant, with the two post-tests not differing from each other; see Table 4-4 for means and p-values. No significant main effects were observed for age ($F(1, 21) = .38$, $p = .54$, $\eta_p^2 = .02$) or gender ($F(1, 21) = .36$, $p = .56$, $\eta_p^2 = .02$). However, a significant gender x children's science learning of natural selection interaction was observed, $F(2, 42) = 7.38$, $p < .01$, $\eta_p^2 = .26$.

Table 4-4

*Pairwise Comparisons for Research Question 1: Pre-test to Post-test measure*s

Variable	*M*	*SD*	*SE*	1	2
Pre-test	3.53	2.37	.50		
Post-test Measure of Comprehension	8.56	1.52	.33	$p < .001$ [-6.04, -4.01]	
Post-test Measure of Generalization	8.41	1.64	.33	$p < .001$ [-5.86, -3.89]	$p = 1.00$ [-.68, .99]

Note. M indicates mean. *SD* indicates standard deviation. *SE* indicates standard error. Confidence Intervals in brackets.

Exploring the gender x children's science learning of natural selection interaction further, a multivariate test was conducted with the sum scores for children's science learning of natural selection as the dependent variable, and age and gender as a fixed factor. Children's sum scores on the pre-test measure did not significantly differ between males ($M = 2.96$, $SE = .68$) and females ($M = 4.10$, $SE = .74$), $F(1, 21) = 1.27$, $p = .27$, $\eta_p^2 = .06$. They also did not significantly differ between males ($M = 8.92$, $SE = .45$) and females ($M = 8.20$, $SE = .49$), $F(1, 21) = 1.19$, $p = .29$, $\eta_p^2 = .05$, on the post-test measure

of comprehension. However, children's sum scores on the post-test measure of generalization did significantly differ between males (M = 9.22, SE = .44) and females (M = 7.60, SE = .48), $F(1, 21) = 6.12$, $p = .02$, $\eta_p^2 = .23$.

Research Question 2: Is there an association between parent pedagogical questioning during a digital book reading and gains in children's understanding about natural selection?

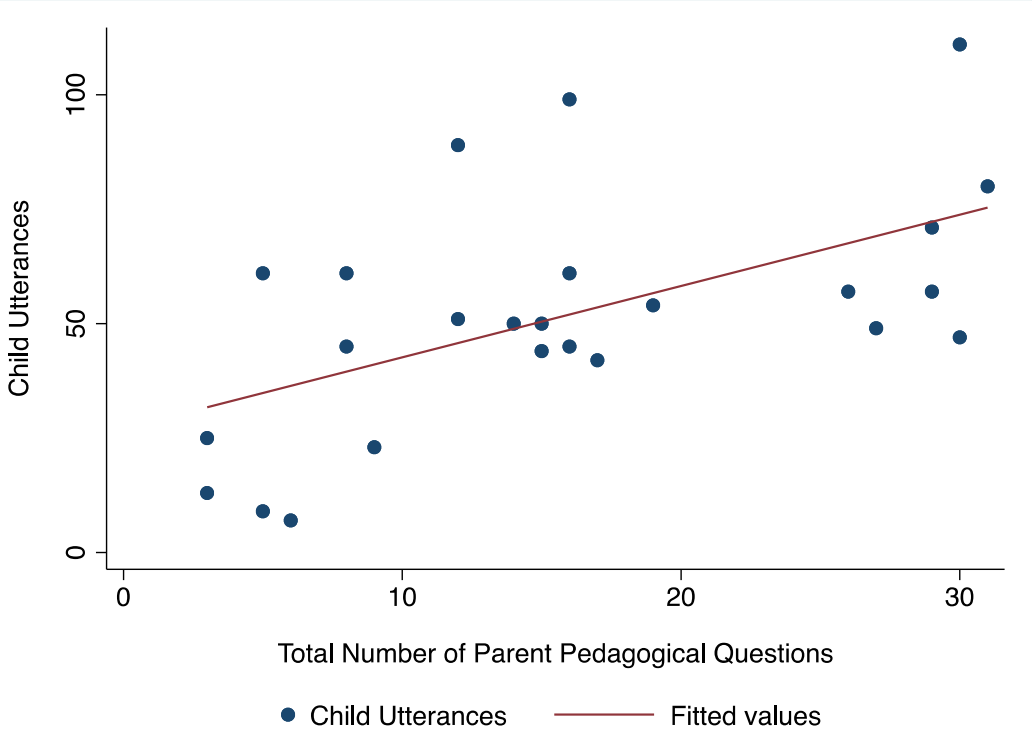
A repeated-measures ANCOVA was used to test whether parents' pedagogical questions during shared book reading were associated with children's learning about natural selection. To test the association, the sum scores for children's science learning of natural selection were included as a within-subject dependent repeated measure variable to assess the difference between the pre- and post-test measures. The independent variable of parent pedagogical questions was included as a covariate, and age (7 or 8) and gender as between-subject variables. I was interested in the learning (i.e., test-time, pretest to post-test difference) by parent questions interaction, which was not significant ($F(2, 40) = 1.56$, $p = .22$, $\eta_p^2 = .07$). I again observed the significant main effect of children's sum scores differing between pre- and post-test was observed, $F(2, 40) = 22.17$, $p < .001$, $\eta_p^2 = .53$, and the significant gender x learning interaction, $F(2, 40) = 6.36$, $p < .01$, $\eta_p^2 = .24$. No significant main effects were observed for parent pedagogical questions ($F(1, 20) = 3.22$, $p = .09$, $\eta_p^2 = .14$), age ($F(1, 20) = .13$, $p = .72$, $\eta_p^2 = .01$) or gender ($F(1, 20) = .89$, $p = .36$, $\eta_p^2 = .04$).

Research Question 3: Does frequency of parent pedagogical questioning relate to frequency in child utterances?

A simple linear regression, controlling for gender and age, showed that frequency of parent pedagogical questioning related to frequency of child utterances, $R^2 = .38$, $F(3, 21) = 4.43$, $p = .01$ (Figure 4-2). Parent pedagogical questioning explained 37.84% of the variation in child utterances when controlling for child's age and gender. The regression coefficient ($B = 1.17$, 95% CI [.56, 2.85], $p = .005$) indicated that a one-unit increase in parent pedagogical questioning was associated with a 1.71 increase in child utterance.

Figure 4-1

Linear regression for Research Question 3



Research Question 4: Is there an association between child utterances during parent reading of a digital storybook and gains in children's understanding about natural selection?

A repeated-measures ANCOVA was used to test whether children's utterances during shared book reading were associated with children's learning about natural selection. To test the association, the sum scores for children's science learning of natural selection were included as a within-subject dependent repeated measure variable to assess the difference between the pre- and post-test measures. The independent variable of child utterance was included as a covariate, as well as age (7 or 8) and gender as between-subject variables. I was interested in the learning (i.e., test-time, pretest to post-test difference) by child utterances interaction, which was not significant ($F(2, 40) = 1.17$, $p = .32$, $\eta_p^2 = .06$). I again observed the significant main effect of children's sum scores differing between pre- and post-test, $F(2, 40) = 17.36$, $p < .001$, $\eta_p^2 = .47$ and the significant gender x learning interaction, $F(2, 40) = 8.00$, $p < .01$, $\eta_p^2 = .29$. No significant main effects were observed for child utterances ($F(1, 20) = .29$, $p = .59$, $\eta_p^2 = .01$), age ($F(1, 20) = .40$, $p = .53$, $\eta_p^2 = .02$) or gender ($F(1, 20) = .26$, $p = .62$, $\eta_p^2 = .01$).

Research Question 5: Do child utterances mediate the relation between parent's pedagogical question asking and gains in children's understanding about natural selection?

A single-level mediation using structural equation modeling was used to test whether children's utterances mediated the association between parent pedagogical

questions and children's learning of natural selection. The direct effect of children's utterances on children's sum scores of science learning of natural selection at the post-test measure of comprehension was estimated to be .02. The effect was not statistically significant, $p = .28$. The direct effect of parents pedagogical questioning on children's utterances was estimated to be 1.71 and was found to be statistically significant, $p < .001$ at the post-test measure of comprehension. The direct effect of parent pedagogical questioning on children's sum scores of science learning of natural selection at the post-test measure of comprehension was estimated to be -.06. The effect was not statistically significant, $p = .14$. The total effect of parent pedagogical questioning on children's sum scores of science learning of natural selection at the post-test measure of comprehension was -.03 and was found to not be statistically significant, $p = .32$.

The direct effect of children's utterances on children's sum scores of science learning of natural selection at the post-test measure of generalization was .01. The effect was not statistically significant, $p = .39$. The direct effect of parents' pedagogical questioning on children's utterances was estimated to be 1.71 and was found to be statistically significant, $p < .001$. The direct effect of parent pedagogical questioning on children's sum scores of science learning of natural selection at the post-test measure of generalization was estimated to be -.07. The effect was not statistically significant, $p = .06$. The total effect of parent pedagogical questioning on children's sum scores of science learning of natural selection at the post-test measure of generalization was -.05 and was found to not be statistically significant, $p = .09$.

Results for the Exploratory Questions

The purpose of asking the exploratory questions was to examine how parents' non-pedagogical questions may relate to children's learning and understanding of natural selection. The first exploratory question asked what proportion of questions asked by parents are non-pedagogical questions? To answer this question the total number of parent questions (N = 773), parents' pedagogical questions (N = 401), and parents' non-pedagogical questions (N = 372) were first calculated. Once the total numbers were calculated then the percentage of questions that were pedagogical and non-pedagogical were calculated. Results showed that 48.12% of questions asked by parents were non-pedagogical and 51.88% of questions asked were pedagogical.

A repeated-measures ANCOVA was used to test whether parents' non-pedagogical questions during shared book reading are associated with children's learning about natural selection. To test the association, the sum scores for children's science learning of natural selection were included as a within-subject dependent repeated measure variable to assess the difference between the pre- and post-test measures. The independent variable of parent non-pedagogical questions was included as a covariate, as well as age (7 or 8) and gender as between-subject variables. I was interested in the learning (i.e., test-time, pretest to post-test difference) by parent non-pedagogical questions interaction, which was not significant ($F(2, 40) = 1.31$, $p = .28$, $\eta_p^2 = .06$). I again observed the significant main effect of children's sum scores differing between pre- and post-test was observed,, $F(2, 40) = 24.81$, $p < .001$, $\eta_p^2 = .55$, and the significant

gender x learning interaction, $F(2, 40) = 7.85$, $p < .01$, $\eta_p^2 = .28$. No significant main effects were observed for parent non-pedagogical questions ($F(1, 20) = 2.35$, $p = .14$, $\eta_p^2 = .11$), age ($F(1, 20) = .83$, $p = .37$, $\eta_p^2 = .04$) or gender ($F(1, 20) = .26$, $p = .62$, $\eta_p^2 = .01$).

Chapter 5

DISCUSSION

Prior research has focused largely on the support that shared parent-child book reading experiences provide for children's literacy and language development. Limited work has examined the support these experiences can provide for children's science learning. Children have the capacity to learn and understand science concepts from book reading during interactions with a researcher or teacher (Altun, 2019; Brown et al., 2020; Daubert et al., 2020; Ganea et al., 2011; Kelemen et al., 2014), and work by Kelemen and colleagues showed consistent positive associations between science book reading and children's understanding and learning about natural selection (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). One aim of the current study was to expand upon their work by testing to see if learning will occur when reading is performed by a parent. Another aim of the current study was to explore factors related to parent-child interactions, parent pedagogical questions and child utterances, that might relate to children's learning from reading a science book. Previous studies on parent-child interactions and children's self-explanations have shown that parent questions and child utterances can support children's learning (Benjamin et al., 2010; Jant et al., 2014; Legare et al., 2009; Legare & Lombrozo, 2014). Compared to these studies, I examined whether these factors will support learning of natural selection.

To address the aims of the current study, five research questions were asked. Results for all questions did not differ by child's age or gender. Analyses did show

significant gains in children's learning of natural selection from pre-test to post-test. Also observed was a significant interaction between gender and test time, with boys having higher scores at post-test compared to girls. Frequency of child's utterances significantly related to frequency of parent's pedagogical questions asked while reading. However, results showed that the frequency of parent questions and child utterances were not significantly related to children's science learning. The frequency of child utterances also did not mediate the association between parent pedagogical questions and children's science learning. A more in-depth discussion of these results and how they connect to prior literature is reviewed below. The chapter will then end with a discussion on study limitations and future directions.

Research Question 1

I expected children's natural selection understanding to improve after shared digital book reading with a parent. This hypothesis was supported and addressed aim 1 of this dissertation. Children's scores were found to significantly improve from pre-test to post-test measures after shared parent-child digital book reading. This result provides support to the prior work that found children's learning was induced by the storybook used in this dissertation (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). It also showed that children's learning of a complex science concept like natural selection can occur when reading with a parent. This expands upon the literature that has shown children's learning occurring with a researcher or teacher when reading a science book about natural selection (Brown et al.,

2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021).

The storybook was written with the intention of helping children learn about adaptation by natural selection (Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014), and these results suggest that the story was a sufficient social tool that parents can use because it is presenting information about natural selection within the child's zone of proximal development. This informs further our understanding that when using storybooks to aid children's learning about a science concept, how the information is presented in the story matters. As supported by Altun (2019), Ganea et al. (2011), and Leech et al (2020) showing that the inclusion of factual information and mechanistic explanations in stories help to scaffold children's learning.

The results also show a significant gender and test time interaction. Boys were found to perform higher on post-test measures, with both boys and girls still showing significant differences in scores between the pre-test and the post-test measure of generalization. This is inconsistent with prior studies of natural selection learning from this book, as Kelemen and colleagues did not find any gender differences across their studies (Brown et al., 2020; Emmons et al., 2016; Emmons et al., 2017; Kelemen et al., 2014; Ronfard et al., 2021). One possibility is that there is a gender difference in the boys' ability to better generalize what was learned, as the generalization post-test was the only measure that showed the gender difference, but prior research shows the opposite to be true; girls outperformed boys on a transfer task after a story-based learning experience

(Casey et al., 2008). As this result was unexpected and my sample size is quite small with more boys than girls, I am cautious about drawing conclusions about why this interaction might have occurred, and suggest that this is an interesting topic to explore in future research.

Research Question 2

For this question, I expected that parent pedagogical questions would relate to children's natural selection understanding from a storybook. Analyses did not support this hypothesis, indicating that the number of pedagogical questions asked by a parent during shared book reading did not relate to children's science learning. This result is surprising because it is believed that when a parent asks their child pedagogical questions it gives that child the space to think about and explore more deeply the topic they are learning about (Jean et al., 2019; Yu et al., 2018). However, these results suggest that a higher quantity of pedagogical questions asked by a parent does not support children's learning. This relates to Sheehan et al.'s (2019) findings of negative effects on children's learning when questions made up a larger proportion of parent-child conversations during a learning task. In thinking about the current study, this could mean that parent questions could have distracted the child from being able to learn from the story. This could lead to the child not being fully sensitive to the parent's intention and goal of elicit learning about natural selection when asking their pedagogical questions.

When considering that the goal of asking pedagogical questions is to elicit learning (Jean et al., 2019; Yu et al., 2018; Yu et al., 2019), it is possible that parents only

need to ask a few pedagogical questions in order to support their child's learning. Jant et al.'s (2019) work focusing on pedagogical questions and problem solving found that just overhearing a pedagogical question being asked led to more variability in children's exploration and perseverance in problem solving. Daubert et al.'s (2020) work found that just reading a pedagogical question in a story led to children's causal learning.

In Blewitt et al.'s (2009) study children in the question conditions only heard six questions per story that were read to them and experienced gains in the learning outcome of novel word comprehension. These questions were extratextual, meaning that they conveyed information outside of the story text itself, with each question asked focused on a different novel target word (Blewitt et al., 2009). Half of the questions were high demand questions that focused on inferences and predictions, while the others were low demand questions that focused on story element recall and pictures descriptions (Blewitt et al., 2009). This past study suggests that fewer questions can contribute to learning when these questions are relevant to the learning outcome, conveying greater information beyond what is covered in the story and including a mix of low and high demand questions. Based on this prior work, it is possible that there was not a mixture within the pedagogical questions asked by parents during the shared reading that required children to do both high demand thinking such as making inferences, and low demand thinking, such as story recall, or that there were too many questions asked for children to adequately process and monitor the information. It is also possible that the questions were asked because of the instructions given to parents, and that children may not respond in

the same way to questioning behavior that is not typical of their parent-child reading experiences. What this suggests is it is also very likely that there are other factors of parent questioning and pedagogical questioning beyond frequency that support children's learning, and higher quantity on its own is not what is necessary to aid children's learning.

Research Question 3

I expected parent pedagogical questioning to positively relate to child utterances. As expected, frequent parent pedagogical questions were significantly associated with more child utterances made during the shared reading. This suggests that parents' pedagogical questioning was eliciting greater verbal engagement from the child, indicating that the more questions provided by parents the more engaged children were in the shared reading experience and with the story they were learning from. In past studies, more elaborative and/or joint talk between a parent and child were found when parents asked more questions during learning experiences (Benjamin et al, 2010; Jant et al., 2014). The results of this study also relate to the literature on parent-child shared experiences with books that found that children used more words, spoke longer sentences, and improved in their expressive language skills when they engaged in shared reading experiences (Chow et al., 2008; Lever & Sénéchal, 2011; Parish-Morris et al., 2013; Richter & Courage, 2017; Wasik & Bond, 2001), although I did not compare shared to independent reading. These findings also tell us that pedagogical questions themselves seem to support and scaffold child engagement in shared reading experiences.

This expands upon prior literature which found that questions in general are supportive of learning in shared reading experiences (Blewitt et al., 2009; Walsh & Blewitt, 2006).

An alternative explanation to the association observed is that due to the fact that parents heard the pre-test questions asked of their child, they may have identified both the learning goal of the book and the possible questions that their child would encounter in the post-test measure activities. Wanting their child to answer correctly these questions may have encouraged some parents to ask more frequent pedagogical questions and/or better questions, leading to children's higher engagement with the story and ensuring that their child understood what they were learning about. This is also consistent with the research on parent-child interactions in museums that found that when parents are given cues, they are able to support their child's engagement in learning activities on a deeper level (Benjamin et al., 2010; Callanan et., 2017; Jant et al., 2014). Both the pre-test questions and directions in the current study can be thought of then as cues that helped in supporting more child utterances during reading of a science book, however the resulting parent questioning and child utterances did not relate to learning in the current study.

Research Question 4 and 5

My fourth hypothesis was that child utterances would relate to their science learning and understanding from a storybook. This hypothesis was not supported, indicating that the number of child utterances made during the shared book reading session did not relate to children's science learning. My final expectation was that child

utterances would mediate the association between parent's pedagogical questions and children's science learning. This hypothesis was also not supported.

Prior studies on children's explanations did not examine the frequency of child speech or explanations. Rather, they found that when children were prompted to give an explanation it aided their learning of the concept that they were trying to grasp, even in the absence of feedback (Legare, 2014; Lombrozo, 2006; Wellman, 2011). In the case of the current study, parents asked questions, which led to more child talk and thus could have led to more child explanations to respond to parents' questions; however, children also without being prompted by their parents gave explanations and made comments about things they were seeing in the storybook, so simply looking at frequency of child utterances may have missed the associations between child explanations and learning, which is an interesting question that can be explored further with these data or in future studies. Children also were able to receive feedback from their parents when their responses about items in the story or in response to their parent's questions were incorrect. Regardless of these opportunities for explaining and receiving feedback, higher frequency of child utterance while reading did not benefit children's learning. Another possibility for this inconsistency with prior findings, explanations don't always support learning and can have the potential for harming learning. For example, Walker et al. (2014) found that explanations can impair children's memory on certain properties and features of the item or concept that they are explaining. This has been found to be especially true for memory of non-causal properties (Legare & Lombrozo, 2014; Walker

et al., 2014). It is possible then that higher frequency of utterances could distract the child from remembering aspects of the story, such as by bringing in incorrect prior knowledge or just using cognitive resources that are then more limited for integrating new information from the story, which could be why frequency of utterances were not found to support children's learning in this study. Another possible explanation is that the content of children's utterances is what matters, rather than the frequency. For example, whether the child utterance was deep or shallow may matter more for supporting their learning and mediating the support that parents questions can have on their learning as well. When a child can make deeper utterances about science this could lead to greater learning, similar to how high demand questions that require the child to make inferences and predictions were found to aid children's novel word learning (Blewitt et al., 2009).

Exploratory Questions and Analyses

The intent of the exploratory questions was to examine whether parents' non-pedagogical questions were associated with children's learning and understanding of natural selection. Results of the first exploratory question showed that a little less than half (48.12%) of the questions asked by parents were non-pedagogical. This showed that during the shared book reading session there was little variation in the percentages of non-pedagogical and pedagogical questions asked. Prior research shows that parents ask different types of questions outside of pedagogical questions that could support their child's learning, such as information seeking and rhetorical questions (Yu et al., 2019). Yu et al. (2019) found though that the proportion of non-pedagogical questions (e.g.,

information seeking and rhetorical questions) increase as the proportion of parents' pedagogical questions decrease with age. For example, Yu et al. (2019) found in mother-child conversations that 27% of questions asked are pedagogical questions while 60% are information seeking and 13% are rhetorical. In the current study, parents asked fewer non-pedagogical questions proportionally than in prior research, and this result did not differ by the child's age. It is possible that the reason fewer non-pedagogical questions were asked was because parents' were aware of the specific pretest questions asked of their child. In wanting their child to correctly answer any follow-up questions asked at post-test, parents may have been intentional in ensuring that they asked more questions that were pedagogical and related to these learning measures questions. If questions then related to children's learning, that would suggest that this could be an interesting and simple way of promoting questions to promote learning, but the results do not show that. Instead, this may suggest that parents' questions asked because they know the assessment questions are superficial, and not related to learning (and, while not statistically significant, could negatively relate to learning, perhaps by being distracting or prompting child responses that distract from learning, which could be studied in future research).

The results of the second exploratory question indicated that the association between the number of parents' non-pedagogical questions and children's natural selection understanding was not significant. These results were similar to the findings in research question two when examining parents' pedagogical questions, suggesting that asking more questions is not always best for children's learning in the context of shared

book reading. As previously discussed, in Blewitt et al.'s (2009) study only six questions were asked per story and children experienced learning of novel words. What this study shows is that many questions were asked both, pedagogical or non-pedagogical, and neither related to children's learning. From the current analyses, it is unclear whether questions during book reading simply don't matter, or whether the type of question is important, which is something that can be further explored in these data and in future research.

Limitations

The online format of this study resulted in several limitations. The first limitation being data quality issues stemming from using Zoom. All study sessions with participants were video recorded; however, the recordings varied in their audio quality. If there was, for example, any loud background noises during the session the audio quality of the recording was affected because it was hard to clearly hear what was being said by the child and parent participants. Secondly, if more than one person was talking at a time the participants' words ended up sounding muffled in the video recording. These audio quality issues led to missing some of the child's utterances and parent's questions made during their study session. In addition to the audio quality impeding the ability to hear and code parents' questions and child utterances, the analyses included overall frequency of each of these, and future analysis of these data can explore whether the content of questions and utterances varies and if different types of questions and child utterances relate to learning. Related to this, parents were often in the room during the pre-test, and,

as discussed above, may have changed their typical questioning behavior in response to hearing the pretest questions their child was asked. Another limitation includes the small sample size, which may have made interactions hard to detect due to reduced statistical power.

Future Directions

The next steps in this work involve more meaningful coding of the parent questions and child utterances to explore whether there might be associations with learning that were missed by analyzing these using overall frequency. Future work can also replicate this study and conduct it in a controlled setting. Completing the study in a controlled setting may lead to less generalizable results; however, it could help me gain an understanding about what mechanisms may affect children's science learning in the context of parent-child shared reading. It also would help in addressing the limitations I faced when using Zoom along with lessening the numbers of distractions around the parent-child dyad. Additionally, it would allow for parents to be separated from their child when pre-test and post-test measures are given. This would provide an opportunity to collect and observe the number of pedagogical questions parents would ask naturally on their own without hearing the pre-test questions and if parents would ask on average better or more questions.

Another potential project is to randomly assign parent-child dyads to conditions where I manipulate the book format. Those in the control condition would read with a traditional print book format and dyads in the experimental condition would read with a

digital book format. By comparing the two formats, I would have the opportunity to examine whether learning of a complex science concept would still occur when reading with a parent regardless of format.

Another future direction for this work would be conducting an experimental study where the directions parents receive on asking questions during shared parent-child reading are manipulated. A larger sample size would be needed to have a control condition and two experimental conditions. The control condition would receive directions that encourage them to read as they normally would and the experimental conditions both would hear the current studies' directions but one of the conditions would be provided with additional example questions. This comparison would allow me to examine whether providing parents with additional questions would hurt or lead to greater question-asking and support of children's learning of natural selection from the storybook used in this current study.

Conclusion

Past studies found that children are capable of learning about natural selection when reading with a researcher or teacher (Brown et al., 2020; Emmons et al., 2016; Kelemen et al., 2014). This dissertation expands on this by showing that children's learning of natural selection also occurs after reading a digital science book with parents. This shows that parents can effectively use this storybook to support their child's science learning. The findings of this study also suggest that children talk more during a science learning task through book reading when parents ask more pedagogical questions.

However, neither the number of parent pedagogical questions nor child utterances related to children's learning of natural selection, suggesting that more nuanced factors related to parents' questions and children's utterances may influence children's learning rather than overall frequency. Taken together these results reveal that shared book reading with a parent has potential to teach complex science concepts; however, more research is needed to understand what aspects of these interactions are needed to most effectively support children's learning.

References

Akpan, B., & Kennedy, T. J. (Eds.). (2020). *Science education in theory and practice: An introductory guide to learning theory*. Springer Nature.

Altun, D. (2019). From story to science: The contribution of reading fiction and hybrid stories to conceptual change with young children. *Children & Society, 33*(5), 453-470. https://doi-org.proxy01.its.virginia.edu/10.1111/chso.12321

Anderson, A., Anderson, J., Lynch, J., Shapiro, J., & Eun Kim, J. (2012). Extra-textual talk in shared book reading: A focus on questioning. *Early Child Development and Care, 182*(9), 1139-1154.

Andersson, I., Gauding, J., Graca, A., Holm, K., Öhlin, L., Marklund, U., & Ericsson, A. (2011). Productive vocabulary size development in children aged 18-24 months–Gender differences. *Proceedings from Fonetik 2011: Speech, Music and Hearing; Quarterly Progress and Status Report*, *51*, 109-112.

Aram, D., Fine, Y., & Ziv, M. (2013). Enhancing parent–child shared book reading interactions: Promoting references to the book's plot and socio-cognitive themes. *Early Childhood Research Quarterly*, *28*(1), 111-122.

Benjamin, N., Haden, C. A., & Wilkerson, E. (2010). Enhancing building, conversation, and learning through caregiver–child interactions in a children's museum. *Developmental Psychology*, *46*(2), 502-515.

Bingham, G. E. (2007). Maternal literacy beliefs and the quality of mother-child book-reading interactions: associations with children's early literacy development. *Early Education and Development*, *18*(1), 23-49.

Blewitt, P., Rump, K. M., Shealy, S. E., & Cook, S. A. (2009). Shared book reading: When and how questions affect young children's word learning. *Journal of Educational Psychology*, *101*(2), 294-304.

Bornstein, M. H., Tal, J., Rahn, C., Galperin, C. Z., Pecheux, M. G., Lamour, M., Toda, S., Azuma, H., Ogino, M., & Tamis-LeMonda, C. S. (1992). Functional analysis of the contents of maternal speech to infants of 5 and 13 months in four cultures: Argentina, France, Japan, and the United States. *Developmental Psychology*, *28*(4), 593-603.

Bowman, J. L. (2014). *The effects of book format on parent-child interaction during joint book reading*. [Unpublished doctoral dissertation]. University of Arkansas.

Britto, P. R., Brooks-Gunn, J., & Griffin, T. M. (2006). Maternal reading and teaching patterns: Associations with school readiness in low-income African American families. *Reading Research Quarterly, 41*(1), 68-89. doi:10.1598/RRQ.41.1.3

Brown, S. A., Ronfard, S., & Kelemen, D. (2020). Teaching natural selection in early elementary classrooms: can a storybook intervention reduce teleological misunderstandings?. *Evolution: Education and Outreach*, *13*, 1-19.

Bruner, J. S. (1967). On knowing: Essays for the left hand. Cambridge, MA: Harvard University Press.

Butler, L. P., & Markman, E. M. (2014). Preschoolers use pedagogical cues to guide radical reorganization of category knowledge. *Cognition*, *130*(1), 116-127.

Callanan, M. A., Castañeda, C. L., Luce, M. R., & Martin, J. L. (2017). Family science talk in museums: Predicting children's engagement from variations in talk and activity. *Child Development*, *88*(5), 1492-1504.

Casey, B., Erkut, S., Ceder, I., & Young, J. M. (2008). Use of a storytelling context to improve girls' and boys' geometry skills in kindergarten. *Journal of Applied Developmental Psychology*, *29*(1), 29-48. https://doi-org.proxy01.its.virginia.edu/10.1016/j.appdev.2007.10.005

Chouinard, M. M., Harris, P. L., & Maratsos, M. P. (2007). Children's questions: A mechanism for cognitive development. *Monographs of the Society for Research in Child Development*, i-129.

Chow, B., & McBride-Chang, C. (2003). Promoting language and literacy development through parent–child reading in Hong Kong preschoolers. *Early Education and Development*, *14*(2), 233-248.

Chow, B. W. Y., McBride-Chang, C., Cheung, H., & Chow, C. S. L. (2008). Dialogic reading and morphology training in Chinese children: effects on language and literacy. *Developmental Psychology*, *44*(1), 233.

Code, J. R., & Zaparyniuk, N. E. (2009). The emergence of agency in online social networks. In Hatzipanagos, S., & Warburton , S. (Ed.), *Handbook of Research on*

Social Software and Developing Community Ontologies (pp. 102-118). IGI Global. http://doi:10.4018/978-1-60566-208-4.ch008

Cooper, R. (2007). *Those who can teach* (11th ed.). New York, NY: Houghton Mifflin.

Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences*, 13, 148–153.

Daubert, E. N., Yu, Y., Grados, M., Shafto, P., & Bonawitz, E. (2020). Pedagogical questions promote causal learning in preschoolers. *Scientific Reports*, *10*(1), 1-8.

De Jong, M. T., & Bus, A. G. (2002). Quality of book-reading matters for emergent readers: An experiment with the same book in a regular or electronic format. *Journal of Educational Psychology, 94*, 145–155.

Emmons, N., Smith, H., & Kelemen, D. (2016). Changing minds with the story of adaptation: Strategies for teaching young children about natural selection. *Early Education and Development*, *27*(8), 1205-1221.

Emmons, N., Lees, K., & Kelemen, D. (2017). Young children's near and far transfer of the basic theory of natural selection: An analogical storybook intervention. *Journal of Research in Science Teaching*, *55*(3), 321-347. https://doi-org.proxy01.its.virginia.edu/10.1002/tea.21421

Eriksson, M., Marschik, P. B., Tulviste, T., Almgren, M., Pereira, M. P., Wehberg, S., Marjanovič- Umek, L., Gayraud, F., Kovačevič, M., & Gallego, C. (2012). Differences between girls and boys in emerging language skills: Evidence from 10

language communities. *British Journal of Developmental Psychology*, *30*(2), 326–343.

Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, 14(3), 315–336. doi:10.1007/s10956-005-7198-9

Ezell, H. K., & Justice, L. M. (2005). Shared storybook reading. *Baltimore, MD: Brookes*.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191.

Fletcher, K. L., Cross, J. R., Tanney, A. L., Schneider, M., & Finch, W. H. (2008). Predicting language development in children at risk: The effects of quality and frequency of caregiver reading. *Early Education and Development*, *19*(1), 89-111.

Flynn, K. S. (2011). Developing children's oral language skills through dialogic reading: Guidelines for implementation. *Teaching Exceptional Children*, *44*(2), 8-16.

Ganea, P. A., Ma, L., & DeLoache, J. S. (2011). Young children's learning and transfer of biological information from picture books to real animals. *Child Development*, *82*(5), 1421-1433.

Haden, C. A. (2010). Talking about science in museums. *Child Development Perspectives*, *4*(1), 62-67.

Hemmeter, M. L., & Kaiser, A. P. (1994). Enhanced milieu teaching: Effects of parent-implemented language intervention. *Journal of Early Intervention*, *18*(3), 269-289.

Hood, M., Conlon, E., & Andrews, G. (2008). Preschool home literacy practices and children's literacy development: A longitudinal analysis. *Journal of Educational Psychology*, *100*(2), 252-271.

Hunt, K. W. (1965). Grammatical structures written at three grade levels. Champaign, IL: National Council of Teachers of English.

Jant, E. A., Haden, C. A., Uttal, D. H., & Babcock, E. (2014). Conversation and object manipulation influence children's learning in a museum. *Child Development*, *85*(5), 2029-2045.

Jean, A., Daubert, E., Yu, Y., Shafto, P., & Bonawitz, E. (2019, January). Pedagogical questions empower exploration. In *Proceedings of the Annual Conference of the Cognitive Science Society*.

Kang, J. Y., Kim, Y. S., & Pan, B. A. (2009). Five-year-olds' book talk and story retelling: Contributions of mother—child joint book reading. *First Language*, *29*(3), 243-265.

Kelemen, D., Emmons, N. A., Schillaci, R. S., & Ganea, P. A. (2014). Young children can be taught basic natural selection using a picture-storybook intervention. *Psychological Science*, *25*(4), 893-902. https://doi-org.proxy01.its.virginia.edu/10.1177/0956797613516009

Kelemen & The Child Cognition Lab. (2017). *How the piloses evolved skinny noses*. Boston, MA: Tumblehome Learning.

Krcmar, M., & Cingel, D. P. (2014). Parent–child joint reading in traditional and electronic formats. *Media Psychology*, *17*, 262–281.

Lauricella, A., Calvert, S., & Barr, R. (2014). Parent–child interactions during traditional and computer book reading for children's story comprehension. *International Journal of Child-Computer Interaction*, *2*(1), 17–25.

Law, J., Charlton, J., McKean, C., Beyer, F., Fernandez-Garcia, C., Mashayekhi, A., & Rush, R. (2018). Parent-child reading to improve language development and school readiness: A systematic review and meta-analysis.

Leech, K. A., Salo, V. C., Rowe, M. L., & Cabrera, N. J. (2013, November). Father input and child vocabulary development: The importance of *wh* questions and clarification requests. In *Seminars in speech and language* (Vol. 34, No. 04, pp. 249-259). Thieme Medical Publishers.

Leech, K. A., Haber, A. S., Jalkh, Y., & Corriveau, K. H. (2020). Embedding scientific explanations into storybooks impacts children's scientific discourse and learning. *Frontiers in Psychology*, *11*, 1016.

Legare, C. H. (2014). The contributions of explanation and exploration to children's scientific reasoning. *Child Development Perspectives*, *8*(2), 101-106.

Legare, C. H., & Lombrozo, T. (2014). Selective effects of explanation on learning during early childhood. *Journal of experimental child psychology*, *126*, 198-212.

Legare, C. H., Wellman, H. M., & Gelman, S. A. (2009). Evidence for an explanation advantage in naïve biological reasoning. *Cognitive psychology*, *58*(2), 177-194.

Lever, R., & Sénéchal, M. (2011). Discussing stories: On how a dialogic reading intervention improves kindergartners' oral narrative construction. *Journal of Experimental Child Psychology*, *108*(1), 1-24.

Loban, W. (1976). Language development: Kindergarten through grade twelve. Urbana, IL: National Council of Teachers of English.

Lombrozo, T. (2006). The structure and function of explanations. *Trends in cognitive sciences*, *10*(10), 464-470.

Medina, C., & Sobel, D. M. (2020). Caregiver–child interaction influences causal learning and engagement during structured play. *Journal of Experimental Child Psychology*, *189*, 104678.

Mol, S. E., Bus, A. G., De Jong, M. T., & Smeets, D. J. (2008). Added value of dialogic parent–child book readings: A meta-analysis. *Early Education and Development*, *19*(1), 7-26.

Mol, S. E., Bus, A. G., & de Jong, M. T. (2009). Interactive book reading in early education: A tool to stimulate print knowledge as well as oral language. *Review of Educational Research*, *79*(2), 979-1007.

Narayan, R., Rodriguez, C., Araujo, J., Shaqlaih, A., & Moss, G. (2013). Constructivism—constructivist learning theory. In B. J. Irby, G. Brown, R. Lara-

Alecio, & S. Jackson (Eds.), *The handbook of educational theories* (pp. 169–183). IAP Information Age Publishing.

Nicholas, M. (2020). *Mothers' interactions with two-year-olds when reading printed and electronic texts*. [Unpublished doctoral dissertation]. Deakin University.

Parish-Morris, J., Mahajan, N., Hirsh-Pasek, K., Golinkoff, R. M., & Collins, M. F. (2013). Once upon a time: Parent–child dialogue and storybook reading in the electronic era. *Mind, Brain, and Education, 7,* 200–211.

Piaget, J. (1970). *Genetic epistemology*. New York: W. W. Norton and Company.

Reese, E., & Cox, A. (1999). Quality of adult book reading affects children's emergent literacy. *Developmental Psychology*, *35*(1), 20-28.

Richter, A. & Courage, M. L. (2017). Comparing electronic and paper storybooks for preschoolers: attention, engagement, and recall. *Journal of Applied Developmental Psychology, 48,* 92–102.

Robbins, C., & Ehri, L. C. (1994). Reading storybooks to kindergartners helps them learn new vocabulary words. *Journal of Educational psychology*, *86*(1), 54.

Ronfard, S., Brown, S., Doncaster, E., & Kelemen, D. (2021). Inhibiting intuition: Scaffolding children's theory construction about species evolution in the face of competing explanations. *Cognition*, *211,* 104635.

Ronfard, S., Zambrana, I. M., Hermansen, T. K., & Kelemen, D. (2018). Question-asking in childhood: A review of the literature and a framework for understanding its

development. *Developmental Review*, *49*, 101-120. https://doi-org.proxy01.its.virginia.edu/10.1016/j.dr.2018.05.002

Rowe, M. L., Leech, K. A., & Cabrera, N. (2017). Going beyond input quantity: Wh-questions matter for toddlers' language and cognitive development. *Cognitive Science*, *41*, 162-179.

Scarborough, H. S., & Dobrich, W. (1994). On the efficacy of reading to preschoolers. *Developmental Review*, *14*, 245–302.

Schiff, R., & Vakil, E. (2015). Age differences in cognitive skill learning, retention and transfer: The case of the Tower of Hanoi Puzzle. *Learning and Individual Differences*, *39*, 164-171.

Scholastic. (2019). Kids & family reading report: The rise of read-aloud. (7th ed.). https://www.scholastic.com/content/dam/KFRR/Downloads/KFRR_The%20Rise%20of%20Read%20Aloud.pdf

Schunk, D. H. (2019). Constructivism. *Learning theories: An educational perspective* (8th ed., pp. 228-276). Boston, MA: Pearson

Sheehan, K. J., Pila, S., Lauricella, A. R., & Wartella, E. A. (2019). Parent-child interaction and children's learning from a coding application. *Computers & Education*, *140*, 103601.

Shirefley, T. A., Castañeda, C. L., Rodriguez-Gutiérrez, J., Callanan, M. A., & Jipson, J. (2020). Science conversations during family book reading with girls and boys in two cultural communities. *Journal of Cognition and Development*, *21*(4), 551-572.

Silvén, M., Ahtola, A., & Niemi, P. (2003). Early words, multiword utterances and maternal reading strategies as predictors of mastering word inflections in Finnish. *Journal of Child Language, 30,* 253–279

Sonnenschein, S., & Munsterman, K. (2002). The influence of home-based reading interactions on 5-year-olds' reading motivations and early literacy development. *Early Childhood Research Quarterly*, *17*(3), 318-337.

StataCorp. 2021. *Stata Statistical Software: Release 17*. College Station, TX: StataCorp LLC.

Strouse, G. A., O'Doherty, K., & Troseth, G. L. (2013). Effective coviewing: Preschoolers' learning from video after a dialogic questioning intervention. *Developmental Psychology*, *49*(12), 2368-2382.

Strouse, G. A., & Ganea, P. A. (2017). Parent–toddler behavior and language differ when reading electronic and print picture books. *Frontiers in Psychology*, *8*, 677.

Swanson, H. L. (1996). Individual and age-related differences in children's working memory. *Memory & Cognition*, *24*(1), 70-82.

Tare, M., French, J., Frazier, B. N., Diamond, J., & Evans, E. M. (2011). Explanatory parent–child conversation predominates at an evolution exhibit. *Science Education*, *95*(4), 720-744.

Towson, J. A., Fettig, A., Fleury, V. P., & Abarca, D. L. (2017). Dialogic reading in early childhood settings: A summary of the evidence base. *Topics in Early Childhood Special Education*, *37*(3), 132-146.

Ugur, E., Celikkanat, H., Şahin, E., Nagai, Y., & Oztop, E. (2011, October). Learning to grasp with parental scaffolding. In *2011 11th IEEE-RAS International Conference on Humanoid Robots* (pp. 480-486). IEEE.

U.S. Department of Education. (2007). *What works clearinghouse: Dialogic reading* (WWC Intervention Report). Retrieved from http://ies.ed.gov/ncee/wwc/pdf /WWC_Dialogic_Reading_020807.pdf

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Walker, C. M., Lombrozo, T., Legare, C. H., & Gopnik, A. (2014). Explaining prompts children to privilege inductively rich properties. *Cognition*, *133*(2), 343-357.

Wallentin, M. (2008). Putative sex differences in verbal abilities and language cortex: A critical review. *Brain & Language, 108*(3), 175–183.

Walsh, B. A., & Blewitt, P. (2006). The effect of questioning style during storybook reading on novel vocabulary acquisition of preschoolers. *Early Childhood Education Journal, 33*(4), 273-278.

Wasik, B. A., & Bond, M. A. (2001). Beyond the pages of a book: Interactive book reading and language development in preschool classrooms. *Journal of Educational Psychology, 93*(2), 243-250.

Wellman, H. M. (2011). Reinvigorating explanations for the study of early cognitive development. *Child Development Perspectives*, *5*(1), 33-38.

Whitehurst, G. J., Falco, F. L., Lonigan, C. J., Fischel, J. E., DeBaryshe, B. D., Valdez-Menchaca, M. C., & Caulfield, M. (1988). Accelerating language development through picture book reading. *Developmental Psychology*, *24*(4), 552-559.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, *17*(2), 89-100.

Yu, Y., Landrum, A. R., Bonawitz, E., & Shafto, P. (2018). Questioning supports effective transmission of knowledge and increased exploratory learning in pre-kindergarten children. *Developmental Science*, *21*(6), e12696.

Yu, Y., Bonawitz, E., & Shafto, P. (2019). Pedagogical questions in parent–child conversations. *Child Development*, *90*(1), 147-161.

Appendix A

Study Script

Confirm consent and assent:

"Hello! I'm so glad you were able to log on okay and participate today. To make sure you can successfully participate, can you tell me what device you're using for this Zoom call?

- *If they are using a tablet or mobile device that is NOT Apple or Android, they will NOT be able to access remote control*
- *PCs/laptops are compatible*

Before we start, I wanted to make sure that it is okay if we record the session so that we can remember what [child's name] tells us during the session. We won't post the video anywhere where people can see it outside of our research team, and if you change your mind and want us to delete it at any time, we will do that. Is it okay if I start the recording? [make sure both parent and child say ok]

- *In Zoom menu, click 'record' button – looks like a target, next to 'share screen' button. Select 'Record to the cloud' as the record option.*
- *Make sure that the live transcription option is on.*

"Okay, we are recording. Thank you for filling out the consent form online already! As mentioned, we are trying to learn more about children's knowledge and reasoning about natural selection. During our session, you and [child name] will read a book called *"How The Piloses Evolved Skinny Noses",* where [child name] will learn more about a fictional animal called Piloses. The book will be provided to you in digital form through Zoom. Where you will be able to use your mouse to flip through the book's pages. [Child Name] will also do three activities to help me learn more about what thoughts she has about natural selection. Do either of you have any questions at this point? [answer any questions].

We'll start this session with a quick fun game! [Child Name] are you ready? Great! Let's start by playing a game!

"[Name], can you tell me what you see?" *pause* Great, now I'm going to have your Mom/Dad select an object in the picture. They will give you a hint about it and you must tell them which one it is. Ready?

Example: I spy with my little eye an object that is yellow, and you eat with it. Can you find the object that is yellow, and you can eat with it?

Provide 10 seconds of wait time to guess

[Child guesses incorrectly] "Hmm no not quite...try again! *Repeat hint*

[Child guesses correctly] **"Great job! Now I want you to pick an object and have your Mom/Dad try to guess. Take a few moments to choose and object and when you're ready, give them a hint about the object you chose so they can guess it.**

[child gives hint] "Hmm... Is it [insert guess]?

Continue to guess until guess correctly

[Parent guesses incorrectly] "Hmm no not quite...try again! *Child repeats hint*

[Parent guesses correctly] **"Great job! Now I want you to pick an object and I will try to guess. Take a few moments to choose and object and when you're ready, give me a hint about the object you chose so I can guess it.**

Experimenter guesses

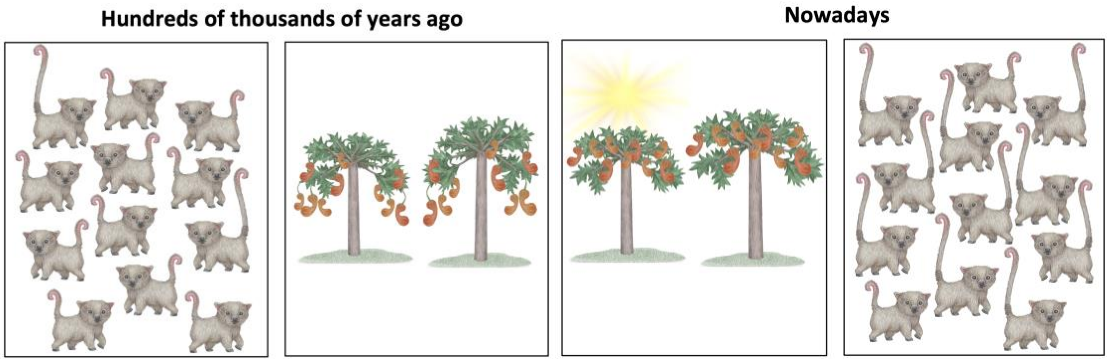
"Great, that was fun! [child name], do you want to start with one of the activities now? [once says yes/nods/etc.] **Okay great, then we can start!**

Activity 1:

Before I let you begin reading the story, I would like to do an activity with [child name] to learn more about what thoughts they have about natural selection. You may stay sitting with [Child name] as they do the activity, but I do ask that you let your child do this activity on their own. [Child name] are you ready to start the activity? {wait for child's answer} Great!

I'm going to share my screen for you to view the activity.

- *Research assistant shares their screen to show the images below.*



Here we have a group of tardons. I want to tell you more about them!

- *Research assistant places the mouse on the first picture in the first set of images label hundreds of thousands of years ago.*

This is what the group of tardons looked like many hundreds of years ago. Many had stumpier tails and a small number had stretchier tails

- *Research assistant now places the mouse on the second picture in the first set of images label hundreds of thousands of years ago.*

This is where the tardons lived and what they ate, the orange melons, many hundreds of years ago.

- *Research assistant now places the mouse on the first picture in the second set of images label nowadays.*

But then the weather became very hot and sunny all of the time, and now the melons mostly grow on the tops of trees. So, this is where tardons live and what they eat, the orange melons, now.

- *Research assistant now places the mouse on the second picture in the second set of images label nowadays.*

And this is what the group of tardons looks like now. They mostly all have stretchier tails.

Now I have some questions about the tardons that I will like for you to answer. For some of the questions, you will have two answer choices to choose from. I will, also, have pictures up on the screen so you can use them to help you.

Questions:
1) Nowadays, will a tardon with a stumpy tail probably be healthy and live for a long time? Why?  YES: They will be healthy and live for a long time NO: They will not be healthy and live for a long time

2) Nowadays, will a tardon with a stretchy tail probably be healthy and live for a long time? Why?

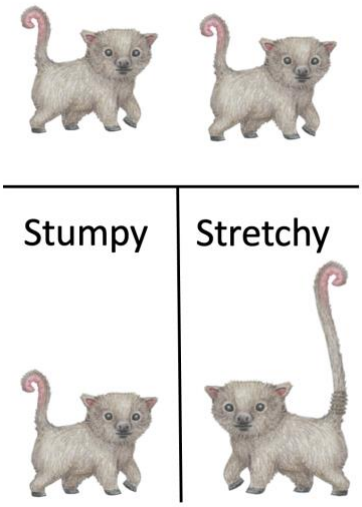
YES	NO
They will be healthy and live for a long time	They will not be healthy and live for a long time

3) Nowadays, will a tardon with a stumpy tail probably have lots of children? Why?

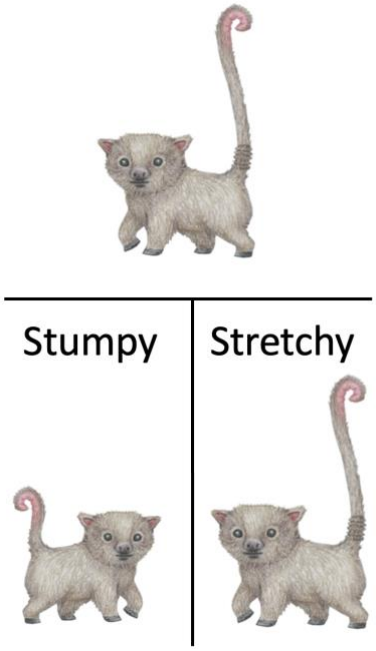
YES	NO
They will have lots of children	They will not have lots of children

4) Nowadays, will a tardon with a stretchy tail probably have lots of children? Why?

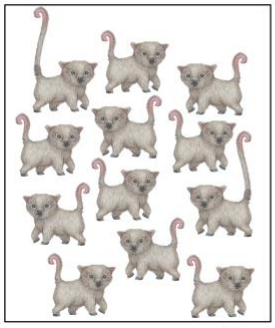
5) These grown-up tardons both have stumpy tails. If these two tardons with stumpy tails had a child, what kind of tail [stumpy or stretchy] would their child probably have? Why?

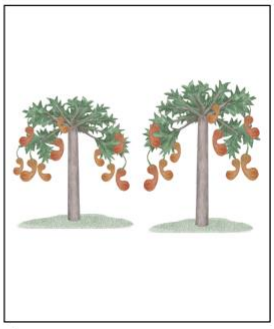


6) See this young tardon. It was born with a stretchy tail. When this tardon grows up to be an adult, what kind of tail will it have [stumpy or stretchy]?

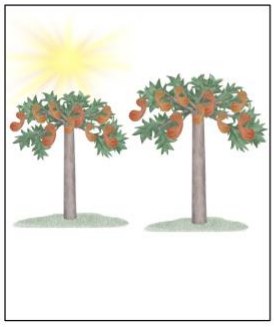


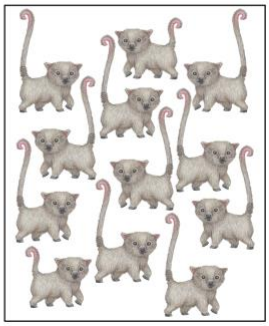
Hundreds of thousands of years ago





Nowadays





7) Many hundreds of years ago most of the grown-up tardons had stumpy tails but now most of the grown-up tardons have stretchy tails. How do you think that happened?

8) What happened to the tardons with stumpy tails?

Why?

What happened next after ….? [repeat child's response to previous question]

Why?

What happened next after ….? [repeat child's response to previous question]

Why?

9) What happened to the tardons with stretchy tails?

Why?

What happened next after ….? [repeat child's response to previous question]

Why?

What happened next after ….? [repeat child's response to previous question]

Why?

10) Did it take a short time or a long time for the tardons to go from having mostly stumpy tails in the past to having mostly stretchy tails now?

Why?

- *Give the child a chance to respond.*
- *Once the child finishes responding, stop sharing your screen.*

Thank you for giving your responses!

- *Continue to not share your screen as you give the directions for the book reading time.*

Directions for the Parents

You and your parent [mom/dad] will now get a chance to read together. Before you both begin, here are some directions. [address the parent now] Mom/Dad please read the story to [child name] and try to ask them questions while reading. These questions could be about things in the book, like words, pictures, or content, or about what you or your child may be thinking about. For example, you might ask something like "How do you think the animals get their food?" or "Which animals have more babies?". You can ask your child as many questions as you'd like, but please try to ask a question at least every four or so pages. A Question Mark will be shown in the corner of some pages to help remind you to ask your child a question. If you forget that's okay. I will now share my screen with you and allow you to turn the pages of the digital book. I'll be working on some other items of mine while you are reading. When you are finish reading you can get my attention by saying, "Hello, we have completed the story," and I'll return to do an activity with [child name]. Do either of you have any questions? [answer any questions].

- *Check to make sure the parent is able to flip through the pages of the stories. Once you see its working allow them to start reading without interrupting them.*

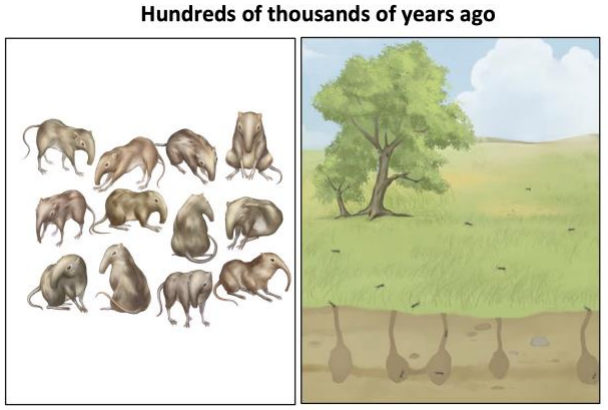
Response to the dyads once they are finish reading:

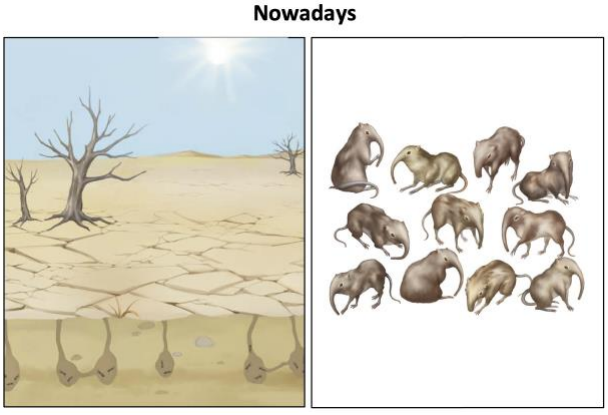
- *When parent and child are finish reading the story, you may stop sharing your screen to give them the directions for the final activities.*

I hope you both enjoyed reading the story about the Piloses. Before we end our time together, I have two final activities that I would like to do [Child name]. Again, you may stay with your child as they complete the activities, but I do ask that you let your child do this activity on their own. [Child name] are you ready to start the activities? {wait for child's answer} Great! I'm going to share my screen for you to view the activity.

- *Research assistant shares their screen to show the images below.*

Activities 2:





Let's revisit the animals called piloses!

- *Research assistant places the mouse on the first picture in the first set of images label hundreds of thousands of years ago.*

This is what the group of piloses looked like many hundreds of years ago. Many had wider trunks and a small number had thinner trunks.

- *Research assistant now places the mouse on the second picture in the first set of images label hundreds of thousands of years ago.*

This is where the piloses lived and what they ate, the milli bugs, many hundreds of years ago.

- *Research assistant now places the mouse on the first picture in the second set of images label nowadays.*

But then the weather became very hot and sunny all of the time, and now the milli bugs mostly move about underground. So, this is where piloses live and what they eat, the milli bugs now.

- *Research assistant now places the mouse on the second picture in the second set of images label nowadays.*

And this is what the group of piloses looks like now. They mostly all have thinner trunks.

Now I have some questions about the piloses that I will like for you to answer. For some of the questions, you will have two answer choices to choose from. I will, also, have pictures up on the screen so you can use them to help you.

Questions:
1) Nowadays, will a pilose with a wider trunk probably be healthy and live for a long time? Why?    

2) Nowadays, will a pilose with a thinner trunk probably be healthy and live for a long time? Why?

YES	NO
They will be healthy and live for a long time	They will not be healthy and live for a long time

3) Nowadays, will a pilose with a wider trunk probably have lots of children? Why?

YES	NO
They will have lots of children	They will not have lots of children

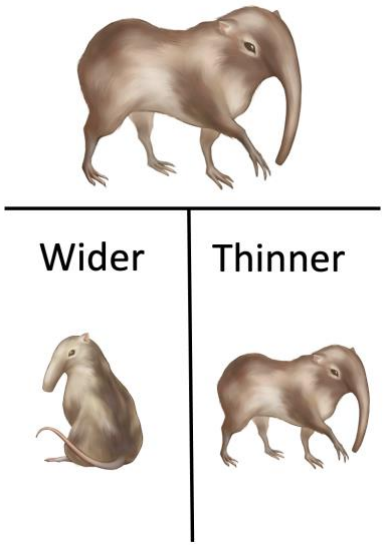
4) Nowadays, will a pilose with a thinner trunk probably have lots of children? Why?

YES	NO
They will have lots of children	They will not have lots of children

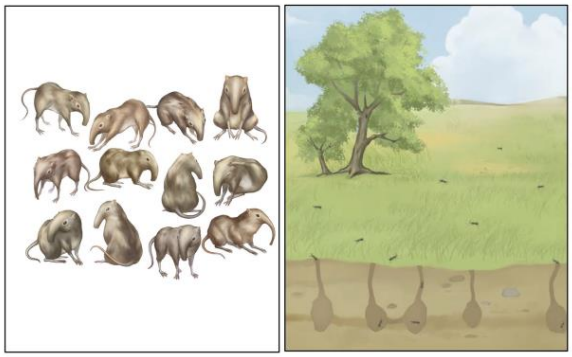
5) These grown-up piloses both have wider trunks. If these two piloses with wider trunks had a child, what kind of trunk [wider or thinner] would their child probably have? Why?

Wider	Thinner
	

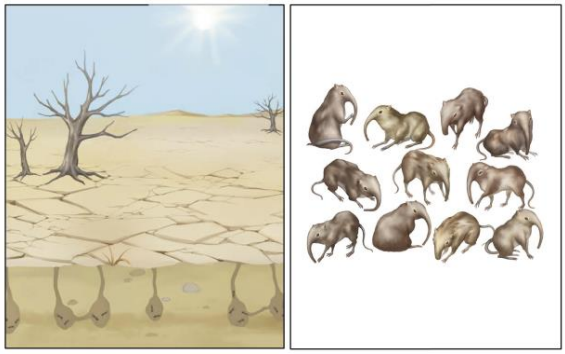
6) See this young piloses. It was born with a thinner trunk. When this pilose grows up to be an adult, what kind of trunk will it have [wider or thinner]?



Hundreds of thousands of years ago



Nowadays



7) Many hundreds of years ago most of the grown-up piloses had wider trunks but now most of the grown-up piloses have thinner trunks. How do you think that happened?

8) What happened to the piloses with thinner trunks?
Why?
What happened next after ….? [repeat child's response to previous question]
Why?
What happened next after ….? [repeat child's response to previous question]
Why?

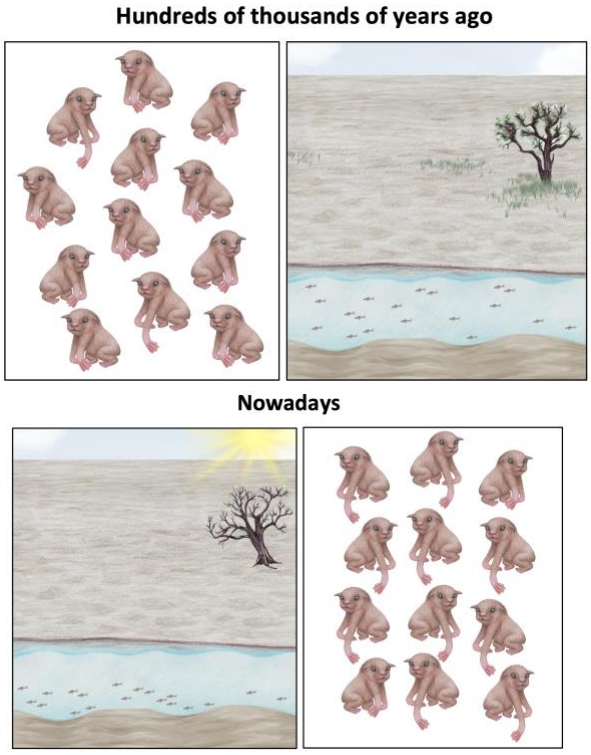
9) What happened to the piloses with wider trunks?
Why?
What happened next after ….? [repeat child's response to previous question]
Why?
What happened next after ….? [repeat child's response to previous question]
Why?

10) Did it take a short time or a long time for the piloses to go from having mostly wider trunks in the past to having mostly thinner trunks now?
Why?

- *Give the child a chance to respond.*
- *Stop sharing your screen, in order to move to the next activity of showing them another animal*

Thank you for giving your responses! Are you ready to start the last activity? {wait for child's answer} Great!

Activities 3:



Now let's look at another animal called the orpeds. I want to tell you some things about them!

- *Research assistant places the mouse on the first picture in the first set of images label hundreds of thousands of years ago.*

This is what the group of orpeds looked like many hundreds of years ago. Many had shorter arms and a small number had longer arms.

- *Research assistant now places the mouse on the second picture in the first set of images label hundreds of thousands of years ago.*

This is where the orpeds lived and what they ate, the minnows, many hundreds of years ago.

- *Research assistant now places the mouse on the first picture in the second set of images label nowadays.*

But then the weather became very hot and sunny all of the time, and now the minnows mostly swim at the bottom of the water. So, this is where orpeds live and what they eat, the minnows now.

- *Research assistant now places the mouse on the second picture in the second set of images label nowadays.*

And this is what the group of orpeds looks like now. They mostly all have longer arms.

Now I have some questions about the orpeds that I will like for you to answer. For some of the questions, you will have two answer choices to choose from. I will, also, have pictures up on the screen so you can use them to help you.

Questions:

1) Nowadays, will a orped with shorter arms probably be healthy and live for a long time? Why?

YES	NO
They will be healthy and live for a long time	They will not be healthy and live for a long time

2) Nowadays, will a orped with longer arms probably be healthy and live for a long time? Why?

YES	NO
They will be healthy and live for a long time	They will not be healthy and live for a long time

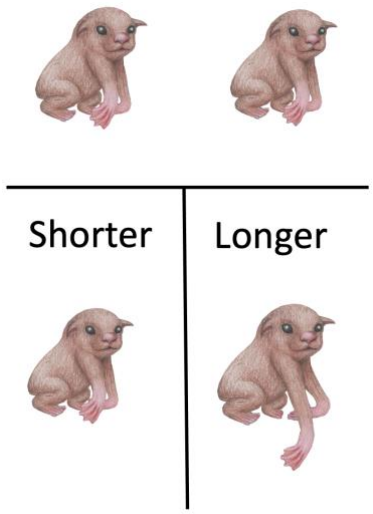
3) Nowadays, will a orped with shorter arms probably have lots of children? Why?

YES	NO
They will have lots of children	They will not have lots of children

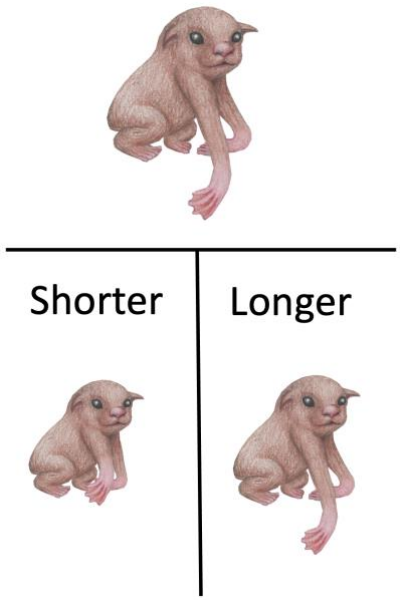
4) Nowadays, will a orped with longer arms probably have lots of children? Why?

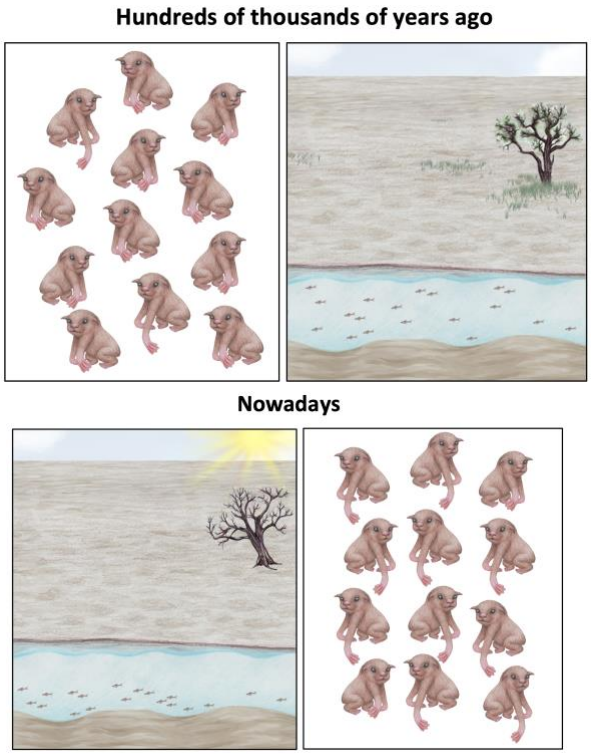
YES	NO
They will have lots of children	They will not have lots of children

5) These grown-up orpeds both have shorter arms. If these two orpeds with shorter arms had a child, what kind of arms [shorter or longer] would their child probably have? Why?



6) See this young orped. It was born with a longer arms. When this orped grows up to be an adult, what kind of arms will it have [shorter or longer]?





7) Many hundreds of years ago most of the grown-up orpeds had shorter arms but now most of the grown-up orpeds have longer arms. How do you think that happened?

8) What happened to the orpeds with shorter arms?
Why?
What happened next after ….? [repeat child's response to previous question]
Why?
What happened next after ….? [repeat child's response to previous question]
Why?

9) What happened to the orpeds with longer arms?
Why?
What happened next after ….? [repeat child's response to previous question]
Why?
What happened next after ….? [repeat child's response to previous question]
Why?

10) Did it take a short time or a long time for the orpeds to go from having mostly shorter arms in the past to having mostly longer arms now?
Why?

- *Give the child a chance to respond.*
- *Stop sharing your screen.*

Thank you for giving your explanation! You have now completed all the activities. Before we end this session, [refer to the parent] I would like to let you know that tomorrow, I will send you a brief survey to fill out about this session. Thank you so much for participating and I hope you enjoyed spending some time reading with one another. Have a lovely day!

- *Wait until the parent and child exit the Zoom room. Once they exit download the live transcript before ending the Zoom call.*
- *Remember all Zoom recordings will save to the cloud*

Appendix B

Slides used to present the study, pre-test measures, and post-tests measures and the book:

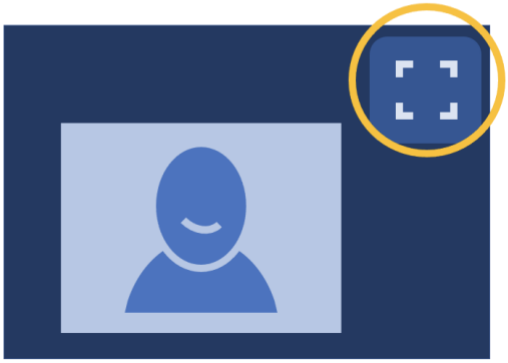
What device are using?

Are you in full-screen mode?

Yes

No

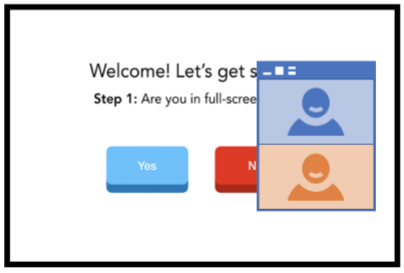
Please enter full screen mode.
The full screen icon looks like this:



Can you see **both** of our videos on the screen, or just the **experimenter**?

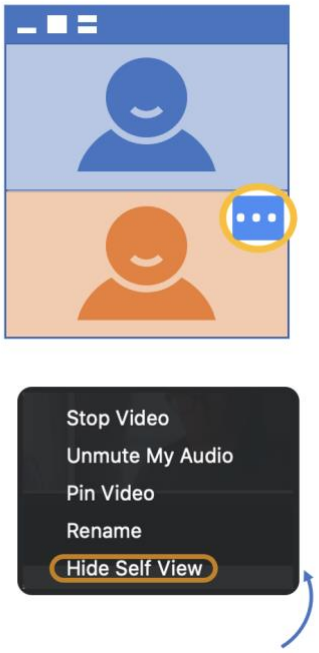
Experimenter

Both Videos



Move your mouse over the upper right corner of your video.

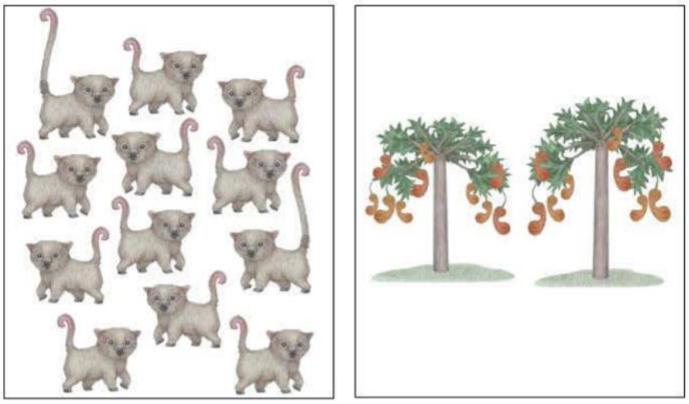
Hover over the blue and white ellipsis and select Hide Self View from the dropdown menu that appears.



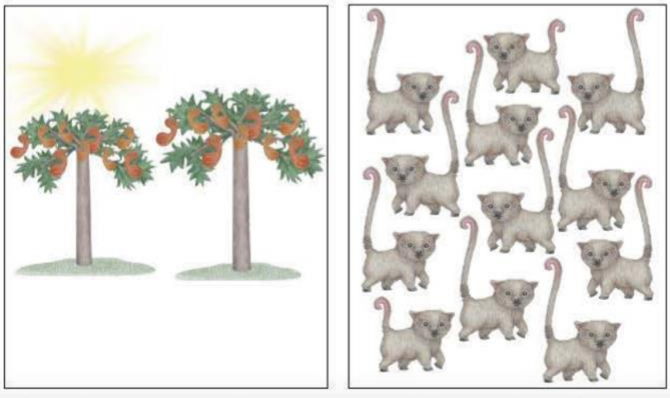
Activity Time!

Pre-test Measure

Hundreds of thousands of years ago



Nowadays

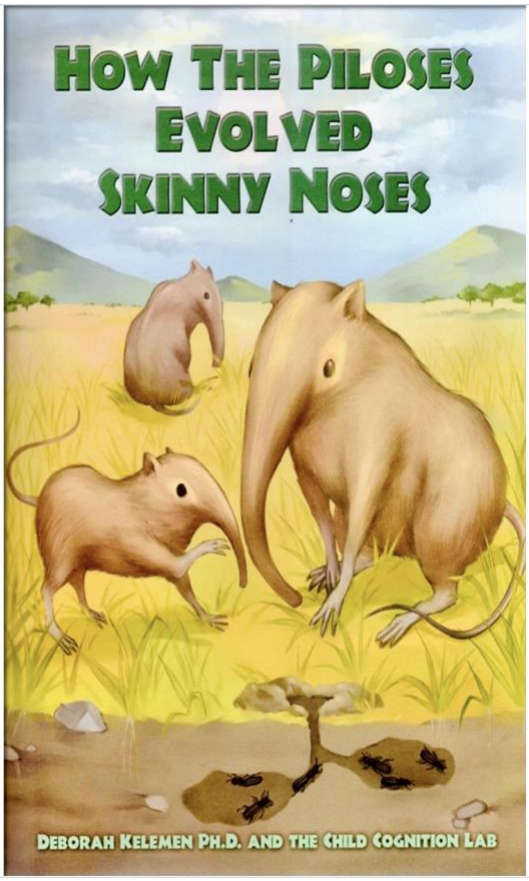


Book Reading Time!

Practice Page

Practice Page

Practice Page
(Pause Here)

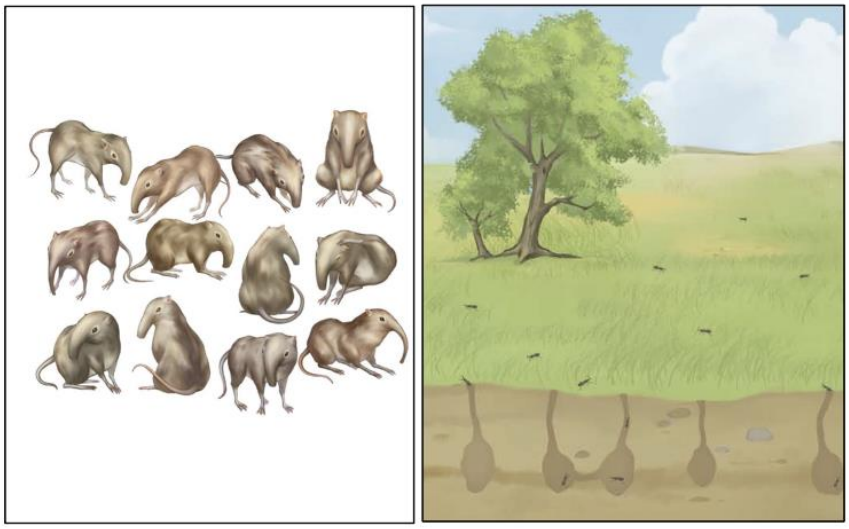


*All book pages look similar to the page above

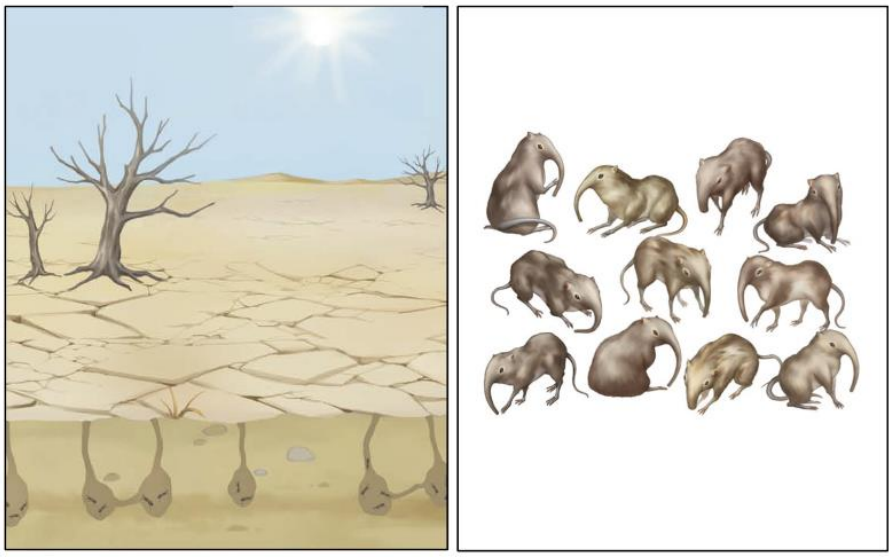
Activity Time!

Post-test Measure 1

Hundreds of thousands of years ago

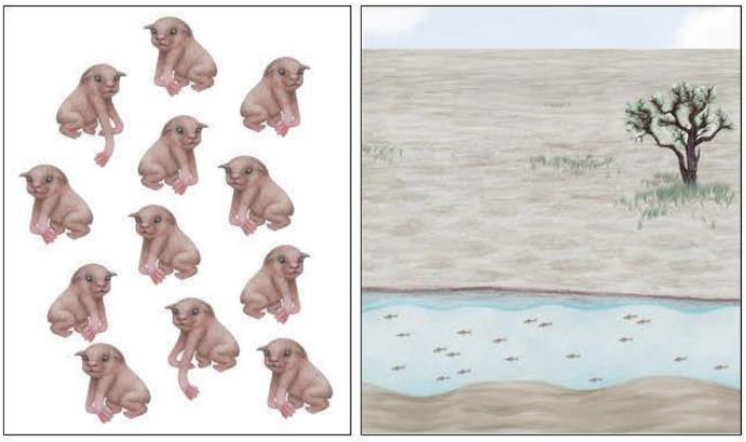


Nowadays

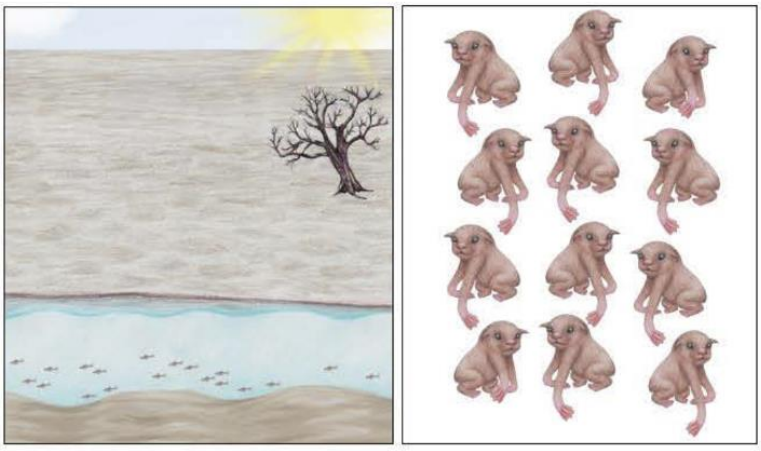


Post-test Measure 2

Hundreds of thousands of years ago



Nowadays



Appendix C

Power Test

Sixty-eight parent-child dyads would be needed to detect change when analyzing the data using the ordinal scale in Kelemen et al.'s coding rubric. Medina and Sobel (2020) when examining how caregiver-child interactions relate to children's learning when doing a task had a large effect size of Cohen's *w* (*w* = 0.5). Based on this study and my research questions of interest, I conducted a power analysis using G*Power (Faul et al., 2007). The a priori analysis indicated that sixty-eight parent-child dyads were sufficient to achieve 80% power using a two-tailed test with a large Cohen's *d* effect size of 0.7 and alpha of 0.05.

Ordinal Logistic Regression Analyses for the sample of 25 participants for Research Questions 1, 2, and 4 and Exploratory Question 2

Research Question 1: Are gains in children's understanding about natural selection associated with a shared parent-child digital book reading about natural selection?

At pre-test, 96% of the children sample were at Level 0 (no isolated facts) and 4% were at Level 1 (isolated facts but no natural selection understanding) (Kelemen et al., 2014) (See Figure 1). After reading the story with their parent, only 4% remained at Level 0 at the post-test measure on comprehension or understanding of natural selection within the species the child read about. The rest of the sample fell within the other levels with 64% at Level 1, 4% at Level 2 (foundational natural selection understanding), 12%

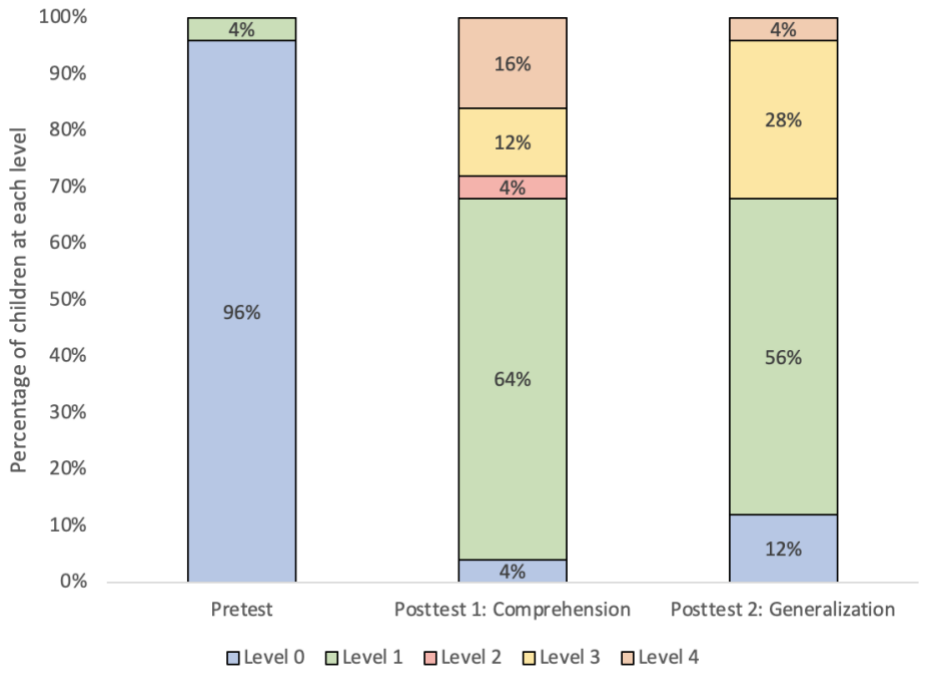
at Level 3 (natural selection understanding in one generation), and 16% at Level 4 (natural selection understanding in multiple generations).

A one-sample within-subjects test using ordinal logistic regressions was used to examine whether children's understanding of natural selection after shared digital book reading with a parent is associated with their understanding at pre-test. Child's age and gender were controlled for in all analyses for this question. Analyses showed the difference between children's natural selection understanding at pre-test and post-test measure on comprehension was not significant, Wald χ^2 (3, N = 25) = 5.07, p = .17. For a one unit change in the ordinal level score on the pre-test measure, the odds of children being in a higher ordinal level at the post-test measure on comprehension versus a lower level was 2.94 times greater, p = .99, 95% confidence interval (CI) = [-2583.85, 2618.25].

Compared to the 96% of the children at Level 0 at pre-test, only 12% were at Level 0 at the post-test measure on generalization, or transfer of what was learned about natural selection to a new species. Most (56%) of children were at Level 1, 28% were at Level 3, and 4% were at Level 4 (Figure 1). Ordinal logistic regression showed that, the difference between children's understanding of natural selection at pre-test and post-test measure on generalization, was not significant, Wald χ^2 (3, N = 25) = 1.97, p = .58. For a one unit change in the ordinal level score on the pre-test measure, the odds of children being in a higher ordinal level at the post-test measure on generalization versus a lower level was 1.17 times greater, p = .94, 95% CI = [.02, 55.42].

Figure 1

Percentage of children classified at each level for pre-test and post-test measures



Research Question 2: Is there an association between parent pedagogical questioning during a digital book reading and gains in children's understanding about natural selection?

Ordinal logistic regressions were used to examine whether there is an association between parent pedagogical questioning during book reading and children's understanding about natural selection. Child's age, gender, and pre-test understanding level were controlled for in all analyses for this question. Analyses revealed that the association between parent pedagogical questioning and the likelihood of children being

in a higher level of natural selection understanding at the post-test measure for comprehension was not significant, Wald χ^2 (3, N = 25) = 7.57, p = .11. For a one unit change in the number of parent pedagogical questions asked, the odds of children being in a higher ordinal level at post-test measure on comprehension versus a lower level was .93 times greater, p = .13, 95% CI = [.84, 1.02]. Parent pedagogical questioning was also not significantly associated with the likelihood of children being in in a higher level of natural selection understanding at the post-test measure for generalization, Wald χ^2 (3, N = 25) = 3.15, p = .53. For a one unit change in the number of parent pedagogical questions asked, the odds of children being in a higher ordinal level at post-test measure on generalization versus a lower level was .95 times greater, p = .28, 95% CI [.87, 1.04].

Research Question 4: Is there an association between child utterances during parent reading of a digital storybook and gains in children's understanding about natural selection?

Ordinal logistic regressions were used to examine whether there is an association between child utterances and children's understanding about natural selection. Child's age, gender, and pre-test understanding level were controlled for in all analyses for this question. Analyses indicated that child utterances were not significantly associated with the likelihood of children being in a higher level of natural selection understanding at the post-test measure for comprehension, Wald χ^2 (4, N = 25) = 5.52, p = .24. For a one unit change in the number of child utterance made, the odds of children being in a higher ordinal level at post-test measure on comprehension versus a lower level was .98 times

greater, p = .51, 95% CI = [.95, 1.02]. Child utterances was also not significantly associated with the likelihood of children being in in a higher level of natural selection understanding at the post-test measure for generalization, Wald χ^2 (3, N = 25) = 2.13, p = .71. For a one unit change in the number of child utterance made, the odds of children being in a higher ordinal level at post-test measure on generalization versus a lower level was .99 times greater, p = .69, 95% CI [.97, 1.02].

Exploratory Question 2

The second exploratory question asked: is there an association between parent non-pedagogical questioning and children's natural selection understanding? To answer this question ordinal logistic regressions were used. Child's age, gender, and pre-test understanding level were controlled for in all analyses for this question. Analyses showed that parent non-pedagogical questioning was not significantly associated with the likelihood of children being in a higher level of natural selection understanding at the post-test measure for comprehension, Wald χ^2 (4, N = 25) = 6.15, p = .19. For a one unit change in the number of parent non-pedagogical questions asked, the odds of children being in a higher ordinal level at post-test measure on comprehension versus a lower level was .95 times greater, p = .31, 95% CI = [.86, 1.05]. Parent non-pedagogical questioning was also not significantly associated with the likelihood of children being in a higher level of natural selection understanding at the post-test measure for generalization, Wald χ^2 (4, N = 25) = 5.94, p = .20. For a one unit change in the number of parent non-pedagogical questions asked, the odds of children being in a higher ordinal

level at post-test measure on generalization versus a lower level was .91 times greater, p = .06, 95% CI [.81, 1.00].

Appendix D

IRB Protocol (#4705) Approval

Office of the Vice President for Research

Human Research Protection Program

Institutional Review Board for the Social and Behavioral Sciences

IRB-SBS Chair: Moon, Tonya

IRB-SBS Director: Blackwood, Bronwyn

Protocol Number (4705) Approval Certificate

The UVA IRB-SBS reviewed "Children's Knowledge and Reasoning about Natural Selection" and determined that the protocol met the qualifications for approval as described in 45 CFR 46.

Principal Investigator: Matthews, Shoronda

Faculty Sponsor: Jirout, Jamie

Protocol Number: 4705

Protocol Title: Children's Knowledge and Reasoning about Natural Selection

Is this research funded? Yes

Funding Source(s): Federal government

All Agency Grant Numbers & Titles currently associated with this protocol:

Institute of Education Sciences, U.S. Department of Education; Grant R305B200005

Review category: Exempt Review

1. Normal educational practice in educational settings

Review Type:

Modifications: Yes
Continuation: No
Unexpected Adverse Events: No

Approval Date: 2022-01-07

As indicated in the Principal Investigator, Faculty Sponsor, and Department Chair Assurances as part of the IRB requirements for approval, the PI has ultimate responsibility for the conduct of the study, the ethical performance of the project, the protection of the rights and welfare of human subjects, and strict adherence to any stipulations imposed by the IRB-SBS.

The PI and research team will comply with all UVA policies and procedures, as well as with all applicable Federal, State, and local laws regarding the protection of human subjects in research, including, but not limited to, the following:

1. That no participants will be recruited or data accessed under the protocol until the Investigator has received this approval certificate.
2. That no participants will be recruited or entered under the protocol until all researchers for the project including the Faculty Sponsor have completed their human investigation research ethics educational requirement (CITI training is required every 3 years for UVA researchers). The PI ensures that all personnel performing the project are qualified, appropriately trained, and will adhere to the provisions of the approved protocol.
3. That any modifications of the protocol or consent form will not be implemented without prior written approval from the IRB-SBS Chair or designee except when necessary to eliminate immediate hazards to the participants.
4. That any deviation from the protocol and/or consent form that is serious, unexpected and related to the study or a death occurring during the study will be reported promptly to the SBS Review Board in writing.
5. That all protocol forms for continuations of this protocol will be completed and returned within the time limit stated on the renewal notification letter.
6. That all participants will be recruited and consented as stated in the protocol approved or exempted by the IRB-SBS board. If written consent is required, all participants will be consented by signing a copy of the consent form unless this requirement is waived by the board.
7. That the IRB-SBS office will be notified within 30 days of a change in the Principal Investigator for the study.
8. That the IRB-SBS office will be notified when the active study is complete.
9. The SBS Review Board reserves the right to suspend and/or terminate this study at any time if, in its opinion, (1) the risks of further research are prohibitive, or (2) the above agreement is breached.

Date this Protocol Approval Certificate was generated: 2022-02-02