The Power of “Same” and “Different”:

Relations Between Relational Language and Science Knowledge

By

Emma Esther Vieira Lazaroff

A dissertation submitted in partial fulfillment of

the requirements for the degree of

Doctor of Philosophy

(Educational Psychology)

at the

UNIVERSITY OF WISCONSIN-MADISON

2022

Date of final oral examination: 1/24/2022

The dissertation is approved by the following members of the Final Oral Committee:

Haley Vlach, Associate Professor, Educational Psychology

Heather Kirkorian, Associate Professor, Human Development and Family Studies

Percival Matthews, Associate Professor, Educational Psychology

Sarah Short, Assistant Professor, Educational Psychology

TABLE OF CONTENTS

Abstract……………………………………………………………………………………... ii

Acknowledgements……………………………………………………………………….iii

Chapter 1: Introduction…………………………………………………………………….. 1
Current Study………………………………………………………………………….. 6

Chapter 2: Method……………………………………………………………………….8
Participants……………………………………………………………………………..8
Materials and Procedure………………………………………………………………..9
Peabody Picture Vocabulary Test……………………………………………... 9
Relational Vocabulary Checklist………………………………………..…….10
Science Attitudes and Behaviors Checklist…………………………..……….11
Woodcock Johnson Science Assessment……………………….…………….12

Chapter 3: Results……………………………………………………………….……….13
Planned Analyses…………………………………………………………..…….13
Descriptive Statistics………………………………………………………….……13
Bivariate and Partial Correlations Between Tasks and
Demographic Variables………………………………………………………….13
Hierarchical Linear Regression Models Predicting Science Knowledge..………14

Exploratory Analyses………………………………………………….…………... 15
Subcategories of Relational Words and Science Knowledge…………………... 15
Child Characteristics and Science Knowledge………………………………. 17
Parent and Family Characteristics and Science Knowledge…………………….20
Exploratory Analysis of Questions on the Woodcock Johnson
Science Assessment……………………………………………………………….. 23

Chapter 4: General Discussion……………………………………………………… 25
Directions for Future Research…………………………………………………….27
Concluding Thoughts……………………………………………………………….29

References……………………………………………………………………………….31

Tables…………………………………………………………………………………….41

Appendices……………………………………………………………………………….67

Abstract

Science learning is important for the well-being of individuals and society. Acquiring the knowledge necessary for success in science is not easy because science involves relational thinking, or the ability to abstract and generalize from similarities between concepts. Using relational words, or shared linguistic labels that identify commonalities between at least two entities, has been shown to promote relational thinking. However, research has yet to directly link relational language and science knowledge. Thus, my dissertation examined the nature of this link by examining whether children's relational productive vocabulary predicted their science knowledge above and beyond other factors, such as general vocabulary, demographic variables, and science attitudes and behaviors. Results revealed that, contradictory to my main hypothesis, children's relational vocabulary size did not predict their science knowledge above and beyond general vocabulary and demographic variables. Instead, relational vocabulary was linked to science knowledge by serving as an intermediate step between children's science talk frequency and science knowledge. In brief, the findings from this study are a key step towards fully understanding the mechanism(s) by which relational language drives changes in science knowledge.

ACKNOWLEDGEMENTS

This dissertation is but one piece of a 5-plus-year Ph.D. journey, a wonderful and enriching experience for which I have many to thank. I most certainly would not have reached this milestone without the support of many people.

First, I want to express my gratitude to my advisor, Haley Vlach. Thank you for giving me the tools I need to succeed as an independent researcher and for allowing me to pursue the questions I am passionate about. Thank you for teaching me the hidden curriculum of the academia/research world and for teaching me how to find optimism in any situation. And of course, thank you for always being present and for being so invested in your students. Mentoring graduate students (especially me!) is not easy, but you make it look effortless. I am incredibly fortunate to have had you as my advisor.

I also want to thank my committee members, Dr. Heather Kirkorian, Dr. Percival Matthews, and Dr. Sarah Short, for their insights and encouragement throughout this process. I want to give special thanks to Percival, Haley's office neighbor who played a similar role in my grad school journey. Percival, thank you for your many insights and influences on my work and for pushing me to think about my research in new ways. Without you, I would not have the network instrumental to navigating the challenges that come with being a historically underrepresented graduate student. On that note, I cannot go without thanking those who gave me the financial support necessary to complete this degree: the Wisconsin Center for Education Research and the WCER Fellows program, the Ed-GRS program and the School of Education, and the Department of Educational Psychology.

Thank you to the LCD Lab members, to WiSolve Consulting Group and WCER Fellows, to Sarah at the Career Center, and to countless other fellow students, postdocs, and staff, for your feedback and advice. There are too many of you to list. I am glad to have had the opportunity to work alongside so many exceptional scientists and kindhearted people. I am also endlessly thankful for all of the families and children who participated in this study in the middle of a pandemic; research would not advance without you!

Muito obrigada to my family for their love and support and for inspiring in me a lifelong passion for education. Thank you to my best friend, Rosanna, for being there throughout the happy and the difficult times, even from 1,000 miles away. And thank you to Benjamin, my partner of the past 9 years – for your unconditional love, your intellectual and emotional support, and your unwavering confidence in me.

Finally, in the words of Snoop Dogg: "Last but not least: I want to thank me. I want to thank me for believing in me. I want to thank me for doing all this hard work. I want to thank me for having no days off. I want to thank me for never quitting. I want to thank me for always being a giver, and trying to give more than I receive. I want to thank me for trying to do more right than wrong. I want to thank me for just being me at all times."

CHAPTER ONE

INTRODUCTION

Science education is important; the science achievement resulting from a high quality science education leads to benefits for individuals and society. On an individual level, children's success in science directly impacts whether they choose to major in STEM fields and thus pursue STEM careers in adulthood (Wang, 2013). In turn, these careers often result in higher earnings and social status later in life (Russell & Atwater, 2005). Critically, this science knowledge is beneficial regardless of whether children choose to pursue STEM fields. Children with more science knowledge are more likely to later make well-informed voting decisions on public policy issues such as climate change, as well as more well-informed personal decisions such as selecting an appropriate medical treatment (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine [NASNAEIM], 2010, 2011; National Research Council, 2012). On a larger, societal scale, high-quality science education builds and diversifies the workforce capacity inside and outside of STEM fields, allowing the United States to maintain its competitiveness in the global economy (Drew, 2011; NASNAEIM, 2010).

However, acquiring the science knowledge necessary for success is not an easy task. Science knowledge can be increasingly challenging for children to gain because science concepts build in complexity over the school years (Jaakkola & Veermans, 2018). The Next Generation Science Standards recommend that teachers construct progressions across development (National Research Council, 2013). That is, the standards from each grade build on prior knowledge gained in previous grades, starting with simple descriptions and moving on to progressively more sophisticated explanations of science phenomena. For example, the physics module on motion and stability for grades K-2 involves simple investigations such as observing how different objects move when they are pushed or pulled. Subsequently, the unit for grades 3-5 builds on K-2 knowledge by controlling for variables, such as mass. The unit for grades 6-8 builds on K-5 knowledge to include children constructing their own explanations and designing solutions to problems supported by scientific evidence and theories, such as Newton's laws of motion. Finally, the unit for grades 9-12 builds on K-8 knowledge by using statistical analysis and forming scientific claims or solutions based on this data, such as graphing the motion of an object to support the claims from Newton's second law of motion. As outlined in the Next Generation Science Standards, overcoming the increasingly challenging concepts that constitute science is important for successfully acquiring science knowledge.

One major factor contributing to the difficulty in acquiring and building on science knowledge is the relational nature of science. **Relational thinking,** the ability to abstract and generalize a commonality between two or more entities, is a fundamental process of human cognition that supports learning across domains (Alfieri et al., 2013; Goldwater & Schalk, 2016; Vendetti et al., 2015). There are many steps to reach the end goal of generalizing relations to new contexts. In particular, children must learn to overlook the perceptual features they tend to focus on in early childhood (Gentner, 1988) and must instead extract an underlying relational structure between exemplars before they can generalize. For example, density is one commonly misunderstood science concept where this challenge is particularly salient (Kloos et al., 2010). Objects that children frequently assume will float based on their perceptual features, such as wooden objects (Smolleck & Hershberger, 2011), may actually sink because they have a higher density than the surrounding water. Thus, children learning about density must overlook an object's physical appearance to determine the relation between its mass and volume, a relation which they can then generalize from to predict whether other objects float or sink. To further complicate this process of generalization, science often involves abstract conceptual knowledge and is often encountered in unfamiliar examples in which children cannot rely on their perceptual biases (Alfieri et al., 2013; Orton et al., 2012). In brief, relational thinking is a fundamental component of science knowledge; many science concepts are inherently relational and exist as formalized representational systems, such as Newtonian laws in physics (Goldwater & Schalk, 2016).

The process of generalizing relations often does not happen spontaneously. Children are likely to need cognitive supports to generalize information. As a result, researchers have studied how to promote relational thinking. **Comparison**, or the process of presenting at least two exemplars of a concept simultaneously, has been identified as one such cognitive support (Gentner, 1983, 2010). In a typical experiment using comparison, participants view two relationally similar category exemplars (e.g., turtles and cows of different sizes) which are often paired with verbal labels (e.g., nonce words; "These are blickets"). Participants are then prompted to compare the exemplars to draw their attention to similarities: for example, the experimenter might ask, "Can you see why these are both blickets?" (e.g., Gentner & Namy, 1999). During testing, participants view multiple options and choose which option is also a "blicket". For example, they may be asked to choose between a photo of a turtle and a cow of identical size (a perceptual match only) and a photo of a smaller rhino next to a larger one (a relational match) (e.g., Christie & Gentner, 2010). With this type of comparison-based training, participants gradually learn to direct attention to and generalize from relational similarities across exemplars instead of focusing on purely perceptual matches.

One of the key mechanisms underlying comparison is language. Specifically, using relational words during comparison facilitates relational thinking. **Relational words** are linguistic labels that identify commonalities between at least two entities, such as “between”, “greater”, or “same”. Research has suggested that relational words offer benefits for relational learning through adding stability to representations and allowing for consistent encoding of relevant relational information over irrelevant perceptual features (Gentner, 2003; Gentner & Christie, 2010). These relational words come in multiple forms. For example, research has used shared noun or adjective labels to facilitate learning of object-based relational categories (e.g., “These are both *daddies/little*”) (Gentner & Namy, 1999) or novel words for action-based relational categories (e.g., “The knife is the *dax* (cutter) for the watermelon”) (Gentner et al., 2011). Relational words have also been used in a spatial context, such as when asking children to map items between physical spaces (e.g., “I’m putting this *next to* the box”) (Loewenstein & Gentner, 2001, 2005). Indeed, children are more likely to choose relational matches over perceptual matches when the relations are assigned these common labels (Namy & Gentner, 2002; Rattermann & Gentner, 1998). Taken together, this research argues that children attend to and generalize from relational information more when they are prompted using relational words.

If we were to step back and look back at this body of work, one may predict that children’s relational vocabulary would be predictive of their science learning. If children have access to relational labels, they would be able to engage in relational thinking to a greater degree and thus acquire more science knowledge. For example, if a child who knows the word “similar” is told “These two objects are both floating because their density is similar” during a science lesson, then the word “similar” would prompt them to compare the objects to determine how they both float rather than drawing attention to perceptual similarities, such as size or shape. This relational thinking ability of comparing mass and volume is necessary for learning density. Thus, the relational label of “similar” is what may be driving this change in science knowledge.

Interestingly, researchers often mention this proposal in their work (Gentner et al., 2015; Goldwater & Schalk, 2016; Jee et al., 2014). However, no study has empirically tested this possibility: previous research has only separately examined how relational language supports general relational knowledge or how relational thinking ability supports science learning (e.g., Gentner et al., 2011; Loewenstein & Gentner, 2005; Matlen et al., 2011; Resnick et al., 2017). That is, a direct link between relational language and science knowledge has never been established. Moreover, research has not considered other variables that should be controlled for to determine a relation between relational language and science knowledge. These include demographic variables purported to be responsible for science knowledge differences such as age, gender, and socioeconomic status (SES) (Morgan et al., 2016; National Science Board, 2018; Reardon, 2011; Sackes et al., 2011; U.S. Department of Education, 2015) or children's general vocabulary size, which is likely highly correlated with their relational vocabulary size.

There are also factors beyond demographics that could explain a link between relational vocabulary and science knowledge. For instance, many science attitudes and behaviors are associated with science knowledge. This includes child and parent attitudes towards and interest in science (Lipham et al., 2013; Osborne et al., 2003; Perera, 2014). Furthermore, children's engagement in informal science activities is associated with their science knowledge. These activities range from family activities inside and outside the home (e.g., cooking, visiting museums or zoos) (Benjamin et al., 2010; Callanan et al., 2020; Cumming, 2003; Joy et al., 2021) to the consumption of science media (e.g., television shows and books) (Bonus, 2019; Paulsen et al., 2021). Finally, these attitudes and behaviors also include how often children and their families engage in science talk across informal learning environments (Callanan & Jipson, 2001; Crowley & Galco, 2001; Tenenbaum & Callanan, 2008; Tscholl & Lindgren, 2016).

Therefore, this dissertation addresses these limitations by examining how these factors may contribute to children's science knowledge, and thus is a critical first step in determining the mechanism(s) by which relational language itself contributes to science knowledge.

Current Study

To determine whether children's relational vocabulary ability directly predicts their science knowledge, this study examined children's relational vocabulary, general vocabulary, science knowledge, and demographic variables simultaneously. **My hypothesis was that children's relational vocabulary would predict their level of science knowledge** above and beyond demographic factors including age, gender, and socioeconomic status. Specifically, I predicted that a larger relational vocabulary would be related to higher levels of science knowledge, and a smaller relational vocabulary would be related to lower levels of science knowledge. If I did not find these results, it would provide support for alternative hypotheses. For example, relational words children say may be unrelated to what they know and understand about science, suggesting mechanisms other than relational language contribute to the development of children's science knowledge. Alternatively, there may be an indirect relation between relational language and science knowledge; that is, intermediate steps may explain this broader relation. One last possibility is that relational vocabulary is part of a chain of events that contribute to science knowledge. I planned to conduct exploratory analyses to begin to understand the nature of these intermediate steps or events if the results did not support my hypothesis.

I used a series of four tasks to determine whether the amount and type of relational words children produce relates to their science knowledge. The science knowledge task consisted of the Woodcock Johnson Science Assessment (WJ) (Schrank et al., 2014), a standardized test of children's conceptual and fact-based science knowledge. The general language measure was the Peabody Picture Vocabulary Test (PPVT) (Dunn & Dunn, 2007), a measure of children's domain-general receptive vocabulary. Parents completed a Relational Vocabulary checklist that measured children's productive vocabulary of relational words, which I developed based on relational language used in previous research. Finally, parents completed a Science Attitudes and Behaviors Checklist which measured child and family science attitudes and behaviors. I developed this checklist based on science attitude and behavior questions used in previous surveys (i.e., the Next Generation Science Standards Statewide Parent Survey [California State PTA, 2018]; the Programmer for International Student Assessment Parent Questionnaire [Organisation for Economic Co-operation and Development, 2015]; and the Science Motivation Questionnaire II [Glynn et al., 2011]). These four tasks afforded the opportunity to examine whether there were relations between children's relational vocabulary and science knowledge.

CHAPTER TWO

METHOD

Participants

The participants were 80 children (42 females; Mean age = 77.6 months; Median age = 79.5 months; SD = 17.55; Range = 48-107 months) recruited online via email or through advertisements on websites (e.g., parent event blogs). I chose this period of development because it spans the time in which children are acquiring and using relational words and formal science knowledge for the first time, thus affording an understanding of the foundation of this relation (Gentner, 2010; National Research Council, 2007). Experimental sessions were conducted using Zoom, a secure live video-chat application. Parents were sent a survey on Qualtrics prior to the study to provide demographic data about their child and family, as well as to complete the Relational Vocabulary Checklist and the Science Attitudes and Behaviors Checklist.

All parents provided demographic data about their child and family; children came from predominantly White middle to upper SES families. Socioeconomic status (SES) was calculated on a point-based scale combining information on household income and parental education (e.g., a family with a household income of $50,000 to $99,999 [3] and an education level of college graduate [5] would receive a score of 8). Demographic information about the sample is provided in Appendix A. Parents received an online Amazon gift card for $10 as a thank you for their participation in the study.

An effect size could not be derived from previous research, as previous research has measured relational language and science knowledge separately. Given this limitation, a power analysis was conducted for a regression analysis with five predictor variables and an estimated medium effect size (Cohen's $d = .42$). The five predictor variables were age, gender, SES, PPVT score, and Relational Vocabulary Checklist score. Age, gender, and SES were included as variables because previous research has suggested they are related to differences in children's science knowledge (Morgan et al., 2016; National Science Board, 2018; Reardon, 2011; Sackes et al., 2011; U.S. Department of Education, 2015). I also expected to see an increase in vocabulary size with age, minor differences based on gender (Huttenlocher et al., 1991; Hyde & Linn, 1988), and significant differences based on SES (Fernald et al., 2013). The results of the power analysis indicated that a sample size of 80 children would yield at least 80% power. Thus, the data collection plan used a cutoff of 80 participants successfully completing the study, with data collection ending when this number of participants was reached.

Materials and Procedure

Children participated in two tasks: the Peabody Picture Vocabulary Test (PPVT), Fourth Edition (Dunn & Dunn, 2007) and the Woodcock Johnson, Test 18: Science, Fourth Edition as the outcome variable (Schrank et al., 2014). Children were randomly assigned to one of two orders of task presentation (PPVT first or Woodcock Johnson first). Parents completed the Relational Vocabulary Checklist, Science Attitudes and Behaviors Checklist, and family demographics survey for their children on Qualtrics prior to the start of the experiment.

Peabody Picture Vocabulary Test

I used the Peabody Picture Vocabulary Test (Dunn & Dunn, 2007) to assess children's general receptive vocabulary. This study sought to determine the unique contribution of relational vocabulary to children's science knowledge, and thus I used this measure to control for general vocabulary size. In this standardized test, the experimenter said a word to children, and children were instructed to state the number corresponding to the picture (out of four possible pictures) that best represented the given word. Because at least one third to one half of children under kindergarten age are not familiar with all of their letters and single-digit numbers (U.S. Department of Education, 2001), children under kindergarten age were instructed to point to the picture on the screen and a parent or guardian was present to tell the experimenter which picture the child pointed to. The PPVT was completed after children made eight or more errors within a set of 12 items (i.e., children completed their Ceiling Set). Children's raw score on the PPVT-IV was used as a measure of their general receptive vocabulary. The PPVT is provided in Appendix B.

Relational Vocabulary Checklist

I used a parent report Relational Vocabulary Checklist to assess children's relational vocabulary. I developed this checklist myself, as other measures to assess children's relational vocabulary do not exist. This checklist afforded a relative estimate of how many relational words children produce. The checklist was designed after other parent report measures of vocabulary, such as the MacArthur-Bates Communicative Development Inventory (Fenson et al., 2007), which have been shown to be reliable ways of measuring children's word knowledge (Fenson et al., 2007). It was also designed to include words that are typically acquired before, within, and beyond the age range of this study, as determined by adult age of acquisition norms (Kuperman et al., 2012). Parents reported the relational words they had heard their child say out loud using an online Qualtrics survey.

The 195 words were organized into three categories based on relational words used in previous research (e.g., Gentner et al., 2011; Loewenstein & Gentner, 2005; Waxman & Klibanoff, 2000): General relational words ($N = 74$), Specific relational words ($N = 52$), and Spatial relational words ($N = 69$). General relational words consisted of words that are used across multiple settings, as well as words that are used to compare any number of entities (e.g., align, contrast, similar). Specific relational words consisted of words that are used to compare only two entities on a specific quality (e.g., bigger, greater, slower). Spatial relational words consisted of words used to describe dimensions, locations, and directions, as well as relations between objects in space (e.g., around, diagonal, over). The Spatial words in the Checklist were taken from both the MCDI: Words and Sentences (Fenson et al., 1994) and from a spatial word coding manual (Cannon et al., 2007). The Relational Vocabulary Checklist is provided in Appendix C.

Science Attitudes and Behaviors Checklist

I used a parent report Science Attitudes and Behaviors Checklist to measure child and family attitudes and behaviors surrounding the practice of science. There was no existing checklist that afforded a comprehensive look into child and family science attitudes and behaviors. Thus, I developed this checklist by adapting questions from multiple existing questionnaires used to assess these variables, which have been shown to be reliable ways of measuring child and family science attitudes and behaviors (i.e., the Next Generation Science Standards Statewide Parent Survey [California State PTA, 2018]; the Programme for International Student Assessment Parent Questionnaire [Organisation for Economic Co-operation and Development, 2015]; and the Science Motivation Questionnaire II [Glynn et al., 2011]). The questions consisted of variables previously purported to be associated with children's science knowledge, including: children's interest in science (Leibham et al., 2013; Osborne et al., 2003); children's consumption of science media such as television shows and books (Bonus, 2019; Paulsen et al., 2021); children's engagement in informal science activities inside and outside the home (Benjamin et al., 2010; Callanan et al., 2020; Cumming, 2003; Joy et al., 2021); and frequency of child and family science talk (Callanan & Jipson, 2001; Crowley

& Galco, 2001; Tenenbaum & Callanan, 2008; Tscholl & Lindgren, 2016). Questions from the checklist are listed in Tables 7 and 12. The Science Attitudes and Behaviors Checklist is provided in Appendix D.

Woodcock Johnson Science Assessment

I used the Woodcock Johnson Science Assessment (Schrank et al., 2014) to assess children's science knowledge. I chose this standardized test because unlike previous measures used to assess children's science knowledge, it covered the broadest range of science topics, was adapted for the broadest age range, and was standardized for a national sample. In this standardized test, the experimenter asked children science questions that require a verbal response (i.e., "How do we take in the air we breathe?") or asked children to identify a picture of a science-related item. The science concepts covered in this test range from concepts typically understood by children under 2 years of age through adulthood. The Woodcock Johnson Science Assessment was completed after children made six consecutive errors. The number of correct items was used as the measure of children's science knowledge. The Woodcock Johnson Science Assessment is provided in Appendix E.

CHAPTER THREE

RESULTS

Planned Analyses

Descriptive Statistics

I started my planned analyses by calculating the descriptive statistics for children's performance on the Relational Vocabulary Checklist, Woodcock Johnson Science Assessment, and PPVT, as well as the demographic variables of age, gender, and socioeconomic status. Children's performance on the PPVT was measured using the raw score. Children's performance on the Woodcock Johnson Science Assessment was measured using the total number of correct items. Children's relational vocabulary was calculated by summing the number of words children produced according to the Relational Vocabulary Checklist. Age was measured in months. For gender, females were coded as 1 and males were coded as 2. Socioeconomic status was calculated on a point-based scale combining information on household income and parental education. Results of these analyses are described in Table 1.

Bivariate and Partial Correlations Between Tasks and Demographic Variables

I continued my analyses by conducting bivariate and partial correlations between children's scores on the Woodcock Johnson Science Assessment, the Peabody Picture Vocabulary Test, and the Relational Vocabulary Checklist as a whole, plus the demographic variables of age, gender, and socioeconomic status. The partial correlations controlled for age, gender, and socioeconomic status, variables previously purported to be associated with science knowledge (Morgan et al., 2016; National Science Board, 2018; Reardon, 2011; Sackes et al., 2011; U.S. Department of Education, 2015). Correlations are also listed in Table 1.

Results from bivariate correlations revealed that, as expected, age was significantly correlated with performance on all tasks children completed: the Relational Vocabulary Checklist, the Woodcock Johnson Science Assessment, and the PPVT (*p*s < .001). In other words, older children demonstrated stronger performance on these tasks. There were no other notable patterns between the other demographic variables (i.e., gender and SES) and task performance. I also found that children's performance on the Relational Vocabulary Checklist, the Woodcock Johnson Science Assessment, and the PPVT were all directly correlated with each other (*p*s < .001). When controlling for age, gender, and SES in the partial correlations, however, some of these correlations were no longer significant. Specifically, children's scores on the Relational Vocabulary Checklist were no longer significantly correlated with Woodcock Johnson or PPVT scores, *p*s > .05.

Hierarchical Linear Regression Models Predicting Science Knowledge

To test my main hypothesis that relational vocabulary directly predicts children's science knowledge, I conducted a hierarchical linear regression model with Woodcock Johnson score as the outcome measure. Results of the planned hierarchical regression model (Table 2) revealed that PPVT score (general receptive vocabulary) predicted science knowledge above and beyond relational productive vocabulary and demographic variables previously purported to be associated with science knowledge, such as age, gender, and SES (Step 3; $\beta = .65$, $p < .001$). No multicollinearity symptoms were found for the regression model (all VIFs < 5). Taken together, these results suggest that general vocabulary is important for science knowledge. However, the results do not support my main hypothesis that relational language directly contributes to science knowledge.

Exploratory Analyses

As described above, the results from the planned analyses did not support my main hypothesis. This led me to conduct several sets of exploratory analyses. One potential explanation for why I found these results is that not all types of relational words matter for children's science knowledge. Instead, certain subcategories of relational words, such as spatial words, may explain variability in children's science knowledge. Thus, I began my exploratory analyses by examining the relation between the subcategories of relational words (i.e., General words, Specific words, and Spatial words) and children's science knowledge.

Subcategories of Relational Words and Science Knowledge

I began these analyses by calculating descriptive statistics for the different subcategories of relational words in the Relational Vocabulary Checklist (Table 3). The number of relational words was summed for each category of the checklist separately: General words, Specific words, and Spatial words. I performed bivariate correlations for each category of relational words; all correlations are listed in Table 4. Age was significantly correlated with performance on all subcategories of the Relational Vocabulary Checklist. In other words, older children produced more General, Specific, and Spatial words. There were no significant correlations between subcategories of relational words and the other demographic variables from the planned analyses (e.g., gender and SES). Furthermore, I found that children's performance on subcategories of the Relational Vocabulary Checklist, the Woodcock Johnson Science Assessment, and the PPVT were all directly correlated with each other (ps $< .001$; ps $< .01$ for Specific Relational Words x Woodcock Johnson score and Specific Relational Words x PPVT score). When controlling for age, gender, and SES in the partial correlations, some of these correlations were no longer significant. Children's scores on the Relational Vocabulary Checklist were no longer correlated with Woodcock Johnson or PPVT scores, *p*s > .05 (with the exception of General and Spatial words still being correlated with Woodcock Johnson score, *p*s < .05).

Following the descriptive statistics and correlations, I conducted three exploratory hierarchical linear regression models similar to the model from the planned analyses, but with each subcategory of relational words (General, Specific, and Spatial) as a predictor in the final step. The outcome measure was the Woodcock Johnson score. Results of these models (Table 5) showed that PPVT score (general receptive vocabulary) predicted science knowledge above and beyond all subcategories of relational productive vocabulary and demographic variables previously purported to be associated with science knowledge, such as age, gender, and SES (General Words: $\beta = .65$, $p < .001$; Specific Words: $\beta = .67$, $p < .001$; and Spatial Words: $\beta = .65$, $p < .001$). No multicollinearity symptoms were found for any of the regression models (all VIFs < 5).

In sum, results of the exploratory analyses on subcategories of relational words mirrored those from the planned analyses: children's general receptive vocabulary (PPVT score) predicted their science knowledge above and beyond General, Specific, and Spatial relational words. Taken together, this suggests that subcategories of relational words do not predict science knowledge. This led me to an alternative potential explanation for these results: it may be particular characteristics of the children, such as their science attitudes and behaviors, that explain the relation between relational language and science knowledge. I therefore continued my exploratory analyses by completing analyses with the child-specific demographic characteristics and the child-specific items from the Science Attitudes and Behaviors Checklist.

Child Characteristics and Science Knowledge

Children's Age and Science Knowledge. I began conducting exploratory regressions on child-specific variables by looking further into the potential role of age in the relation between relational vocabulary and science knowledge. Thus, I split the sample into children with ages above and below the median age (rounded to 79). When hierarchical regressions were completed with younger children only (≤ 79 months, n = 40), I found that PPVT scores still predicted science knowledge above and beyond all other variables (Table 6, Models 1-4, All Relational Words: β = .59, p < .001; General Words: β = .59, p < .001; Specific Words: β = .6, p < .001; Spatial Words: β = .58, p < .001). When these regressions were completed with older children only (≥ 80 months, n = 40), I found the same pattern of results (Models 5-8, All Relational Words: β = .59, p < .001; General Words: β = .58, p = .001; Specific Words: β = .6, p < .001; Spatial Words: β = .6, p < .001). No multicollinearity symptoms were found for any of the regression models (all VIFs < 5). Again, children's general receptive vocabulary explained variability in their science knowledge above and beyond their relational vocabulary.

Children's Science Attitudes and Behaviors and Science Knowledge. I calculated the descriptive statistics for the child-specific items from the Science Attitudes and Behaviors Checklist. Results of these analyses are described in Table 7. Overall, there was variability in children's attitudes towards and engagement with science activities. Most children had a medium or high interest in science, but only a slight majority (n = 45; 56.3%) were interested in working in a science career specifically. Child science talk frequency varied considerably, with children talking about science daily, once or twice a week, or once or twice a month. Regarding children's science activities, children tended to watch science TV shows and videos or read science books and magazines more regularly than other types of science activities. In comparison, most children seldom participated in science-oriented clubs, groups, or camps, and visited science places infrequently (i.e., typically less than once or twice a month).

To further examine this variability, I conducted bivariate and partial correlations (controlling for age, gender, and SES) with these child-specific variables (Tables 8-10). When looking at the study tasks, performance on the Woodcock Johnson and PPVT were not correlated with any of the measures on the Science Attitudes and Behaviors Checklist. Both bivariate and partial correlation analyses controlling for age, gender, and SES did not reveal any significant correlations, *p*s > .05.

Unlike the Woodcock Johnson and PPVT, however, many significant results emerged from the bivariate and partial correlations between children's performance on the Relational Vocabulary Checklist and the child-specific items on the Science Attitudes and Behaviors Checklist. The strongest correlations were between relational vocabulary and child science talk frequency. In other words, children who produced more relational vocabulary words also engaged in science talk more often (*ps* < .001). This was also true when looking at each subcategory of relational words (*p*s < .001). Besides science talk, children's relational vocabulary was also correlated with the frequency in which they engaged in science-related activities (e.g., cooking, building); whether doing well in science is important to them; and their confidence in their own science ability. In sum, it appears that children's relational vocabulary is related to multiple aspects of their science attitudes and behaviors, and is particularly associated with how often children engage in science talk.

I conducted further exploratory regressions with Woodcock Johnson score (science knowledge) as the outcome variable. Age, gender, and SES were included in Step 1, child science talk frequency was included in Step 2, and total relational words or each subcategory of relational words was included in Step 3. All models are listed in Table 11. I chose to include child science talk frequency in Step 2 to replace PPVT because it is a broader measure of children's language use than relational vocabulary alone and is domain-specific to science. Moreover, this variable was found to be highly correlated with relational vocabulary. Results revealed that children's overall relational vocabulary predicted their science knowledge above and beyond their science talk frequency ($\beta = .24$, $p = .033$). Furthermore, children's General ($\beta = .24$, $p = .031$) and Spatial relational vocabulary ($\beta = .24$, $p = .032$) also predicted science knowledge above and beyond science talk frequency. However, age was the strongest predictor of science knowledge across all models (βs $> .57$, *p*s $< .001$). No multicollinearity symptoms were found for any of the regression models (all VIFs < 5). These results suggest that while PPVT remains the strongest predictor of science knowledge, children's relational vocabulary is also a significant predictor over other potential contributors, such as the frequency at which they engage in science talk.

Finally, I performed a mediator path analysis with children's science talk frequency to elucidate where relational language lies in the process of building science knowledge. The path analysis is illustrated in Figure 1. The model fit statistics confirmed that the data fit the model (CFI = 1.000, TLI = 1.000, RMSEA < 0.001). The model indicated that children's science talk frequency has no direct link to science knowledge ($\beta = -.150$, $t = -1.216$, $p = .228$), but does have an indirect link through relational vocabulary ($\beta = .542$, $t = 4.406$, $p < .001$). Specifically, for every a = 26.56 unit increase in the association between science talk frequency and total relational words, there was an ab = 1.82 (*SE* = .49) increase in the number of items correct on the Woodcock Johnson. There was no evidence that science talk frequency was directly associated with how many items children got correct on the Woodcock Johnson independent of its association with total relational words, c' = -0.87 (*SE* = .82). Importantly, a bias-corrected bootstrapped confidence interval with 10,000 samples was above zero, suggesting that this indirect effect was significant (95% CI [0.96, 2.9]). Thus, the apparent indirect effect of children's science talk frequency on their science knowledge (r = .472) is mediated by relational vocabulary. In brief, this analysis revealed that when factoring in relational vocabulary as a mediator, a pathway exists between children's science talk frequency and their science knowledge.

Together, these results suggest that some child-specific characteristics, particularly the frequency of children's science talk, may explain the relation between children's relational vocabulary and their science knowledge. However, children's relational language and science knowledge acquisition do not only happen independently: the family context likely also plays a significant role. Therefore, I then chose to investigate whether family characteristics, such as family science talk, family science careers, or parents' views on their children's science learning, are involved in the relation between relational language and science knowledge. For these exploratory analyses, I used the family-specific questions from the Science Attitudes and Behaviors Checklist.

Parent and Family Characteristics and Science Knowledge

As with the child-specific variables, I began this analysis by calculating descriptive statistics for the parent and family-specific variables in the Science Attitudes and Behaviors Checklist (Table 12). The results were similar to my findings with child-specific variables. That is, there was also variability in family characteristics and parents' attitudes towards their children's science learning. A slight majority of the families in this study (n = 47; 58.8%) had at least one person in the household who worked in a science-related career (e.g., science teacher, engineer, meteorologist, optician, doctor). Like child science talk frequency, family science talk frequency also varied considerably, with nearly all families talking about science with their children daily, once or twice a week, or once or twice a month.

Parents almost never disagreed or strongly disagreed on items regarding their attitude towards their child's science learning. For instance, 93.8% of parents agreed or strongly agreed with the statement "I believe my child can master science knowledge and skills", and 83.8% of parents agreed or strongly agreed with the statement "It is important to me that my child does well in science". This pattern of results reflects previous research, in which parents tend to answer questions about their children consciously or unconsciously in a manner that will be viewed favorably by others (Law & Roy, 2008; Merydith et al., 2003; Zaslow et al., 2006). Additionally, middle to upper income families (the majority of our sample) tend to be more emotionally and behaviorally involved in their children's science education, which is positively correlated with student success (Berthelsen & Walker, 2008; McQuiggan & Megra, 2017).

Continuing my analysis with bivariate and partial correlations (Table 13), I found significant correlations between relational vocabulary and how often families engaged in science talk (*p*s $< .01$ for partial correlations; *p*s $< .01$ for direct correlations with Total Relational Words and Specific Words; *p*s $< .05$ for direct correlations with General and Spatial Words). This aligns with the finding that child science talk frequency was strongly correlated with relational vocabulary. Besides science talk, children's relational vocabulary was correlated with parents' confidence in their children's science ability. It was also correlated with multiple parental beliefs, including: how much effort their child puts into science learning; whether their child uses strategies for learning science well; the effort their child puts into learning science; and whether their child engages in strategies for helping them learn science (*p*s < .01 for partial correlations; *p*s ranging from < .05 to < .001 for direct correlations).

Finally, I performed a mediator path analysis with family science talk frequency to further elucidate where relational language lies in the process of building science knowledge. The path analysis is illustrated in Figure 2. The model fit statistics confirmed that the data fit the model (CFI = 1.000, TLI = 1.000, RMSEA < 0.001). The model indicated that family science talk frequency has no direct link to children's science knowledge (β = -.073, $t = -.691$, $p = .491$), but does have an indirect link through children's relational vocabulary (β = .478, $t = 4.509$, $p < .001$). Specifically, for every a = 13.84 unit increase in the association between science talk frequency and total relational words, there was an ab = 0.84 (*SE* = .43) increase in the number of items correct on the Woodcock Johnson. There was no evidence that science talk frequency was directly associated with how many items children got correct on the Woodcock Johnson independent of its association with total relational words, c' = -0.43 (*SE* = .68). Importantly, a bias-corrected bootstrapped confidence interval with 10,000 samples was above zero, suggesting that this indirect effect was significant (95% CI [0.21, 1.93]). Thus, the indirect effect of family science talk frequency on children's science knowledge ($r = .461$) is mediated by children's relational vocabulary. This analysis revealed that when factoring in relational vocabulary as a mediator, a pathway exists between family engagement in science talk and children's science knowledge.

In conclusion, it appears that children's relational vocabulary is also related to multiple aspects of their families' science attitudes and behaviors. In particular, children's relational vocabulary is associated with how often families engage in science talk. In the next series of exploratory analyses, I further examined the outcome variable of this study (i.e., the Woodcock

Johnson Science Assessment) and how it measured children's science knowledge. Specifically, I looked at the nature of the questions asked on the Woodcock Johnson Science Assessment and how the questions aligned with the measure of general receptive vocabulary (the PPVT).

Exploratory Analysis of Questions on the Woodcock Johnson Science Assessment

I started my exploratory analysis of the Woodcock Johnson by examining the nature of the questions asked in the Woodcock Johnson. I coded for two possible types of questions: fact-based and conceptual questions. Fact-based questions were coded as questions that required identifying isolated pieces of information. For instance, the question "What is this?" when showing a picture of a mushroom is a fact-based question. Conceptual questions were coded as questions that required understanding relations between facts. For instance, the question "What causes the phases of the moon?" is a conceptual question because a correct response must mention the positions of the Sun, Moon, and Earth relative to each other. All questions and the way in which they were coded are listed in Table 14.

The Woodcock Johnson was found to have significantly more fact-based questions (82.5% of questions; n = 33) than conceptual questions (17.5% of questions; n = 7). Four of the conceptual questions were clustered towards the beginning of the assessment (questions 5, 6, 8, and 9) with at least 80% of children answering them correctly, and three of these questions were spread across the remainder of the assessment (questions 15, 18, and 30) with 28.7%, 41.3%, and 6.3% of children answering those questions correctly, respectively. Most children did not have the opportunity to answer all conceptual questions: only 18.8% of children reached question 30. In sum, the Woodcock Johnson was inconsistent regarding the nature of questions asked, with most questions only capturing children's knowledge of science facts.

In my planned analyses, I found that general receptive vocabulary (as measured by PPVT score) was the strongest predictor of children's science knowledge. Thus, I continued my analysis of the Woodcock Johnson by examining how the questions on the Woodcock Johnson and PPVT may have been similar to each other. I looked across both assessments to find questions that measured children's knowledge of the same science topic; that is, if a word on the PPVT matched a question on the Woodcock Johnson. There was overlap among four questions; these questions and their associated age estimates are listed in Table 15. The age estimates for these questions differed significantly for three of these items. For example, the Woodcock Johnson question "What part of the body is used to take in the air we breathe?" has an age estimate of 6 years 1 month, but the associated PPVT item for the word "inhaling" has an age estimate of 14-16 years. Thus, while I found more overlap between the Woodcock Johnson and PPVT than anticipated, these measures could not be compared appropriately because age estimates were significantly different for most items.

In brief, these results suggest that the measure of science knowledge used in this study may not have allowed the earlier planned and exploratory analyses to best capture the relation between relational language and science knowledge. It is possible that modifying the Woodcock Johnson Science Assessment, or using a different and newly developed measure of science knowledge, would have produced different results. This idea is explored further in the discussion.

CHAPTER FOUR

GENERAL DISCUSSION

The central goal of this study was to determine whether there was a direct link between children's relational vocabulary and their science knowledge. Contradictory to my main hypothesis, I found that relational vocabulary did not predict science knowledge above and beyond general receptive vocabulary and demographic variables previously purported to explain science knowledge gaps, including age, gender, and socioeconomic status. However, I did find that relational vocabulary was highly correlated with the frequency at which individual children and their families talked about science. Moreover, I found that relational vocabulary mediated the relation between children's and families' science talk frequency and children's science knowledge. This suggests that while children's relational vocabulary size does not directly predict their science knowledge, children's relational vocabulary use within the context of child and family science talk may be important for children's science knowledge.

I did not find evidence to support my main hypothesis: that relational language predicts science knowledge above and beyond general vocabulary. In other words, there was no direct link between children's relational vocabulary and their science knowledge. Why might this be? One possibility is that it may not be the number of relational vocabulary words one produces that supports science knowledge. Rather, it may be the degree to which children have opportunities to talk about science and use relational vocabulary while doing so, both on an individual child and a family level. Evidence for this idea comes from the correlations from this study which revealed a link between relational vocabulary and child and family science talk frequency. More compelling evidence comes from the mediation analyses, which revealed a significant indirect link between the amount that children and families talk about science and children's science knowledge. That is, talking about science more frequently gives children opportunities to learn and use relational vocabulary, which in turn may support their science learning. This is likely to be true both for children talking about science and for families talking about science.

Given these results, I propose that there is an alternate mechanism by which relational vocabulary drives changes in science knowledge: it does so by serving as an intermediate step between science talk frequency and science knowledge. This alternate mechanism can be explained by reusing the concept of density from the Introduction. To illustrate, imagine that two children are talking to each other while doing a density experiment. One child frequently uses relational words when talking about the concept of density, such as "The blue block is the *same* size as the red block *but* it's *also lighter* - that means it will float because its density is *different*!" In contrast, the other child says few relational words: "The blue and red block are small *but* the blue one is light, so the blue one will float." In this case, the first child will likely have better knowledge of the concept of density than the second child: their consistent use of relational words helps prompt them to compare different blocks to determine how they both float, instead of focusing only on perceptual features of the blocks. In sum, learning and using more relational words, which is achieved in part through frequent science talk, is what may be helping children build science knowledge.

These findings have implications for developing a wide range of interventions designed to leverage relational vocabulary for building children's science knowledge. This work suggests that simply teaching children as many relational words as possible is not an ideal approach when trying to build their science knowledge. Instead, children should be given multiple exemplars of relational words before engaging in a science interaction (e.g., discussing a science topic, doing a science experiment at home, reading a science book, going to a science museum) or a science lesson in a classroom. Next, they could be told how these relational words could be used when discussing science (e.g., using words such as “greater” when comparing quantities of items), as well as when it is appropriate to use relational words in a science context (e.g., when comparing facts children have already learned). Finally, children should be given frequent opportunities to talk about science across formal and informal settings, and should be encouraged to discuss science as often as possible. In brief, children should be taught *how* to use relational words while engaging in science talk, and should be given plentiful opportunities to use these relational words through science talk.

Directions for Future Research

Future research should examine relational language use interventions by analyzing how often children and their families use relational words when discussing a science concept, as well as whether they are producing relational words in appropriate contexts and at appropriate times. Children’s generalization of the science concept could then be assessed to determine how the use of relational language may have contributed to their ability to generalize to related exemplars of the same concept. Additionally, information on relational words and their appropriate use would be simple to integrate into lesson plans, children’s digital and print science media, and museum exhibits as a set of prompts for children, parents, and educators to engage in. Characterizing children’s use of relational words in this manner could help parents and educators identify areas of support for their science learning.

Furthermore, future research should expand the ways in which science knowledge is measured to better capture the relation between relational language and children’s science knowledge. I used the Woodcock Johnson Science Assessment to measure science knowledge because it is the best existing measure for the purpose of this study. It is the only standardized science assessment that is both standardized for a wide age range and covers a broad range of science topics. Moreover, since the Woodcock Johnson contains mostly fact-based questions, it is appropriate for the children in the age range of this study because it covers the period when children are learning foundational science facts. Indeed, the Next Generation Science Standards suggest that learning these facts or “core ideas” are an essential foundation that prepares children for deeper levels of understanding, as science becomes more difficult to learn over time (National Research Council, 2012). Alternatively, this strength could be seen as a limitation: the Woodcock Johnson consisted almost entirely of questions assessing only one aspect of science knowledge (i.e., science facts). Consequently, few questions were dedicated to assessing science concepts, which are also critical for building children’s science knowledge throughout the school years (National Research Council, 2012). A second limitation of the Woodcock Johnson is that it had more overlap with the PPVT in science topics than anticipated; thus, these questions were measuring similar areas of knowledge. These limitations suggest that if the measure of science knowledge in this study had been different, the results may also have been different: namely, relational vocabulary may have directly predicted science knowledge. Therefore, the Woodcock Johnson could be revised to include a more diverse set of questions. These changes would allow the Woodcock Johnson to provide a richer, more comprehensive idea of children’s science knowledge.

Researchers and psychometricians should actively collaborate to create new measures of children’s science knowledge. One alternative way to assess children’s science knowledge is by giving children a traditional science lesson and measuring their comprehension of that lesson through an experimenter-created assessment or through children’s science talk. Another way of measuring science knowledge could involve children participating in interactive science activities or experiments with their families at home or at a science location such as a museum. This could also be measured through an experimenter-created assessment or through children's science talk. Indeed, several studies have measured children's science learning in informal settings with their parents (e.g., Benjamin et al., 2010; Jant et al., 2014; Junge et al., 2021). While it would take a long time to standardize such science assessments, it is critical for the field to have more diverse standardized measures of children's science knowledge so we can best capture individual differences in children's science learning and how different factors may contribute to it.

Concluding Thoughts

In conclusion, the current study provides evidence to suggest that children's relational vocabulary is linked to their science knowledge. However, this link is not direct as it was hypothesized: children's relational vocabulary explained the relation between children's and families' science talk and children's science knowledge. Existing work investigating the impact of relational language on relational thinking may lead one to believe that simply saying more relational words is enough to explain how children learn (e.g., Gentner et al., 2011; Gentner & Namy, 1999; Loewenstein & Gentner, 2001, 2005). In contrast, this work paints a richer picture of this relation: science learning may not be about how many relational words children know, but instead how often they say these words when discussing science. Focusing on child and family science talk in this way presents several exciting avenues for future research. Moving forward, future work on relational vocabulary and science knowledge could leverage relational language use during science talk in the development of interventions designed to target children's science learning. The current study also sheds light on the limitations of the Woodcock Johnson Science Assessment as the standardized measure of children's science knowledge and suggests several potential alternatives. Such future directions would allow a comprehensive look at how relational language can be leveraged as a critical tool for improving children’s science learning, both as children begin acquiring formal science knowledge and as they build upon this knowledge with age.

References

Alfieri, L., Nokes-Malach, T., & Schunn, C. (2013). Learning through case comparisons: A meta-analytic review. *Educational Psychologist, 48*(2), 87-113. http://dx.doi.org/10.1080/00461520.2013.775712

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. https://doi.org/10.1037/a0017822

Berthelsen, D., & Walker, S. (2008). Parents' involvement in their children's education. *Family Matters, 79*, 34-41.

Bonus, J. A. (2019). The impact of pictorial realism in educational science television on U.S. children's learning and transfer of biological facts. *Journal of Children and Media, 13*(4), 433-451. https://doi.org/10.1080/17482798.2019.1646295

California State PTA (2018). *Next Generation Science Standards Statewide Parent Survey Findings.* 2B Communications. http://downloads.capta.org/NGSS/CAPTA_NextGenerationScienceStandards_FINALSurvey2018.pdf

Callanan, M.A. , & Jipson, J.L. (2001). Explanatory conversations and young children's developing scientific literacy. In K. Crowley , C.D. Schunn , & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings* (pp. 21—49). Mahwah, NJ: Erlbaum.

Callanan, M. A., Legare, C. H., Sobel, D. M., Jaeger, G. J., Letourneau, S., McHugh, S. R., Willard, A., Brinkman, A., Finiasz, Z., Rubio, E., Barnett, A., Gose, R., Martin, J. L., Meisner, R., & Watson, J. (2020). Exploration, explanation, and parent-child interaction in museums. *Monographs of the Society for Research in Child Development, 85*(1), 7-137. https://doi.org/10.1111/mono.12412

Cannon, J., Levine, S. C., & Huttenlocher, J. (2007). A system for analyzing children and caregivers' language about space in structured and unstructured contexts. Spatial Intelligence and Learning Center (SILC) Tech. Rep. Retrieved from http://spatiallearning.org/index.php/resources/testsainstruments

Christie, S., & Gentner, D. (2010). Where hypotheses come from: Learning new relations by structural alignment. *Journal of Cognition and Development, 11*(3), 356-373. http://dx.doi.org/10.1080/15248371003700015

Crowley, K., & Galco, J. (2001). Everyday activity and the development of scientific thinking. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings* (pp. 393-413). Lawrence Erlbaum Associates Publishers.

Cumming, J. (2003). Do runner beans really make you run fast? Young children learning about science-related food concepts in informal settings. *Research in Science Education, 33*(4), 483-501. https://doi.org/10.1023/B:RISE.0000005254.53876.6e

Drew, D. E. (2011). *STEM the tide: Reforming science, technology, engineering, and math education in America*. Baltimore: Johns Hopkins University Press.

Dunn, L. M., & Dunn, D. M. (2007). *PPVT-4: Peabody Picture Vocabulary Test*. Minneapolis, MN: Pearson Assessments.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., … Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, 59* (Serial No. 242), i–185. https://doi.org/10.2307/1166093

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007*)*. *MacArthur-Bates Communicative Development Inventories* (2nd ed.). Baltimore, MD: Brookes.

Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science, 16*(2), 234-248. http://doi.org/10.1111/desc.12019

Gentner, D. (1983). Structure mapping: A theoretical framework for analogy. *Cognitive Science, 7*, 155-170. https://doi.org/10.1016/S0364-0213(83)80009-3

Gentner, D. (1988). Metaphor as structure mapping: The relational shift. *Child Development, 59*(1), 47-59. https://doi.org/10.2307/1130388

Gentner, D. (2003). Why we're so smart. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind: Advances in the study of language and thought* (p. 195-235). MIT Press.

Gentner, D. (2010). Bootstrapping the mind: Analogical processes and symbol systems. *Cognitive Science, 34*, 752-775. http://doi.org/10.1111/j.1551-6709.2010.01114.x

Gentner, D., & Christie, S. (2010). Mutual bootstrapping between language and analogical processing. *Language and Cognition, 2*(2), 261-283. https://doi.org/10.1515/langcog.2010.011

Gentner, D., Anggoro, F.K., & Klibanoff, R.S. (2011). Structure mapping and relational language support children's learning of relational categories. *Child Development, 82*(4), 1173-1188. https://doi.org/10.1111/j.1467-8624.2011.01599.x

Gentner, D., Levine, S.C., Ping, R., Isaia, A., Dhillon, S., Bradley, C., & Honke, G. (2015). Rapid learning in a children's museum via analogical comparison. *Cognitive Science, 40*(1), 224-240. http://doi.org/10.1111/cogs.12248

Gentner, D., & Namy, L. L. (1999). Comparison in the development of categories. *Cognitive Development*, *14*(4), 487-513. https://doi.org/10.1016/S0885-2014(99)00016-7

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science Motivation Questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching, 48*(10), 1159-1176. https://doi.org/10.1002/tea.20442

Goldwater, M. B., & Schalk, L. (2016). Relational categories as a bridge between cognitive and educational research. *Psychological Bulletin, 142*(7), 729-757. http://doi.org/10.1037/bul0000043

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology, 27*(2), 236-248. https://doi.org/10.1037/0012-1649.27.2.236

Hyde, J. S., & Linn, M. C. (1988). Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin*, *104*(1), 53-69. https://doi.org/10.1037/0033-2909.104.1.53

Jaakkola, T., & Veermans, K. (2018). Exploring the effects of concreteness fading across grades in elementary school science education. *Instructional Science, 46*(2), 185-207. https://doi.org/10.1007/s11251-017-9428-y

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. https://doi.org/10.1111/cdev.12252

Jee, B. D., Gentner, D., Uttal, D. H., Sageman, B., Forbus, K., Manduca, C. A., Ormand, C. J., Shipley, T. F., & Tikoff, B. (2014). Drawing on experience: How domain knowledge is reflected in sketches of scientific structures and processes. *Research in Science Education, 44,* 859-883. http://doi.org/10.1007/s11165-014-9405-2

Joy, A., Law, F., McGuire, L., Mathews, C., Hartstone-Rose, A., Winterbottom, M., Rutland, A., Fields, G. E., & Mulvey, K. L. (2021). Understanding parents' roles in children's learning and engagement in informal science learning sites. *Frontiers in Psychology,* 12: 635839. https://doi.org/10.3389/fpsyg.2021.635839

Junge, K., Schmerse, D., Lankes, E., Carstensen, C. H., & Steffensky, M. (2021). How the home learning environment contributes to children's early science knowledge – Associations with parental characteristics and science-related activities. *Early Childhood Research Quarterly, 56,* 294-305. https://doi.org/10.1016/j.ecresq.2021.04.004

Kloos, H., Fisher, A., & Van Orden, G. C. (2010). Situated naïve physics: Task constraints decide what children know about density. *Journal of Experimental Psychology: General, 139*(4), 625-637. http://doi.org/10.1037/a0020977

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods, 44,* 978-990. https://doi.org/10.3758/s13428-012-0210-4

Law, J., and Roy, P. (2008). Parental report of infant language skills: a review of the development and application of the communicative development inventories. *Child and Adolescent Mental Health*, *13*(4), 198–206. https://doi.org/10.1111/j.1475-3588.2008.00503.x

Leibham, M. B., Alexander, J. M., & Johnson, K. (2013). Science interests in preschool boys and girls: Relations to later self-concept and science achievement. *Science Education*, *97*(4), 574-593. https://doi.org/10.1002/sce.21066

Loewenstein, J., & Gentner, D. (2001). Spatial mapping in preschoolers: Close comparisons facilitate far mappings. *Journal of Cognition and Development*, *2*(2), 189-219. https://doi.org/10.1207/S15327647JCD0202_4

Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50*(4), 315-353. https://doi.org/10.1016/j.cogpsych.2004.09.004

Matlen, B. J., Vosniadou, S., Jee, B., & Ptouchkina, M. (2011). Enhancing the comprehension of science text through visual analogies. In L. Carson, C. Holscher, and T. Shipley (Eds.), *Proceedings of the 34th Annual Conference of the Cognitive Science Society* (pp. 2910-2915).

McQuiggan, M., & Megra, M. (2017). *Parent and family involvement in education: Results from the National Household Education Surveys Program of 2016* (Report No. NCES 2017102). Retrieved from the National Center for Education Statistics: https://nces.ed.gov/pubs2017/2017102.pdf

Merydith, S. P., Prout, H. T., & Blaha, J. (2003). Social desirability and behavior rating scales: An exploratory study with the child behavior checklist/4-18. *Psychology in the Schools, 40*(2), 225-235. https://doi.org/10.1002/pits.10077

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher, 45*(1), 18-35. https://doi.org/10.3102/0013189X16633182

Namy, L. L., & Gentner, D. (2002). Making a silk purse out of two sow's ears: Young children's use of comparison in category learning. *Journal of Experimental Psychology: General, 131*(1), 5-15. http://doi.org/10.1037//0096-3445.131.1.5

National Academy of Sciences, National Academy of Engineering, & Institute of Medicine. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5.* Washington, DC: National Academies Press. https://doi.org/10.17226/12999

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads.* Washington, DC: National Academies Press. https://doi.org/10.17226/12984

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8.* Washington, DC: The National Academies Press. https://doi.org/10.17226/11625

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

National Research Council. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: The National Academies Press. https://doi.org/10.17226/18290

National Science Board. (2018). *Science and Engineering Indicators 2018*. Alexandria, VA: National Science Foundation. Retrieved from https://www.nsf.gov/statistics/indicators/

Organisation for Economic Co-operation and Development. (2015). *Parent Questionnaire for the 2015 Programme for International Student Assessment.* https://www.oecd.org/pisa/data/CY6_QST_MS_PaQ_Final.pdf

Orton, J. M., Anggoro, F. K., & Jee, B. D. (2012). Mutual alignment facilitates abstraction and transfer of a complex scientific concept. *Educational Studies, 38*(4), 473-477. https://doi.org/10.1080/03055698.2011.643104

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079. https://doi.org/10.1080/0950069032000032199

Paulsen, C. A., Carroll, E., Paulsen, O., & Andrews, J. R. (2021). Engaging children and families in active, environmental science learning through digital media. *International Journal of Early Childhood Environmental Education, 8*(2), 43-58. Retrieved from https://files.eric.ed.gov/fulltext/EJ1298025.pdf

Perera, L. D. H. (2014). Parents' attitudes towards science and their children's science achievement. *International Journal of Science Education, 36*(18), 3021-3041. https://doi.org/10.1080/09500693.2014.949900

Rattermann, M.J., & Gentner, D. (1998). More evidence for a relational shift in the development of analogy: Children's performance on a causal-mapping task. *Cognitive Development, 13*(4), 453-478. https://doi.org/10.1016/S0885-2014(98)90003-X

Reardon, S. F. (2011). The widening academic achievement gap between rich and poor: New evidence and possible explanations. In G. J. Duncan & R. J. Murnane (Eds.), *Whither opportunity? Rising inequality, schools, and children's life chances* (pp. 91–115). New York, NY: Russell Sage Foundation.

Resnick, I., Newcombe, N.S., and Shipley, T.F. (2017). Dealing with big numbers: Representation and understanding of magnitudes outside of human experience. *Cognitive Science, 41*(4), 1020-1041. https://doi.org/10.1111/cogs.12388

Russell, M. L., & Atwater, M. M. (2005). Traveling the road to success: A discourse on persistence throughout the science pipeline with African American students at a predominantly white institution. *Journal of Research in Science Teaching, 42*(6), 691-715. https://doi.org/10.1002/tea.20068

Sackes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. A. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the Early Childhood Longitudinal Study. *Journal of Research in Science Teaching, 48*(2), 217–235. https://doi.org/10.1002/tea.20395

Schrank, F. A., McGrew, K. S., & Mather, N. (2014). *Woodcock-Johnson IV Tests of Cognitive Abilities.* Rolling Meadows, IL: Riverside.

Smolleck, L., & Hershberger, V. (2011). Playing with science: An investigation of young children's science conceptions and misconceptions. *Current Issues in Education, 14*(1), 1-32.

Tenenbaum, H. R., & Callanan, M. A. (2008). Parents' science talk to their children in Mexican-descent families residing in the USA. *International Journal of Behavioral Development, 32*(1), 1-12. https://doi.org/10.1177/0165025407084046

Tscholl, M., & Lindgren, R. (2016). Designing for learning conversations: How parents support children's science learning within an immersive simulation. *Science Education*, *100*(5), 877-902. https://doi.org/10.1002/sce.21228

U.S. Department of Education, National Center for Education Statistics. (2001). *Entering kindergarten: A portrait of American children when they begin school: Findings from the condition of education 2000.* (NCES 2001-035). Washington DC: U.S. Government Printing Office. Retrieved from https://nces.ed.gov/pubs2001/2001035.pdf

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. (2015). *National Assessment of Education Progress, science 2011, national results.* Retrieved from http://www.nationsreportcard.gov/science_2011/

Vendetti, M.S., Matlen, B.J., Richland, L.E., & Bunge, S.A. (2015). Analogical reasoning in the classroom: Insights from cognitive science. *Mind, Brain, and Education*, *9*(2), 100-106. https://doi.org/10.1111/mbe.12080

Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081-1121. http://doi.org/10.3102/0002831213488622

Waxman, S. R., & Klibanoff, R. S. (2000). The role of comparison in the extension of novel adjectives. *Developmental Psychology*, *36*(5), 571-581. http://doi.org/10.1037/0012-1649.36.5.571

Zaslow, M. J., Weinfield, N. S., Gallagher, M., Hair, E. C., Ogawa, J. R., Egeland, B., Tabors, P. O., & De Temple, J. M. (2006). Longitudinal prediction of child outcomes from differing measures of parenting in a low-income sample. *Developmental Psychology*, *42*(1), 27-37. https://doi.org/10.1037/0012-1649.42.1.27

Table 1

Descriptive Statistics and Pearson's R Intercorrelations for Variables in Planned Regression Analyses

	Max Score	*Mean*	*Median*	*SD*	*Range*	*1*	*2*	*3*	*4*	*5*	*6*
1. Peabody Picture Vocabulary Test	228	124.9	128	24.14	71-181	-	.614***	.156	-	-	-
2. Woodcock Johnson Science Assessment	40	15.14	15	4.44	4-25	.807***	-	.220	-	-	-
3. Relational Vocabulary Checklist	195	119.71	131	35.1	16-181	.435***	.456***	-	-	-	-
4. Age (in months)	-	77.64	79.5	17.55	48-107	.745***	.680***	.460***	-	-	-
5. Socioeconomic Status (SES)	10	9.19	9	.957	4-10	.230*	.194	.117	.248*	-	-
6. Gender	2	1.48	1	.503	1-2	.004	-.007	.034	.011	.056	-

Note. Females were coded as 1 and males were coded as 2. Correlations below the diagonal are bivariate correlations. Correlations above the diagonal are partial correlations controlling for age, gender, and SES.
* p < .05., ** p < .01., *** p < .001

Table 2

Planned Hierarchical Regression Analyses

		R^2	ΔR^2	b	SE_b	β
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.666	.202***			
	Age (in months)			.045	.026	.178
	Gender			-.100	.591	-.011
	SES			-.024	.338	-.005
	PPVT (raw score)			.124	.018	.676***
Step 3		.674	.008			
	Age (in months)			.037	.026	.145
	Gender			-.128	.588	-.014
	SES			-.019	.336	-.004
	PPVT (raw score)			.120	.019	.654***
	Total Relational Words			.013	.010	.105

Note. Predictor variable: Number correct on Woodcock-Johnson Science Assessment.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

Table 3

Descriptive Statistics for Subcategories of Relational Vocabulary Checklist

	Max Score	*Mean*	*Median*	*SD*	*Range*
General Relational Words	74	27.14	29	11.2	4-61
Specific Relational Words	52	38.1	43	11.88	2-51
Spatial Relational Words	69	54.48	59	13.77	6-69

Table 4

Direct and Partial Correlations for Demographic Variables, Scores on the Woodcock Johnson Science Assessment, PPVT, and Relational Vocabulary Checklist (whole checklist and subcategories)

	Age	*Gender*	*SES*	*WJ Num Correct*	*PPVT Raw Score*	*Total Rel Words*	*Total General*	*Total Specific*	*Total Spatial*
Age	-	-	-	-	-	-	-	-	-
Gender	.011	-	-	-	-	-	-	-	-
SES	.248*	.056	-	-	-	-	-	-	-
WJNumCorrect	.680***	-.007	.194	-	.614***	.220	.230*	.166	.227*
PPVTRawScore	.745***	.004	.230*	.807***	-	.156	.194	.086	.165
TotalRelWords	.460***	.034	.117	.456***	.435***	-	.911***	.958***	.956***
TotalGeneral	.495***	.006	.106	.482***	.480***	.930***	-	.813***	.790***
TotalSpecific	.390***	.104	.108	.375**	.342**	.960***	.839***	-	.891***
TotalSpatial	.434***	-.009	.119	.446***	.423***	.964***	.833***	.902***	-

Note. Correlations below the diagonal are bivariate correlations. Correlations above the diagonal are partial correlations controlling for age, gender, and SES.
* $p < .05$., ** $p < .01$., *** $p < .001$

Table 5

Hierarchical Regression Analyses Using Subcategories of Relational Words

		R^2	ΔR^2	b	SE_b	β
MODEL 1: General Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.666	.202***			
	Age (in months)			.045	.026	.178
	Gender			-.100	.591	-.011
	SES			-.024	.338	-.005
	PPVT (raw score)			.124	.018	.676***
Step 3		.672	.007			
	Age (in months)			.037	.026	.147
	Gender			-.103	.589	-.012
	SES			-.009	.337	-.002
	PPVT (raw score)			.120	.019	.651***
	Total General Words			.038	.031	.097
MODEL 2: Specific Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.666	.202***			
	Age (in months)			.045	.026	.178
	Gender			-.100	.591	-.011
	SES			-.024	.338	-.005
	PPVT (raw score)			.124	.018	.676***
Step 3		.673	.007			
	Age (in months)			.038	.026	.150
	Gender			-.182	.593	-.021
	SES			-.024	.336	-.005
	PPVT (raw score)			.122	.018	.665***
	Total Specific Words			.034	.027	.092

		R^2	ΔR^2	b	SE_b	β
MODEL 3: Spatial Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.666	.202***			
	Age (in months)			.045	.026	.178
	Gender			-.100	.591	-.011
	SES			-.024	.338	-.005
	PPVT (raw score)			.124	.018	.676***
Step 3		.674	.009			
	Age (in months)			.038	.026	.150
	Gender			-.088	.587	-.010
	SES			-.025	.336	-.005
	PPVT (raw score)			.120	.019	.653***
	Total Spatial Words			.034	.024	.105

Note. Predictor variable: Number correct on Woodcock-Johnson Science Assessment.

* $p < .05$. ** $p < .01$. *** $p < .001$

Table 6

Hierarchical Regression Analyses Using Age-Based Variables: Median Split

		R^2	ΔR^2	b	SE_b	β
MODEL 1: All Relational Words (median split - younger children)						
Step 1		.253	.253*			
	Age (in months)			.188	.057	.480**
	Gender			-.737	1.116	-.097
	SES			.333	.509	.096
Step 2		.549	.296***			
	Age (in months)			.082	.050	.209
	Gender			-.359	.883	-.047
	SES			.079	.405	.023
	PPVT (raw score)			.127	.027	.617***
Step 3		.565	.016			
	Age (in months)			.076	.050	.194
	Gender			-.485	.887	-.064
	SES			.077	.404	.022
	PPVT (raw score)			.122	.027	.589***
	Total Relational Words			.013	.012	.132
MODEL 2: General Words (median split - younger children)						
Step 1		.253	.253*			
	Age (in months)			.188	.057	.480**
	Gender			-.737	1.116	-.097
	SES			.333	.509	.096
Step 2		.549	.296***			
	Age (in months)			.082	.050	.209
	Gender			-.359	.883	-.047
	SES			.079	.405	.023
	PPVT (raw score)			.127	.027	.617***
Step 3		.563	.015			
	Age (in months)			.072	.051	.184
	Gender			-.485	.889	-.064
	SES			.091	.404	.026
	PPVT (raw score)			.122	.027	.591***
	Total General Words			.048	.045	.129

		R^2	ΔR^2	*b*	SE_b	β
MODEL 3: Specific Words (median split - younger children)						
Step 1		.253	.253*			
	Age (in months)			.188	.057	.480**
	Gender			-.737	1.116	-.097
	SES			.333	.509	.096
Step 2		.549	.296***			
	Age (in months)			.082	.050	.209
	Gender			-.359	.883	-.047
	SES			.079	.405	.023
	PPVT (raw score)			.127	.027	.617***
Step 3		.559	.010			
	Age (in months)			.079	.051	.201
	Gender			-.486	.897	-.064
	SES			.069	.406	.020
	PPVT (raw score)			.124	.027	.602***
	Total Specific Words			.030	.034	.104
MODEL 4: Spatial Words (median split - younger children)						
Step 1		.253	.253*			
	Age (in months)			.188	.057	.480**
	Gender			-.737	1.116	-.097
	SES			.333	.509	.096
Step 2		.549	.296***			
	Age (in months)			.082	.050	.209
	Gender			-.359	.883	-.047
	SES			.079	.405	.023
	PPVT (raw score)			.127	.027	.617***
Step 3		.568	.019			
	Age (in months)			.078	.050	.198
	Gender			-.448	.880	-.059
	SES			.077	.402	.022
	PPVT (raw score)			.120	.027	.580***
	Total Spatial Words			.036	.029	.146

		R^2	ΔR^2	*b*	SE_b	*β*
MODEL 5: All Relational Words (median split - older children)						
Step 1		.030	.030			
	Age (in months)			.028	.059	.078
	Gender			.643	.966	.111
	SES			-.467	.815	-.095
Step 2		.342	$.312^{***}$			
	Age (in months)			-.041	.052	-.117
	Gender			.290	.811	.050
	SES			-.438	.680	-.089
	PPVT (raw score)			.108	.027	$.598^{***}$
Step 3		.348	.006			
	Age (in months)			-.046	.053	-.131
	Gender			.332	.823	.057
	SES			-.387	.693	-.079
	PPVT (raw score)			.107	.027	$.590^{***}$
	Total Relational Words			.010	.017	.080
MODEL 6: General Words (median split - older children)						
Step 1		.030	.030			
	Age (in months)			.028	.059	.078
	Gender			.643	.966	.111
	SES			-.467	.815	-.095
Step 2		.342	$.312^{***}$			
	Age (in months)			-.041	.052	-.117
	Gender			.290	.811	.050
	SES			-.438	.680	-.089
	PPVT (raw score)			.108	.027	$.598^{***}$
Step 3		.350	.007			
	Age (in months)			-.045	.053	-.129
	Gender			.362	.827	.062
	SES			-.393	.690	-.080
	PPVT (raw score)			.105	.027	$.578^{**}$
	Total General Words			.027	.044	.090

		R^2	ΔR^2	*b*	SE_b	β
MODEL 7: Specific Words (median split - older children)						
Step 1		.030	.030			
	Age (in months)			.028	.059	.078
	Gender			.643	.966	.111
	SES			-.467	.815	-.095
Step 2		.342	$.312^{***}$			
	Age (in months)			-.041	.052	-.117
	Gender			.290	.811	.050
	SES			-.438	.680	-.089
	PPVT (raw score)			.108	.027	$.598^{***}$
Step 3		.348	.006			
	Age (in months)			-.045	.053	-.128
	Gender			.262	.821	.045
	SES			-.379	.695	-.078
	PPVT (raw score)			.109	.027	$.600^{***}$
	Total Specific Words			.029	.052	.079
MODEL 8: Spatial Words (median split - older children)						
Step 1		.030	.030			
	Age (in months)			.028	.059	.078
	Gender			.643	.966	.111
	SES			-.467	.815	-.095
Step 2		.342	$.312^{***}$			
	Age (in months)			-.041	.052	-.117
	Gender			.290	.811	.050
	SES			-.438	.680	-.089
	PPVT (raw score)			.108	.027	$.598^{***}$
Step 3		.345	.002			
	Age (in months)			-.045	.053	-.128
	Gender			.338	.832	.058
	SES			-.410	.693	-.084
	PPVT (raw score)			.108	.027	$.595^{***}$
	Total Spatial Words			.018	.050	.052

Note. Predictor variable: Age Estimate on Woodcock-Johnson Science Assessment.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

Table 7

Descriptive Statistics for the Science Attitudes and Behaviors Checklist: Child-Specific Items

Question Text	*Variable Name*						*Mean*	*Median*	*SD*
Currently, how would you rate your child's interest in science?	ChildScienceInterest	*No Interest (1)*	*Low (2)*	*Medium (3)*	*High (4)*				
		0	8	41	31		3.29	3	.64
Does your child show an interest in working in a science-related career?	SciCareerInterest	*Yes (1)*	*No (2)*						
		45	35				1.44	1	.499
How often does your child talk about science?	SciTalkFrequency	*Daily (1)*	*1-2x/ Week (2)*	*1-2x/ mo. (3)*	*1-2x/ yr. (4)*	*Never (5)*			
		20	45	13	1	1	4.03	4	.763
How often does your child: watch TV shows and videos about science	SciTVandVideo	11	44	24	1	0	3.81	4	.677
How often does your child: play digital learning games or apps about science	SciApps	4	28	26	4	18	2.95	3	1.231
How often does your child: play with science-related puzzles or board games	SciPuzzles	5	21	31	10	12	2.96	3	1.126
How often does your child: read books or magazines about science	SciBooks	8	35	30	7	0	3.55	4	.794
How often does your child: do science-related activities (e.g., cooking, gardening, building, tech, other)	SciActivities	29	33	17	0	1	4.11	4	.827

Question Text	*Variable Name*	*Daily (1)*	*1-2x/ Week (2)*	*1-2x/ mo. (3)*	*1-2x/ yr. (4)*	*Never (5)*	*Mean*	*Median*	*SD*
How often does your child: visit science places (e.g., zoo, pet store, community garden, aquarium, nature center, museum)	SciPlaces	1	2	12	13	52	2.79	3	.774
How often does your child: participate in clubs/groups that do science-related activities (e.g., robotics, scouts)	SciClubs	1	2	12	13	52	1.59	1	.924
How often does your child: participate in a science-oriented camp/other special program (e.g., a fee-based program)	SciCamp	1	1	1	20	57	1.36	1	.698
Doing well in science is important to my child.	DoWellRating	*Strongly Disagree (1)*	*Disagree (2)*	*Neutral (3)*	*Agree (4)*	*Strongly Agree (5)*			
		0	1	22	41	16	3.90	4	.722
My child is confident in their science ability.	ChildConfidenceRating	0	2	28	38	12	3.75	4	.738
My child spends a lot of time learning science.	ChildTimeLearningSciRating	0	9	33	27	11	3.5	3	.871
My child enjoys learning science.	ChildEnjoysLearningRating	0	0	7	44	29	4.28	4	.616

Table 8

Direct and Partial Correlations for Demographic Variables, Scores on the Woodcock Johnson Science Assessment, PPVT, and Relational Vocabulary Checklist, and the Science Attitudes and Behaviors Checklist (First Set of Child-Specific Items: Variables Titled "Age" to "Total Relational Words")

	Age	*Gender*	*SES*	*WJ Num Correct*	*PPVT Raw Score*	*Total Rel Words*
Age	-	-	-	-	-	-
Gender	.011	-	-	-	-	-
SES	.248*	.056	-	-	-	-
WJNumCorrect	.680***	-.007	.194	-	.614***	.220
PPVTRawScore	.745***	.004	.230*	.807***	-	.156
TotalRelWords	.460***	.034	.117	.456***	.435***	-
ChildScienceInterest	.149	.042	-.088	.106	.027	.261*
SciCareerInterest	.117	.069	.106	.098	.173	-.017
SciTalkFrequency	.206	-.097	-.010	.163	.091	.577***
SciTVandVideo	.010	-.293**	-.227*	.114	.107	.126
SciApps	-.029	-.207	-.078	-.022	.042	.062
SciPuzzles	-.025	-.103	-.128	.021	-.059	.172
SciBooks	-.040	-.092	-.010	.079	.046	.105
SciActivities	-.166	-.069	.028	-.046	-.095	.130
SciPlaces	-.172	-.160	.026	-.212	-.122	-.187
SciClubs	.112	-.036	-.065	-.035	.080	-.030
SciCamp	-.074	-.064	-.152	-.045	.020	-.109
DoWellRating	.280*	-.216	.002	.079	.127	.222*
ChildConfidenceRating	.140	-.222*	-.052	.080	.070	.311**
ChildTimeLrngSciRtng	-.090	-.145	-.040	-.051	-.081	.086
ChildEnjoysLearningRtng	.013	-.141	-.085	.005	-.029	.184

Note. Correlations below the diagonal are bivariate correlations. Correlations above the diagonal are partial correlations controlling for age, gender, and SES.
* $p < .05$., ** $p < .01$., *** $p < .001$

Table 9

Direct and Partial Correlations for Demographic Variables, Scores on the Woodcock Johnson Science Assessment, PPVT, and Relational Vocabulary Checklist, and the Science Attitudes and Behaviors Checklist (Second Set of Child-Specific Items: Variables Titled "Child Science Interest" to "Science Camp")

	Child Sci. Interest	*Sci Career Interest*	*Sci Talk Freq.*	*SciTV And Video*	*Sci Apps*	*Sci Puzzles*	*Sci Books*	*Sci Activities*	*Sci Places*	*Sci Clubs*	*Sci Camp*
Age	-	-	-	-	-	-	-	-	-	-	-
Gender	-	-	-	-	-	-	-	-	-	-	-
SES	-	-	-	-	-	-	-	-	-	-	-
WJNumCorrect	.012	.025	.033	.160	-.005	.056	.143	.090	-.140	-.152	.011
PPVTRawScore	-.119	.126	-.093	.176	.100	-.054	.113	.039	.004	.001	.124
TotalRelWords	.220	-.083	.563***	.158	.094	.215	.142	.239*	-.120	-.092	-.084
ChildScienceInterest	-	-.422***	.493***	.214	.058	.118	.122	.373**	.150	.049	.045
SciCareerInterest	-.398***	-	-.286*	-.142	-.132	.003	-.095	-.201	-.199	.037	-.114
SciTalkFrequency	.504***	-.262*	-	.206	.139	.147	.235*	.324**	.104	.001	.132
SciTVandVideo	.214	-.166	.230*	-	.475***	.297**	.310**	.189	.233*	.026	.224
SciApps	.051	-.149	.150	.505***	-	.226	.142	-.100	.052	.063	.059
SciPuzzles	.122	-.016	.152	.328**	.247*	-	.232*	.215	.102	.200	.194
SciBooks	.108	-.104	.228*	.312**	.158	.238*	-	.205	.092	.197	.202
SciActivities	.321**	-.213	.277*	.174	-.081	.210	.213	-	.158	-.049	.055
SciPlaces	.099	-.215	.073	.237*	.082	.109	.110	.196	-	.354**	.457***
SciClubs	.075	.039	.033	.057	.071	.208	.192	-.071	.318**	-	.617***
SciCamp	.047	-.134	.125	.253*	.080	.213	.207	.060	.449***	.608***	-
DoWellRating	.391***	-.228*	.418***	.246*	.279*	.074	.208	.189	.097	.032	.023
ChildConfidenceRating	.529***	-.215	.551***	.285*	.279*	.051	.259*	.358**	.083	.051	.055
ChildTimeLrngSciRtng	.465***	-.306**	.438***	.182	.142	.046	.348**	.466***	.159	.086	.156
ChildEnjoysLearningRtng	.471***	-.396***	.470***	.308**	.102	.168	.360**	.486***	.044	-.065	.030

Note. Correlations below the diagonal are bivariate correlations. Correlations above the diagonal are partial correlations controlling for age, gender, and SES.
* $p < .05$., ** $p < .01$., *** $p < .001$

Table 10

Direct and Partial Correlations for Demographic Variables, Scores on the Woodcock Johnson Science Assessment, PPVT, and Relational Vocabulary Checklist, and the Science Attitudes and Behaviors Checklist (Third Set of Child-Specific Items: Variables Titled "Do Well Rating" to "Child Enjoys Learning Science Rating")

	Do Well Rating	*Child Confid. Rating*	*Child Time LrngSci Rating*	*Child Enjoys Lrng Rating*
Age	-	-	-	-
Gender	-	-	-	-
SES	-	-	-	-
WJNumCorrect	-.165	-.023	.012	-.006
PPVTRawScore	-.128	-.050	-.021	-.053
TotalRelWords	.120	.296**	.151	.208
ChildScienceInterest	.384**	.539***	.500***	.480***
SciCareerInterest	-.262*	-.221	-.292*	-.392***
SciTalkFrequency	.370**	.531***	.461***	.468***
SciTVandVideo	.191	.225*	.152	.270*
SciApps	.262*	.247*	.113	.070
SciPuzzles	.056	.023	.028	.148
SciBooks	.214	.256*	.337**	.355**
SciActivities	.246*	.394***	.457***	.501***
SciPlaces	.128	.084	.128	.032
SciClubs	-.014	.021	.093	-.082
SciCamp	.024	.043	.143	.011
DoWellRating	-	.532***	.430***	.520***
ChildConfidenceRating	.570***	-	.581***	.590***
ChildTimeLearningSciRating	.402***	.571***	-	.586***
ChildEnjoysLearningRating	.518***	.599***	.590***	-

Note. Correlations below the diagonal are bivariate correlations. Correlations above the diagonal are partial correlations controlling for age, gender, and SES.
* $p < .05$., ** $p < .01$., *** $p < .001$

Table 11

Hierarchical Regression Analyses With Child Science Talk Frequency

		R^2	ΔR^2	b	SE_b	β
MODEL 1: All Relational Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.464	.001			
	Age (in months)			.169	.023	.668***
	Gender			-.121	.752	-.014
	SES			.144	.427	.029
	Child Sci. Talk Freq.			.144	.507	.025
Step 3		.496	.032*			
	Age (in months)			.148	.024	.584***
	Gender			-.289	.738	-.033
	SES			.106	.417	.022
	Child Sci. Talk Freq.			-.586	.598	-.101
	Total Relational Words			.031	.014	.244*
MODEL 2: General Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.464	.001			
	Age (in months)			.169	.023	.668***
	Gender			-.121	.752	-.014
	SES			.144	.427	.029
	Child Sci. Talk Freq.			.144	.507	.025
Step 3		.497	.033*			
	Age (in months)			.145	.025	.572***
	Gender			-.217	.735	-.025
	SES			.134	.417	.027
	Child Sci. Talk Freq.			-.491	.573	-.084
	Total General Words			.096	.044	.241*

		R^2	ΔR^2	*b*	SE_b	β
MODEL 3: Specific Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.464	.001			
	Age (in months)			.169	.023	.668***
	Gender			-.121	.752	-.014
	SES			.144	.427	.029
	Child Sci. Talk Freq.			.144	.507	.025
Step 3		.481	.017			
	Age (in months)			.157	.024	.621***
	Gender			-.350	.759	-.040
	SES			.113	.424	.023
	Child Sci. Talk Freq.			-.384	.605	-.066
	Total Specific Words			.064	.041	.172
MODEL 4: Spatial Words						
Step 1		.464	.464***			
	Age (in months)			.170	.022	.673***
	Gender			-.142	.744	-.016
	SES			.136	.424	.028
Step 2		.464	.001			
	Age (in months)			.169	.023	.668***
	Gender			-.121	.752	-.014
	SES			.144	.427	.029
	Child Sci. Talk Freq.			.144	.507	.025
Step 3		.497	.033*			
	Age (in months)			.150	.024	.592***
	Gender			-.188	.734	-.021
	SES			.095	.417	.020
	Child Sci. Talk Freq.			-.526	.581	-.090
	Total Spatial Words			.076	.035	.236*

Note. Predictor variable: Age Estimate on Woodcock-Johnson Science Assessment.

* $p < .05$. ** $p < .01$. *** $p < .001$

Figure 1

Path Analysis for Child Science Talk Frequency, Relational Vocabulary, and Science Knowledge

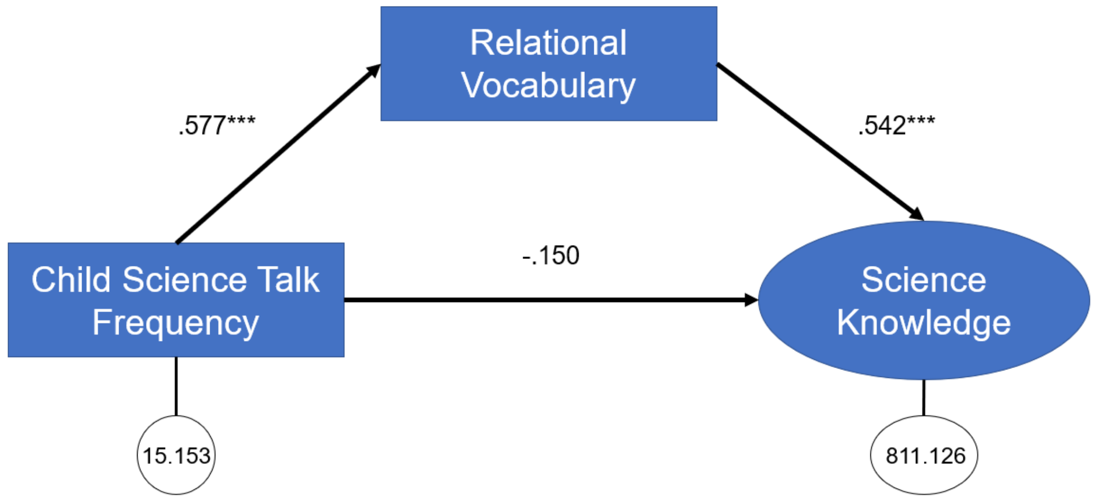


Table 12

Descriptive Statistics for the Science Attitudes and Behaviors Checklist: Parent and Family-Specific Items

Question Text	*Variable Name*						*Mean*	*Median*	*SD*
Does anybody in your family (incl. yourself) work in a science-related career (e.g., science teacher, engineer, weather forecaster, optician, doctor?	FamilyScienceCareer	*Yes (1)*	*No (2)*						
		47	33				1.41	1	.495
How often do you engage in science talk with your child?	EngageinSciTalkwithChild	*Daily (1)*	*1-2x/ Week (2)*	*1-2x/ mo. (3)*	*1-2x/ yr. (4)*	*Never (5)*			
		34	33	12	1	0	4.25	4	.755
The science my child learns is relevant to their life.	RelevantRating	*Strongly Disagree (1)*	*Disagree (2)*	*Neutral (3)*	*Agree (4)*	*Strongly Agree (5)*			
		0	1	10	41	28	4.2	4	.701
My child puts enough effort into learning science.	EffortRating	0	1	25	41	13	3.83	4	.708
My child uses strategies to learn science well.	StrategyRating	0	3	28	38	11	3.71	4	.75
It is important to me that my child does well in science.	ImportantDoWellRating	0	1	12	43	24	4.13	4	.7
I am confident that my child will do well in science.	ParentConfidenceinChildRating	0	0	9	52	19	4.13	4	.582
I believe my child can master science knowledge and skills.	ParentBeliefinMasteryRating	0	0	5	48	27	4.28	4	.573

Table 13

Direct and Partial Correlations for Demographic Variables, Scores on the Woodcock Johnson Science Assessment, PPVT, and Relational Vocabulary Checklist, and the Science Attitudes and Behaviors Checklist (All Family-Specific Items)

	Relevant Rating	*Effort Rating*	*Strategy Rating*	*Important DoWell Rating*	*Parent Confid. inChild Rating*	*Parent Beliefin Mastery Rating*	*Family Science Career*	*Engagein SciTalk withChild*
Age	-	-	-	-	-	-	-	-
Gender	-	-	-	-	-	-	-	-
SES	-	-	-	-	-	-	-	-
WJNumCorrect	.064	.148	.056	-.116	.165	.072	.100	.137
PPVTRawScore	-.038	.089	-.022	-.039	.151	.208	.165	.127
TotalRelWords	.156	.307**	.369**	.123	.350**	.174	-.097	.359**
RelevantRating	-	.277*	.199	.074	.283*	.288*	-.014	.265*
EffortRating	.276*	-	.556***	.145	.557***	.419***	-.164	.442***
StrategyRating	.207	.548***	-	.122	.405***	.159	-.025	.255*
ImportantDoWellRating	.077	.147	.118	-	.306**	.217	-.191	.299**
ParentConfidenceinChildRating	.279*	.546***	.374**	.303**	-	.659***	-.211	.387**
ParentBeliefinMasteryRating	.271*	.401***	.127	.197	.655***	-	-.084	.340**
FamilyScienceCareer	-.022	-.153	-.017	-.187	-.225*	-.093	-	-.175
EngageinSciTalkwithChild	.263*	.439***	.241*	.299**	.389***	.337**	-.178	-

Note. Correlations below the diagonal are bivariate correlations. Correlations above the diagonal are partial correlations controlling for age, gender, and SES.
* $p < .05$., ** $p < .01$., *** $p < .001$

Figure 2

Path Analysis for Family Science Talk Frequency, Relational Vocabulary, and Science Knowledge

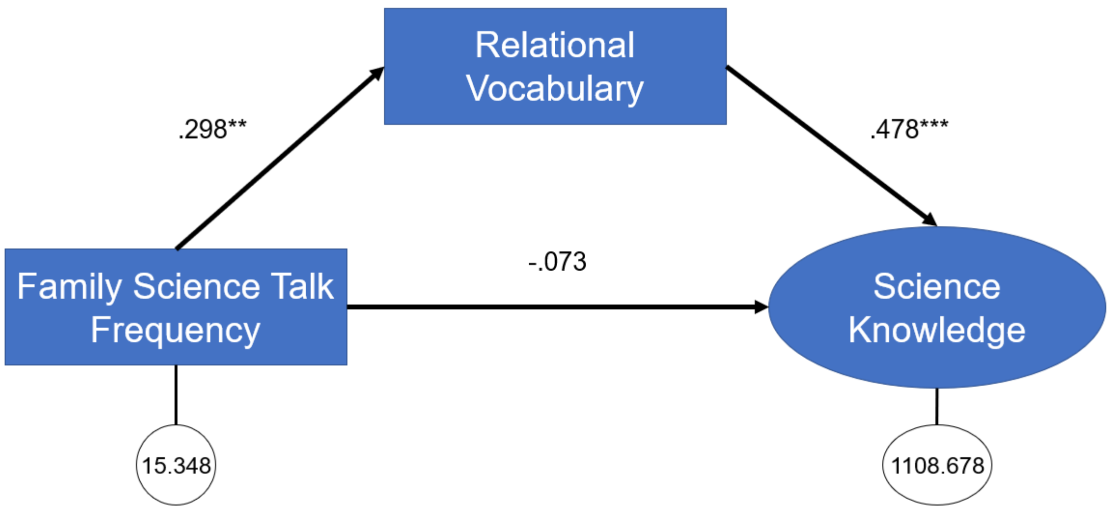
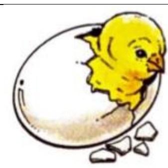


Table 14

Fact-Based and Conceptual Questions on the Woodcock Johnson Science Assessment

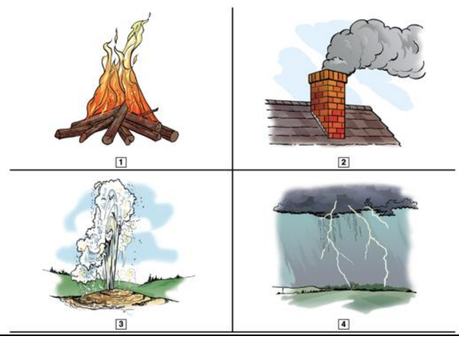
Question Text and Picture	*Question Type*
What are these? 	Fact-Based
Where do fish live?	Fact-Based
What animal barks?	Fact-Based
What kind of animal is this? 	Fact-Based
What is happening? 	Conceptual
What is happening? 	Conceptual
What is this? 	Fact-Based
Look at the pictures. Point to the one that could cause a fire. 	Conceptual
What is this used for? 	Conceptual
What do we breathe?	Fact-Based

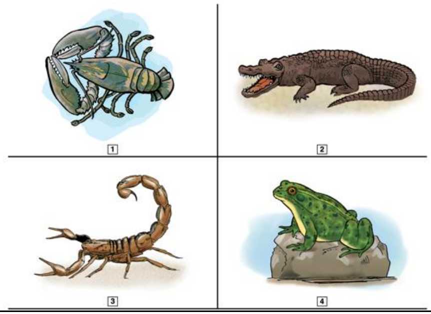
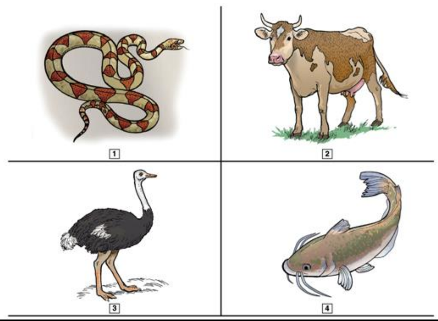
What do we call the loud noise we hear after a flash of lightning?	Fact-Based
What part of the body is used to take in the air we breathe?	Fact-Based
What does a tadpole, or polliwog, become when it grows up?	Fact-Based
What was this before it hatched into a butterfly? 	Fact-Based
When you see this picture, what does it tell you? 	Conceptual
What organ in the body pumps blood?	Fact-Based
Lizards, snakes, and crocodiles are what type of animal?	Fact-Based
How does a plant absorb water from the ground?	Conceptual
What is this formation of stars called? 	Fact-Based
What organ in the human body exchanges carbon dioxide for oxygen?	Fact-Based
What is the distance that light travels from the stars in a year called?	Fact-Based
One characteristic of mammals is that the babies are nursed by the mother. What is another characteristic of animals classified as mammals?	Fact-Based
What does *noncommunicable disease* mean?	Fact-Based
What do the classifications metamorphic, sedimentary, and igneous refer to?	Fact-Based
What is the name of the membrane in the middle ear that vibrates in response to sound?	Fact-Based
What is the name of the sleep disorder characterized by cessation of breathing?	Fact-Based
What is it called when a person excessive sleepiness, or frequently falls asleep at unexpected times?	Fact-Based
What is the name for small planet-like objects that orbit the sun?	Fact-Based
What is the name of the point on the earth's surface directly above an earthquake's focus?	Fact-Based
What causes the phases of the moon?	Conceptual
What does an EEG measure?	Fact-Based
What does the abbreviation LED stand for?	Fact-Based
What is the part of the neuron that receives information from other neurons?	Fact-Based

Cells that produce large amounts of mRNA generally secrete what type of molecule?	Fact-Based
There are many layers of atmosphere. Name three of them.	Fact-Based
What is the name of the center of the retina, where a person has the best, or sharpest, vision?	Fact-Based
What is the name of the bumps on your tongue that contain your taste buds?	Fact-Based
What is the charge on an aluminum cation?	Fact-Based
Which nutrient contains the highest percentage of carbon and hydrogen and has the most energy per ounce?	Fact-Based
What is the name for $HClO_4$?	Fact-Based

Table 15

Overlap Between Questions on the Woodcock Johnson Science Assessment (WJ) and the Peabody Picture Vocabulary Test (PPVT)

WJ Question Text and Picture	*WJ Question Age Estimate*	*PPVT Word and Picture*	*PPVT Question Age Estimate*
Look at the pictures. Point to the one that could cause a fire. 	4 years 10 months	"fire" 	4 years
What part of the body is used to take in the air we breathe?	6 years 1 month	"inhaling" 	14-16 years

Lizards, snakes, and crocodiles are what type of animal?	8 years 2 months	“reptile” 	10 years
One characteristic of mammals is that the babies are nursed by the mother. What is another characteristic of animals classified as mammals?	11 years 7 months	“mammal” 	14-16 years

Appendix A

Descriptive Statistics for Demographic Variables

Demographic Variable	*Number*	*Percent*
Gender		
Female	42	52.5
Male	38	47.5
Race		
American Indian/Alaska Native	0	0
Asian	4	5
Black/African American	0	0
Native Hawaiian/Other Pacific Islander	0	0
White	67	83.75
More than one race	8	10
Prefer not to disclose	1	1.25
Ethnicity		
Hispanic or Latino	2	2.5
Not Hispanic or Latino	75	93.75
Prefer not to disclose	3	3.75
Household Income		
Less than $24,999	1	1.25
$25,000 to $49,999	1	1.25
$50,000 to $99,999	21	26.25
$100,000 or more	44	55
Prefer not to disclose	13	16.25
Parental Education Level		
Some high school	0	0
High school graduate	0	0
Trade/Technical/Vocational	1	1.25
Some college	0	0
College graduate	30	37.5
Postgraduate	49	61.25
Prefer not to disclose	0	0
Socioeconomic Status (Points)		
4	1	1.3
7	1	1.3
8	7	8.8
9	36	45
10	35	43.8
Languages		
English		
Spanish	78	97.5
Bilingual English + Spanish	0	0
Mandarin	2	2.5
Other	0	0
	0	0

Appendix B

Peabody Picture Vocabulary Test

Set 1 (Start Age 2:6-3:11)
ball
dog
spoon
foot
duck
banana
shoe
cup
eating
bus
flower
mouth
Set 2 (Start Age 4)
pencil
cookie
drum
turtle
red
jumping
carrot
reading
toe
belt
fly
painting
Set 3
dancing
whistle
kicking
lamp
square
fence
empty
happy
fire
castle
squirrel
throwing

Set 4 (Start Age 5)
farm
penguin
gift
feather
cobweb
elbow
juggling
fountain
net
shoulder
dressing
roof
Set 5 (Start Age 6)
peeking
ruler
tunnel
branch
envelope
diamond
calendar
buckle
sawing
panda
vest
arrow
Set 6 (Start Age 7)
picking
target
dripping
knight
delivering
cactus
dentist
floating
claw
uniform
gigantic
furry

Set 7 (Start Age 8)
violin
group
globe
vehicle
chef
squash
ax
flamingo
chimney
sorting
waist
vegetable
Set 8 (Start Age 9)
hyena
plumber
river
timer
catching
trunk
vase
harp
bloom
horrified
swamp
heart
Set 9 (Start Age 10)
pigeon
ankle
flaming
wrench
aquarium
refueling
safe
boulder
reptile
canoe
athlete
towing

Set 10 (Start Ages 11-12)
luggage
directing
vine
digital
dissecting
predatory
hydrant
surprised
palm
clarinet
valley
kiwi
Set 11 (Start Age 13)
interviewing
pastry
assisting
fragile
solo
snarling
puzzled
beverage
inflated
tusk
trumpet
rodent
Set 12 (Start Ages 14-16)
inhaling
links
polluting
archaeologist
coast
injecting
fern
mammal
demolishing
isolation
clamp
dilapidated

Set 13 (Start Ages 17-18)
pedestrian
interior
garment
departing
feline
hedge
citrus
florist
hovering
aquatic
reprimanding
carpenter
Set 14 (Start Ages 19-Adult)
primate
glider
weary
hatchet
transparent
sedan
constrained
valve
parallelogram
pillar
consuming
currency
Set 15
hazardous
pentagon
appliance
poultry
cornea
peninsula
porcelain
detonation
cerebral
perpendicular
submerging
syringe

Set 16
lever
apparel
talon
cultivating
wedge
ascending
depleted
sternum
maritime
incarcerating
dejected
quintet
Set 17
incandescent
confiding
mercantile
upholstery
filtration
replenishing
trajectory
perusing
barb
converging
honing
angler
Set 18
wildebeest
coniferous
timpani
pilfering
pestle
reposing
cupola
derrick
convex
embossed
torrent
dromedary

Set 19
legume
cairn
arable
supine
vitreous
lugubrious
caster
terpsichorean
cenotaph
calyx
osculating
tonsorial

Appendix C

Relational Vocabulary Checklist

Children understand many more words than they can say. <u>We are particularly interested in the RELATIONAL WORDS that your child SAYS</u> (e.g., words that are used when comparing things). Please go through this list and check the words that you have heard your child use. If your child uses a different pronunciation of a word, mark it anyway.

This is a "catalogue" of all words that are used by children of a variety of ages. Do not worry if your child says only a few of these words right now.

GENERAL

- ☐ Copy
- ☐ Imitate
- ☐ Relation
- ☐ Instead
- ☐ With
- ☐ Juxtapose
- ☐ Rather
- ☐ Mimic
- ☐ Comparable
- ☐ Difference
- ☐ Similarity
- ☐ However
- ☐ Imitation
- ☐ Nonetheless
- ☐ Whereas
- ☐ Parallel
- ☐ Relative
- ☐ Like
- ☐ Meanwhile
- ☐ Except
- ☐ Also
- ☐ Differ
- ☐ Resemble
- ☐ Likewise
- ☐ Alternative
- ☐ Converse
- ☐ Analog
- ☐ Too
- ☐ Moreover
- ☐ Unlike
- ☐ Analogy
- ☐ Otherwise
- ☐ Though
- ☐ Despite
- ☐ Compare
- ☐ Vary
- ☐ Same
- ☐ Contrast
- ☐ Relate
- ☐ Commonality
- ☐ Although
- ☐ Different
- ☐ While
- ☐ Analogous
- ☐ Yet
- ☐ But
- ☐ As
- ☐ Align
- ☐ Just
- ☐ Mirror
- ☐ Variation
- ☐ Notwithstanding
- ☐ Akin
- ☐ Alike
- ☐ Still
- ☐ Corresponding
- ☐ Common
- ☐ Contrary
- ☐ Correspond
- ☐ Similar
- ☐ Even
- ☐ Link
- ☐ Connect
- ☐ Associate
- ☐ Join
- ☐ Joint
- ☐ Group
- ☐ Relationship
- ☐ Attach
- ☐ Connection
- ☐ Association
- ☐ Support
- ☐ Both
- ☐ Share

SPECIFIC

- ☐ Older
- ☐ Lighter
- ☐ Darker
- ☐ Louder
- ☐ Thinner
- ☐ Later
- ☐ Lower
- ☐ Taller
- ☐ Deeper
- ☐ Healthier
- ☐ Steeper
- ☐ Farther
- ☐ Easier
- ☐ Thicker
- ☐ Newer
- ☐ Weaker
- ☐ Warmer
- ☐ Stronger
- ☐ Faster
- ☐ Broader
- ☐ Quieter
- ☐ Closer
- ☐ Narrower
- ☐ Hotter
- ☐ Softer
- ☐ Brighter
- ☐ Straighter
- ☐ Fewer
- ☐ Earlier
- ☐ Worse
- ☐ Longer
- ☐ Wider
- ☐ Bigger
- ☐ Harder
- ☐ Higher
- ☐ Greater
- ☐ Colder
- ☐ Smaller
- ☐ Denser
- ☐ Heavier
- ☐ Shorter
- ☐ Better
- ☐ Slower
- ☐ Before
- ☐ After
- ☐ More
- ☐ Further
- ☐ Equal
- ☐ Most
- ☐ Opposite
- ☐ Inverse
- ☐ Less

SPATIAL

- ☐ Some
- ☐ Tiny
- ☐ Center
- ☐ Side
- ☐ Flat
- ☐ Tall
- ☐ By
- ☐ Outside
- ☐ Inside
- ☐ Right side up
- ☐ Backward
- ☐ Top
- ☐ Front
- ☐ Left
- ☐ On
- ☐ Big
- ☐ Over
- ☐ Line
- ☐ Long
- ☐ Bottom
- ☐ Around
- ☐ Above
- ☐ Piece
- ☐ Upside down
- ☐ Within
- ☐ Next to
- ☐ Away
- ☐ Edge
- ☐ Under
- ☐ Among
- ☐ Across
- ☐ Behind
- ☐ Low
- ☐ Vertical
- ☐ Somewhere
- ☐ Near
- ☐ Between
- ☐ Horizontal
- ☐ Rotate
- ☐ Together
- ☐ Wide
- ☐ Down
- ☐ All
- ☐ In
- ☐ Up
- ☐ Short
- ☐ Small
- ☐ Far
- ☐ Below
- ☐ Beside
- ☐ Back
- ☐ Forward
- ☐ Apart
- ☐ Sideways
- ☐ Reverse
- ☐ Upright
- ☐ Flip
- ☐ Section
- ☐ Curve
- ☐ High
- ☐ Right
- ☐ Corner
- ☐ Large
- ☐ Diagonal
- ☐ Separate
- ☐ Middle
- ☐ Turn
- ☐ Little
- ☐ Close

Appendix D

Science Attitudes and Behaviors Checklist

1. Currently, how would you rate your child's interest in science?
   - No Interest
   - Low
   - Medium
   - High

2. Does your child show an interest in working in a science-related career?
   - Yes
   - No

3. How often does your child talk about science?
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

4. How often does your child do the following science-related activities?

   a. Watches TV shows and videos about science
      - Daily
      - Once or twice a week
      - Once or twice a month
      - Once or twice a year
      - Never

   b. Plays digital learning games or apps about science
      - Daily
      - Once or twice a week
      - Once or twice a month
      - Once or twice a year
      - Never

   c. Plays with science-related puzzles or board games
      - Daily
      - Once or twice a week
      - Once or twice a month
      - Once or twice a year
      - Never

d. Reads books or magazines about science
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

e. Does activities that are science-related (e.g., cooking, gardening, building, tech, other)
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

f. Visits science places, such as a zoo, pet store, community garden, aquarium, nature center, or museum
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

g. Participates in clubs or groups that do science-related activities (e.g., robotics, scouts)
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

h. Participates in a science-oriented camp or other special program (e.g., a fee-based program)
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

5. To what extent do you agree or disagree with the following statements?

    a. The science my child learns is relevant to their life.
        - Strongly Disagree
        - Disagree
        - Neutral
        - Agree
        - Strongly Agree

    b. Doing well in science is important to my child.
        - Strongly Disagree
        - Disagree
        - Neutral
        - Agree
        - Strongly Agree

    c. My child is confident in their science ability.
        - Strongly Disagree
        - Disagree
        - Neutral
        - Agree
        - Strongly Agree

    d. My child puts enough effort into learning science.
        - Strongly Disagree
        - Disagree
        - Neutral
        - Agree
        - Strongly Agree

    e. My child uses strategies to learn science well.
        - Strongly Disagree
        - Disagree
        - Neutral
        - Agree
        - Strongly Agree

    f. It is important to me that my child does well in science.
        - Strongly Disagree
        - Disagree
        - Neutral
        - Agree
        - Strongly Agree

g. I am confident that my child will do well in science.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

h. My child spends a lot of time learning science.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

i. I believe my child can master science knowledge and skills.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

j. My child enjoys learning science.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

6. Does anybody in your immediate family, including yourself, work in a science-related career (e.g., science teacher, engineer, weather forecaster, optician, doctor)?
   - Yes
   - No

7. If you answered "Yes" to the above, what type of science career/science careers does your family hold?

Insert response here

8. How often do you engage in science talk with your child?
   - Daily
   - Once or twice a week
   - Once or twice a month
   - Once or twice a year
   - Never

Appendix E

Woodcock Johnson Science Assessment

1. What are these?

2. Where do fish live?
3. What animal barks?
4. What kind of animal is this?

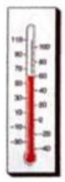
5. What is happening?

6. What is happening?

7. What is this?

8. Look at the pictures. Point to the one that could cause a fire.

9. What is this used for?



10. What do we breathe?
11. What do we call the loud noise we hear after a flash of lightning?
12. What part of the body is used to take in the air we breathe?
13. What does a tadpole, or polliwog, become when it grows up?
14. What was this before it hatched into a butterfly?

15. When you see this picture, what does it tell you?

16. What organ in the body pumps blood?
17. Lizards, snakes, and crocodiles are what type of animal?
18. How does a plant absorb water from the ground?

19. What is this formation of stars called?

20. What organ in the human body exchanges carbon dioxide for oxygen?
21. What is the distance that light travels from the stars in a year called?
22. One characteristic of mammals is that the babies are nursed by the mother. What is another characteristic of animals classified as mammals?
23. What does noncommunicable disease mean?
24. What do the classifications metamorphic, sedimentary, and igneous refer to?
25. What is the name of the membrane in the middle ear that vibrates in response to sound?
26. What is the name of the sleep disorder characterized by cessation of breathing?
27. What is it called when a person excessive sleepiness, or frequently falls asleep at unexpected times?
28. What is the name for small planet-like objects that orbit the sun?
29. What is the name of the point on the earth's surface directly above an earthquake's focus?
30. What causes the phases of the moon?
31. What does an EEG measure?
32. What does the abbreviation LED stand for?
33. What is the part of the neuron that receives information from other neurons?
34. Cells that produce large amounts of mRNA generally secrete what type of molecule?
35. There are many layers of atmosphere. Name three of them.
36. What is the name of the center of the retina, where a person has the best, or sharpest, vision?
37. What is the name of the bumps on your tongue that contain your taste buds?
38. What is the charge on an aluminum cation?
39. Which nutrient contains the highest percentage of carbon and hydrogen and has the most energy per ounce?
40. What is the name for HClO4?