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WHAT'S WRONG WITH BEING WRONG?
MAKING SENSE OF PARENT PERCEPTIONS OF MISCONCEPTIONS

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Abstract

WHAT'S WRONG WITH BEING WRONG?

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Sam R. McHugh

Children often discuss science and nature topics in their everyday conversations with their parents; however, these conversations are not always scientifically accurate. Some researchers argue that these scientifically incorrect conversations interfere with children's learning by reinforcing children's misconceptions (Shtulman, 2017). Others argue that factually incorrect conversations may still support children's learning by giving them opportunities to discuss science in meaningful and contextually relevant ways (Hammer, 1996). This study explores how parents view and approach science misconceptions, comparing high-stakes topics like health and safety versus low-stakes general science topics. I also consider how parents' reported and observed approaches to science misconceptions might vary with child age, parents' attitude towards science or failure mindset, and parent or child gender. Parent-child dyads (*N* = 107) participated in this study (55 girls, 52 boys, *M* = 63.09 months, *SD* = 10.41 months, Range: 48-83 months; 69 mothers, 38 fathers). Parents discussed their views about science misconceptions in a brief interview, and reported they respond to misconceptions by (1) *correcting*, (2) *scaffolding*, or (3) *exploring* their children's science misconceptions. Parents most often reported an approach to misconceptions that was in line with a goal to correct their children's science misconceptions. More positive views of failure predicted a greater likelihood of parents reporting a *scaffolding* compared to a *correcting* or *exploring* approach. In a prompted conversation activity, parents were observed approaching misconceptions by (a) *providing the correct answer*, (b) *scaffolding*, (c) *mixed (scaffolding / correct answer)*, or (d) *exploring*. Parents were more likely to correct children's misconceptions about health and safety than general science topics. Parents' observed approaches to misconceptions also varied based on their mindset about failure and their gender. Their reported approach and observed approaches were generally aligned. Parent talk during the conversation activity was also coded at the utterance level for accuracy talk; fathers used more frequent accuracy talk than mothers, but there was no difference in the proportion of accuracy talk for mothers and fathers. Altogether the present study illuminates how parents and children engage with misconceptions and provides new insights into better understanding children's science learning in real-world contexts.

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Introduction

Children often have numerous misconceptions about the world. For example, young children may think of the sun's movements as rising and falling in the same place, or that coating themselves with soap can prevent them from being sick. Depending on how one views misconceptions, these examples might be seen as a problem to correct, or these ideas could be seen as first steps toward building understandings of astronomy and germ theory (Vosniadou, 2020). By going about their daily lives, children begin to develop conceptual frameworks about how the world works. This learning begins far earlier than children's experience with formalized educational practices; it starts in everyday conversations and activities with their families.

The central aim of my dissertation research is to investigate how parents and children discuss science misconceptions that may arise in their everyday life. There is likely to be individual variation in parents' tendency to correct misconceptions (Kaya & Lundeen, 2010), so I ask how parents' attitudes and demographic factors relate to different ways of discussing misconceptions. In addition, there might be variation in how parents and children discuss misconceptions based on the type of misconception. In the previous examples, although parents may recognize both topics as scientifically incorrect ideas about science, parents may vary in how important they think it is to respond. Even the same parent may believe it is more important to respond to misconceptions that pertain to their child's health and safety than to their ideas about other general aspects of science. This direct comparison had not been previously addressed in research. I argue that children have the opportunity to make sense of the natural and physical world and develop their scientific understanding by engaging in everyday conversations and activities with their parents. This scientific understanding becomes a crucial lifelong skill as there is an ever-increasing need to critically evaluate evidence (Jamil et al., 2024).

The goal of my dissertation research is to contribute to a strengths-based understanding of how families engage in conversations about ideas that are considered factually incorrect or unsupported by science. In my research, I refer to these factually incorrect or unsupported ideas as misconceptions (Nguyen & Rosengren, 2004). I refrain from assigning a negative value to the word "misconceptions," and take a sense-making perspective that views factually incorrect ideas as ways that children and parents build on their scientific understanding by engaging in scientific reasoning practices (Campbell et al., 2016; Driver et al., 1994; Hammer, 1996; Smith et al., 1994). These scientific reasoning practices include everyday behaviors that families often engage in, such as asking questions, providing explanations, and engaging in argumentation from evidence (Lehrer & Schauble, 2015; NGSS Lead States, 2013).

To situate this work, I will begin by reviewing research about conceptual change and misconceptions in the field of psychology. Next, I will review research from the education field that takes a sense-making approach to children's science learning. Then, I will review research that investigates misconceptions in everyday life as well as children's everyday science learning that occurs through conversations with parents. Finally, I will introduce the goals and scope of the current study.

Science Misconceptions as Conceptual Change

When learning about science is viewed as conceptual change, learners are believed to restructure their non-scientific conceptions to conceptions that are consistent with scientifically supported ideas (Duit & Treagust, 2003; Leonard et al., 2014). Children are often thought of as little scientists who acquire theories and knowledge by accumulating input from their environment, and eventually acquiring correct understanding. This input is thought to be data that allows children to experiment, interpret statistical evidence, and learn in ways that are similar to those used by scientists (Gopnik, 2012). According to this perspective, it is also thought that children need to already have a certain set of abilities in order for new learning to occur (Gopnik & Schulz, 2004). Children's initial understanding is often thought to be incorrect and needs to be replaced with correct scientific theories, which are proposed to come about when learners' ideas are challenged (Posner et al., 1982). Some researchers believe that misconceptions have negative consequences for children's learning in that the misconceptions not only get in the way of children's scientific understanding, but they might not ever fully go away (Legare et al., 2012; Shtulman, 2017; Vosniadou, 2019). In work by Potvin and Cyr (2017), researchers found evidence that scientifically incorrect and correct ideas about certain concepts may coexist, even for some science educators. By remaining present, in this view, misconceptions may interfere with children's learning of science concepts and make the correct information more difficult to access in situations that may be more cognitively demanding (Kelemen et al., 2013).

According to this view, opportunities to overcome misconceptions are hypothesized to come about in a variety of situations, and there is conflicting evidence as to which strategies are most successful in the pursuit of correcting erroneous beliefs. For example, in some work, children have revised their misconceptions when they are exposed to compelling conflicting evidence (Kimura & Gopnik, 2019), and are given opportunities to explain instances of inconsistent evidence (Ganea et al., 2021; Legare et al., 2016). However, other research has shown that encountering anomalous evidence may lead children to discount the new information in favor of their naive theories by attributing the discrepancy to unobserved variables (Bonawitz et al., 2012).

I argue that it is not inherently negative that children have scientifically incorrect ideas about how the world works. For example, work by Gripshover and Markman (2013) demonstrated that 4- and 5-year-old children learned more about nutrition when taught in a way that integrated their developing intuitive theories that food has a "vital force." Instead of teaching children about food with a series of facts, these researchers embraced this belief and taught children that nutrients help provide different bodily functions. The children who were taught in the way that built on their scientifically unsupported ideas were then more likely to be observed eating more nutritious snacks than children in a control condition.

When researchers start with the assumption that children's understanding of science is flawed and distinct from that of adults, they may likely take the stance that adults function as teachers. Rogoff et al. (2003) suggest that this approach may lead researchers to believe that children develop a correct understanding primarily through pedagogical intervention. This view has been explored in many studies that aim to pinpoint how children's conceptions of science are different from scientifically accurate beliefs held by adults (e.g., Vosniadou & Ioannides, 1998). However, an alternative field of research centering on children's sense-making suggests that children often engage in sophisticated scientific reasoning practices in both formal and informal learning environments.

Science Misconceptions as Sense-Making

Taking a sense-making approach shifts the focus from evaluating what children know to assessing how children reason about science to make sense of the world (Berland et al., 2016; DeBoer, 1991). This reframing of learning focuses on how children participate in the reasoning practices of science as individuals in social contexts (Driver et al., 1994; Lehrer & Schauble, 2015). Even when children's commonsense reasoning is not considered scientifically accurate, researchers who take a sense-making perspective argue that children's naive ideas are still valuable to the learning process (Campbell et al., 2016; Driver et al., 1994; Hammer, 1996; Smith et al., 1994). The misconceptions, or "alternative frameworks" (Driver & Erickson, 1983; Kuiper, 1994), children hold are not negative in this view but instead represent positive resources in the development of scientific thinking (Smith et al., 1994).

One issue that has historically arisen when researchers study learning is the stark contrast between how science is taught, and how scientists operate (Gil-Perez &

Carrascosa, 1990). This had been a long-standing discrepancy that the Next Generation Science Standards (NGSS) aimed to reconcile (NGSS Lead States, 2013). Science-as-practice has been emphasized by the NGSS, which established a set of standards for content, practices, and cross-cutting themes of science education (NGSS Lead States, 2013). The NGSS supports the belief that children should be given opportunities to think like scientists and learn how scientific knowledge is constructed, critiqued, and revised by engaging in science practices while learning about specific science content (Lehrer & Schauble, 2015). Some of the science practices from NGSS include asking questions, constructing explanations, and engaging in argument from evidence (Lehrer & Schauble, 2015, see also NGSS Lead States, 2013). Considering science learning as a set of practices instead of facts suggests that even children's incorrect ideas can be the basis for scientific reasoning.

In a particular example described by van Zee et al. (2005), the students were actually elementary and middle school teachers participating in a classroom lesson about light and how it moves through water. The students in the session used the science practice of modeling to create visual representations of their ideas. This allowed the learners to work through their understanding, and to have something tangible to discuss with collaborators. When two students held conflicting ideas, the instructor guided students to explain their beliefs. Instead of identifying one idea as correct and one as incorrect, the instructor left the conversation to let the learners discuss possible explanations and work together. By leaving at this point in the discussion, there was a "risk" that the students would come to an understanding that did not represent the true scientific concept idea. This might be a concern for most educators; however, the goal of this lesson was to have students engage in discussions that facilitated their scientific thinking (inquiry, modeling, observation, argumentation, etc.), not to necessarily learn the factual physics explanation (van Zee et al., 2005). By experiencing the world around them, the participants in this course already had everyday understandings of how light moves through water; however, in the context of this activity they were encouraged to reason about their beliefs and think more deeply about how the world works.

It may be beneficial for children to learn when commonsense reasoning is useful and relevant instead of replacing misconceptions with correct information. Teachers can also utilize children's alternative frameworks by incrementally adapting their instruction towards the scientifically accepted theories (Hammer, 1996). In fact, some suggest that when there is a strong focus on replacing the "wrong" ideas with the "right" ones, children may become discouraged from engaging with the process of inquiry related to certain topics. In this situation, learners are more likely to memorize the scientific answer for the purpose of schoolwork, while reverting back to their alternative frameworks in their everyday contexts (Campbell et al., 2016; Hammer, 1996).

One way researchers have redefined learning is by capturing what a community of students say and do within the context of a classroom science activity, as opposed to focusing on a singular individual within the classroom. For example, Hamza and Wickman (2008) considered the full classroom environment that upper secondary students were experiencing while learning, and viewed children's understanding as an ongoing sense-making process without focusing on acquiring an accurate scientific concept. This approach contrasts with the conceptual change perspective, which measures individual children's factual understanding as an outcome of their experience rather than the progression of scientific practices they engage in with one another over time. The holistic approach to learning, as taken by Hamza and Wickman (2008), focuses less on acquiring units of information that can be measured in a test. Instead, Hamza and Wickman (2008) highlight the process of reasoning about one's ideas in a community of learners. These researchers operationalize learning as what people said and did within the context of a classroom science activity, and also considered the full environment that students were experiencing while learning, as opposed to focusing on a singular individual within the classroom. This approach reflects a shift toward viewing misconceptions as an outward display of a thought process that occurs while reasoning about different possibilities, rather than as a stable incorrect idea that prevents learning. This is an exciting approach because it may more accurately reflect children's everyday experiences with learning, instead of highly controlled pretest-posttest interventions, and provide better insights to supporting children's science learning.

While the science education guidelines emphasize reasoning practices involved in scientific thinking (NGSS Lead States, 2013), it is unknown whether this approach is reflected in family contexts. Although it is over 10 years after its initial release, research with parents whose children are in classrooms that implement NGSS concepts has found that the parents were generally uninformed about the principles of NGSS and felt confused about how to support their children's science learning (Channell et al., 2021). Because many parents already take on a teacher-like role when interacting with their children (Gleason & Schauble, 1999; Rogoff, 1990), the right versus wrong misconceptions approach to children's science learning may infiltrate these parent-child interactions. Parents who believe they do not have a scientifically accurate understanding of a concept may then be discouraged from engaging in science conversations when they feel uncertain (Kaya & Lundeen, 2010). The context of parent-child conversation is important because parents' encouragement of children's ideas and beliefs about science may support their children's interest in science and identity development throughout their lifetime (Cian et al., 2022). By studying how parents and children make sense of the world through everyday experiences, researchers can shed light on what "learning" really looks like, both in and out of the classroom (Rogoff et al., 2018).

Science Misconceptions in Everyday Life

Science learning does not occur in a vacuum, yet the context of children's lived experiences has not always been emphasized in research examining children's science misconceptions. For example, previous research by Nguyen and Rosengren (2004) has explored parent survey reports of children's misconceptions and found that misconceptions related to biology are common among 3- to 6-year-olds. They suggest that these misconceptions may arise from children's observations and experiences, or from misinformation provided by parents due to discomfort with sensitive topics such as reproduction or death (Nguyen & Rosengren, 2004). This misinformation might also occur accidentally due to challenges adults face when adapting scientific explanations to children (Vlach & Noll, 2016). Vlach and Noll (2016) sampled college-aged adults and found that participants significantly adapted and provided additional unhelpful information in their explanations of scientific concepts when prompted to talk to a child compared to talking to another adult. Specifically, these explanations to children had more mythical, personification, and unnecessary descriptors than explanations to adults (Vlach & Noll, 2016). These studies provide interesting insights into topics children may have misconceptions about and challenges adults may face when providing scientific explanations to children. Nonetheless, neither of these studies addresses the dynamics that unfold during everyday parent-child conversations.

One dynamic way that families engage in conversations is due to children's active role in making sense of the world by asking questions. Asking questions is both a science practice and an everyday practice that facilitates children's learning from conversations. Researchers have proposed that children as young as 4-years-old ask questions to resolve the tension between what they already know, and what they have yet to fully understand (Chouinard et al., 2007). For example, children's "why" questions have been shown to serve as an information-seeking technique to generate meaningful and helpful explanations from parents (Callanan & Oakes, 1992). When parents or other adults do not provide children with explanatory or satisfactory responses to questions, children are less likely to remember the responses and are more likely to ask the same question repeatedly (Chouinard et al., 2007, Frazier et al., 2016). Additionally, the kinds of questions children ask change over the course of development and vary based on the immediate context. Even before children verbalize questions, they use gestures or other non-linguistic cues to seek information from parents (e.g., pointing) (Chouinard et al., 2007). In the context of a zoo visit, many children asked questions that might support their biological understanding of animals (Chouinard et al., 2007). Thus, conversations prompted by children's questions may be a crucial everyday practice that contributes to science learning throughout childhood.

Parents and children reason about science-related ideas and practices at home and in structured informal learning contexts by engaging in conversations with one another. One study by Callanan et al. (2019) investigated family conversations about nature through the use of a self-report diary. Parents were asked to document conversations with their 3- to 5-year-olds over the course of two weeks, and on average, families recorded about nine nature-related conversations. Researchers found that family conversations most often were about animals, plants, and astronomy but also included topics like geology, physics, weather, psychology, and the human body. Children in this study initiated about 75% of the recorded conversations and were equally likely to begin conversations with statements or questions. These findings demonstrate the prevalence of everyday family conversations about nature and children's active engagement in understanding the natural world (Callanan et al., 2019). However, families may not necessarily provide the correct information when they have conversations about science.

Prior research has suggested that, even for adults, scientific reasoning is often based on misconceptions about science concepts. For example, there is evidence that children and adults conceptualize heat and temperature as a property of objects rather than an emergent process (Chi, 2005). This may be due to the unscientific ways that these concepts are generally discussed in informal contexts (e.g., talking about stoves being hot). Research by Luce and Callanan (2020) aimed to explore how children between 2 and 5 years actually experience information about this topic in their everyday lives in order to shed light on the tension between the idea that misconceptions are unhelpful and disrupt children's accurate understandings, and the idea that these alternative frameworks may serve as building blocks for having a correct scientific understanding. Luce and Callanan (2020) found that families commonly referred to heat as a property as opposed to (the scientific view) as a process. Although this is technically incorrect, parents and children discussed heat- and temperature-related words in a variety of meaningful contexts such as everyday conversations about weather, body temperature, and mealtimes (Luce & Callanan, 2020). Even when the content of conversations does not follow a strictly scientific description, these conversations may contribute to children's developing understanding of science concepts in ways that are relevant to their lived experiences.

Another science topic that is challenging for both adults and children is density (Pick & Pick, 1967; Robinson, 1964). In simple terms, density is a measure of how heavy an object is compared to its size. One way research has captured family conversations about density is through tasks that ask participants to predict which objects sink or float. Solis and Callanan (2016) examined parent-child conversations with 4- and 7-year-old children during an at-home sink-and-float task for Mexican-heritage parents with basic- (less than 12 years) or higher-level (12 years or more) schooling. Researchers found that more parental schooling did not necessarily equate to more scientific conversations about density (Solis & Callanan, 2016). For example, families in the basic-schooling group demonstrated a key aspect of the scientific process by addressing the predictions that were unsupported by evidence more often than higher-schooling parents. The higher-schooling parents also positioned themselves as the teacher or expert that the child needed to learn from by asking more known-answer questions than did parents in the basic-schooling group. Although the task was directly investigating density, the word density was never explicitly mentioned throughout the activity by either group of families. Properties related to density, like the material, weight, and size of the objects, were, however, discussed by both groups of families (see also Siegel et al., 2007). These discussed properties are less complex than the full concept of density and are more frequently discussed in everyday settings. It is likely that children and parents encounter this topic in their everyday lives during activities like bath time, playing in a pool, or children's museums; however, it is a relatively abstract concept, and one might argue that it is not unreasonable for young children to believe weight is the sole factor in why some objects sink and others float.

Factors that May Impact Family Conversations about Science Misconceptions

Often, in research on cognitive development about young children's science misconceptions, there is a focus on somewhat esoteric topics like density, astronomy, or evolution. These are topics that parents might interpret as being inconsequential to children's everyday life. Some of these topics are generally difficult for adults as well (Potvin & Cyr, 2017). For example, engaging with the belief that the sun rises and sets in a single location on the horizon (Plummer, 2009) may not be a priority for parents whose children still have yet to grasp the importance of more health-related topics such as washing their hands after playing outside (Jess & Dozier, 2020). To date, research on parent-child conversations about science misconceptions have not directly compared how discussions vary based on how impactful the topic is for children's scientific understanding in everyday life. In the current study, "low-stakes" topics consist of general science misconceptions that may be seen by parents as less consequential to children's everyday lives. Alternatively, "high-stakes" misconceptions pertain to the health and safety of a child.

In addition to the type or "stakes" of the misconceptions, parents' and children's individual characteristics may also relate to how they engage with science ideas with their children. One way that conversations about misconceptions may vary is based on the age of the child (Nguyen & Rosengren, 2004). In a survey about children's biological misconceptions, parents of 3- and 4-year-old children reported their children had more misconceptions than did parents of 5- and 6-year-old children. Another factor that might influence the way parents and children discuss misconceptions about science is parent and/or child gender. Some previous research has shown that mothers and fathers use different strategies and types of talk when engaging in science activities with their children (Leaper et al., 1998; Leech et al., 2023; Short-Meyerson et al., 2016; Tenenbaum & Leaper, 2003), while other research has shown that parents may explain science topics differently based on the gender of their child (Crowley et al., 2001a). Given these mixed findings, research should continue to explore parent and child gender when investigating how families discuss science misconceptions together. Parents' attitudes toward science may also relate to their conversations about science misconceptions with their children. Research by Szechter and Carey (2009) found that when parents had more positive attitudes towards science and scientists, as measured by a questionnaire, they were more likely to visit a greater number of museum exhibits with their children compared to parents who had less positive attitudes. Finally, parents' view of failure might relate to their approach to science misconceptions. Whether parents view failure as debilitating or enhancing has been shown to predict parent practices that subsequently influence children's growth mindset (Haimovitz & Dweck, 2016). Thus, it is important to consider individual differences when investigating the ways that parents and children experience science together in their everyday lives.

Taken together, the reviewed literature has shown that parents are aware of some of the misconceptions their children hold (Nguyen & Rosengren, 2004). Additional research has also shown that parents and children commonly engage in conversations about science (Callanan et al., 2019; Chouinard et al., 2007; Luce &

Callanan, 2020). While some of these conversations may inadvertently contain scientifically incorrect information (Luce & Callanan, 2020), less is known about how parents navigate conversations when they are aware of the incorrect information. Further, although research has shown that children and parents frequently engage in conversations about science, research has not yet investigated whether parents hold views about misconceptions that are more aligned with conceptual change or sense-making approaches. In the current study, parents who take a conceptual change approach to science are defined as those who correct children's misconceptions and focus on accuracy. Parents who take a sense-making approach are defined as those who encourage children's exploration of ideas. Another likely approach is one that subtly scaffolds or encourages children toward correct answers (Vygotsky, 1962; Wood & Middleton, 1975; Wood et al., 1976); this approach has aspects of both correcting and exploring.

The Current Study

This research aims to understand how parents view and navigate science misconceptions with their children. In order to evaluate this, I asked parents and children to talk about a set of scenarios that pictured a child with a thought bubble showing what they were thinking. Each thought bubble contained a statement of a common incorrect science belief. These misconception statements included statements about health and safety, as well as statements about general science information. After discussing ten such scenarios with their child, parents were asked to participate in a short interview, asking if they could remember any examples of misconceptions expressed by their own child and how they responded. They were also asked if any of the topics in the activity reminded them of previous conversations with their child. After completing the task, parents completed the Attitudes Towards Science survey from Szechter and Carey (2009), a measure of parents' Failure Mindset from Haimovitz and Dweck (2016), as well as a demographic form.

By investigating how parents respond to their children's misconceptions, we can better understand how children learn about science in their everyday lives. Although many parents would not consider themselves to be scientists, people of all ages constantly engage in reasoning and other practices that are considered scientific, such as asking questions, providing explanations, and engaging in argumentation from evidence. While there has been an abundance of research investigating whether parents and children talk about science in their everyday lives, less is known about how parents navigate conversations about scientifically incorrect ideas. My research aims to investigate several confirmatory and exploratory research questions about parents' approaches in these conversations. This study addresses the following questions (with predictions listed for the confirmatory questions):

In response to an interview question:

1a. Do more parents report focusing on correcting their children's misconceptions or on exploring their children's ideas?

1b. What variables predict parents' reported approach to misconceptions (e.g., child age, parents' attitude towards science or failure mindset, and parent or child gender)?

In holistic coding of the prompted conversation activity:

2a. Do parents primarily approach misconceptions by providing the correct answer, scaffolding, or exploring their children's ideas?

2b. Do parents' observed approaches to misconceptions vary with the type of topic (high-stakes vs low-stakes)? I predict that parents will be more likely to provide children with the correct answer when they are talking about "high stakes" topics that involve possible threats to personal health or safety, compared to "low stakes" topics that are less consequential to everyday life and involve general knowledge about science topics. I also predict that parents will be more likely to take an exploring approach for low-stakes topics than high-stakes topics.

2c. What variables predict parents' observed approaches to misconceptions (e.g., child age, parents' attitude towards science or failure mindset, and parent or child gender)? I predict that parents taking an approach that involves providing children with the correct answer will be predicted by: (1) older child age, and (2) parents' negative failure mindset.

2d. How do parents' reported approach to children's misconceptions relate to how they actually approached misconceptions with their children in the prompted conversation activity?

In utterance-based coding of the prompted conversation activity:

3a. How often do parents talk about accuracy when discussing misconceptions with their children?

3b. Do parents talk more about accuracy when discussing high-stakes topics than low-stakes topics? I predict that parents will talk more about accuracy when discussing high-stakes topics compared to low-stakes topics.

3c. What variables predict parents' talk about accuracy (e.g., child age, parents' attitude towards science or failure mindset, and parent or child gender)? I predict that parents will talk more about accuracy with older children than with younger children.

This research provides an initial portrait of how parents navigate misconceptions by asking them to reason together with their child about scientifically incorrect ideas. The findings from this study provide an important stepping stone to developing future research on families' everyday experiences with science misconceptions.

Method

Participants

A total of 107 parent-child dyads participated in this study at Children's Discovery Museum of San Jose in San Jose, California. Children in the sample ranged from 4 to 6 years old (by parent report, 55 girls, 52 boys, M = 63.09 months, SD = 10.41 months, Range: 48-83 months). Sixty-nine children participated with their mother; 38 children participated with their father. In an open-ended question asking how they would describe their families' ethnicity, 44 parents self-reported their family as Asian (or with a more specific description e.g., Korean, Indian, Chinese), 16 as White, 8 as Hispanic, 3 as Middle Eastern, 2 as Jewish, 2 as African American, 26 as of mixed ethnicity (e.g., Asian and White, Indian and Spanish), and 6 did not report their ethnicity. Seventy-three families reported speaking a language other than English at home (e.g., Korean, Urdu, Mandarin). Twenty-three families spoke a language other than English for the majority of the prompted conversation activity; while these families were excluded from analyses involving the conversation activity ($n = 84$), they were included in the interview data because all interviews were in English. Most parents identified their household income as greater than 120K ($n = 82$), and over half of parents identified themselves as having at least a master's degree ($n = 62$). A full breakdown of parents' self-identified schooling level and household income is shown in Table 1. Five families were excluded from the study for the following methodological inconsistencies: did not complete prompted conversation activity ($n = 3$), family did not meet the criteria ($n = 1$), and video camera malfunction ($n = 1$). Data collection took place between September and December of 2023. Each family received one voucher towards their next visit to the museum as a token of appreciation for their participation.

Materials

This study had three main components: (1) a prompted conversation activity for parent-child dyads, (2) a brief interview with parents, and (3) a questionnaire for parents. The entire study took place in the research room at Children's Discovery

Museum of San Jose. The prompted conversation activity and brief interview with parents were audio- and video-recorded on a camcorder and microphone. The stimuli for the prompted activity were presented to families on a laptop with a PowerPoint presentation. Each slide of the presentation consisted of a misconception in a thought bubble coming from an illustration of a child with the words "What do you think?" underneath.

The ten misconceptions presented to families were categorized into two groups. Half of the misconceptions were labeled as high-stakes and pertained to health and safety. The other five were low-stakes and pertained to general science topics like biology and earth sciences. To avoid asking parents and children to talk only about scientifically incorrect ideas, two of the topics in each category were likely to be perceived to be incorrect by children but were scientifically supported. For example, one scientifically supported statement that children were likely to disagree with was "I think trees are still alive when they lose their leaves." All ten misconception statements that were presented in the prompted conversation activity can be found in Table 2. The order of statements was counterbalanced in two random orders. Before beginning data collection, a total of 25 misconception statements were piloted and pretested with a sample of parents (N = 30) and a sample of children (N = 50). The final set of ten items was chosen to ensure that I included misconceptions that parents generally answered correctly and that children generally answered incorrectly. Table 3 shows the accuracy of parents and children for the final set of ten items. The list of all piloted misconception statements can be found in Appendix A.

Measures

The parent questionnaires included were an Attitudes Towards Science Questionnaire by Szechter and Carey (2009), a measure of parents' Failure Mindset from Haimovitz and Dweck (2016), and a demographics questionnaire (see Appendix B).

Attitudes Towards Science

Parents completed the Attitudes Towards Science questionnaire, created and validated by Szechter and Carey (2009). This measure is composed of 15 items with three subscales: *Personal Interest in Science* (5 items; e.g., "Science is fun when compared to other school subjects"), *Views of Science and Scientists* (6 items; e.g., "Scientists are among the smartest people"), and *Utility of Science* (4 items; e.g., "Thinking like a scientist is only useful when taking a test in science class"). Parents rated each item on a 7-point scale ranging from 1 (*mostly disagree*) to 7 (*mostly agree*). Items from each subscale were averaged into an aggregate measure of Attitude Towards Science (M = 5.45, SD = 0.68).

Failure Mindset

Parents completed the Failure Mindset Questionnaire, created and validated by Haimovitz and Dweck (2016). This measure is comprised of 6 items (e.g., "Experiencing failure enhances performance and productivity"); parents rated each item on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). Items that represent a more debilitating view of failure were reversed-scored. Scores for all 6 items were averaged (M = 4.99, SD = 0.76). A higher number indicates that a parent has a more positive failure mindset, i.e., sees failure as part of the learning process.

Procedure

Researchers recruited families from the floor of Children's Discovery Museum of San Jose during regular operating hours on weekends. The research team set up a table outside of the research room with drawing materials to entertain children while a researcher provided parents with information about the study and responded to questions. When parents were interested, researchers provided them with an informed consent form to read and sign, and then invited them into the research room. If the research room was occupied, researchers offered to text parents to return to the research room when researchers were ready for the next participant.

Once in the research room, the main researcher introduced themself to both the parent and child. The researcher explained to the parent and child that they would be doing an activity together and invited them to take a seat at a table with a laptop. The researcher instructed parents and children to read each statement on the slide aloud and talk about their ideas together as if the topic were to come up in their everyday lives. Dyads were informed that they could work through the topics at their own pace and take as long or as short as felt natural and comfortable to them. The researcher then left the room while the dyads completed this activity.

Once the dyad completed the task, one researcher occupied children with an activity making paper airplanes while the main researcher asked the parent two questions. The first set of questions asked parents, "Can you recall any examples of a time when your child said something that wasn't scientifically accurate? How did you respond? Why did you respond the way you did?" They were then asked, "Did any of the statements from the activity remind you of previous conversations with your child?" After the brief interview, parents were asked to complete the Attitudes Towards Science Questionnaire, the measure of parents' Failure Mindset, and the demographics questionnaire on the laptop computer. Once the questionnaire portion of the study was complete, parents and children were thanked for their participation, given a museum voucher as compensation, and invited to return to the museum.

Coding

Three coding schemes were developed in order to address the research questions. Parents' responses to the interview question asking about how they respond to their children's misconceptions were coded. The parent-child discussions during the prompted conversation activity were coded in two ways: parents' holistic approach (at the topic level), and parents' use of particular categories of talk (at the utterance level). Interrater reliability was calculated separately for each coding scheme by having two coders code 20-25% of the videos. Following McHugh (2012), we used a cutoff kappa value of .60, which is defined as moderate agreement. Disagreements in the reliability sets were resolved by the two coders before they went on to each code part of the remaining data. Reliable coders checked in again after completing coding to resolve especially difficult coding decisions. Coder agreements for each coding scheme are reported separately in the following sections.

Parents' Reported Approaches to Children's Misconceptions

We coded parent responses to the interview questions about how they respond to their children's misconceptions: "Can you recall any examples of a time when your child said something that wasn't scientifically accurate? How did you respond? Why did you respond the way you did?" Parents' responses were coded into one of five different approaches to their children's misconceptions; we began with the first and third categories based on the goal of capturing conceptual change versus sense-making approaches to misconceptions; the other categories emerged from the data. Interrater reliability for the full coding scheme was 81% (Cohen's $\kappa = .70$).

The first type of response mentioned *correcting* misconceptions by providing their child with scientific explanations or seeking out additional educational/outside resources (e.g., books, movies). These parents emphasized the importance of their child knowing the correct answer. Other parents mentioned that they prefer to take a *scaffolding* approach and reported guiding their child toward the correct idea, or asking "why" questions to support their child in making their own connections. These parents emphasized the importance of their child coming to their own conclusion and eventually knowing the correct answer, but accuracy was not necessarily a priority for these parents in the moment. Some parents mentioned an *exploring* approach and reported asking their child "why" questions to explore their ideas and mentioned they did not have the goal of getting their children to the right answer. These parents emphasized the importance of their child staying curious or imaginative. Other parents reported that their approach to misconceptions *depends on the topic*. These parents emphasized that some scientifically incorrect beliefs need to be corrected, while others can be left open-ended and uncorrected. Finally, some parents mentioned that their approach to misconceptions *depends on the context* and reported that their responses to their child's scientifically incorrect beliefs depend on outside factors such as their own knowledge about a particular topic, their child's mood, or the time and place of the conversation.

Parents' Holistic Approach to Discussing Misconceptions During Conversation Activity

This coding scheme was designed to characterize the holistic approach to discussing misconceptions that parents used for each individual topic in the prompted conversation activity. The coding scheme was developed by watching videos and taking notes on the behaviors and interaction patterns of dyads while they discussed each topic. The main codes were: (A) *providing the correct answer,* (B) *scaffolding,* (C) *mixed approach (scaffolding with correct answer),* and (D) *exploring*. It is worth noting that the providing the correct answer, scaffolding, and exploring codes mirror parents' reported approaches from the interview; a mixed approach, combining aspects of correcting and scaffolding, emerged in cases where parents used scaffolding techniques but also provided the "correct" answer, often at the end of the conversation. The full coding scheme researchers used can be found in Table 4. Researchers assigned families the best-fitting code for each individual topic in the prompted conversation activity. Interrater reliability for the full coding scheme was 74% ($\kappa = .63$). In a final coding check, the final 10% of videos were coded by both research assistants to calculate how reliable the coding was at the end of the coding process. The interrater reliability for the additional 10% of videos was 82% (Cohen's $\kappa = .71$).

Parents' Accuracy Talk During the Conversation Activity

All talk from the participating parent and child was transcribed and parsed into individual utterances to examine whether parents talked about accuracy more with the high- or low-stakes topics. Parents' utterances during the prompted conversation activity were coded if they were directed at the participating child. The main talk category of interest was *accuracy* which either affirmed or questioned the accuracy of the prompt or children's responses. Other categories such as *information talk* (statements or questions that provide information to the child or request information from the child), *personal connections* (statements or questions about familiar experiences), *seeking external information* (mentioning ways to obtain additional information about a topic or conduct their own experiment), and *expressing uncertainty* (admitting when they are unsure of the scientific explanation for a topic) were also coded. Interrater reliability for the full coding scheme was 79% (Cohen's $\kappa = .75$). The full coding scheme can be found in the Appendix C.

Statement of Ethics

The present research was conducted in accordance with the ethical standards of the American Psychological Association. The human subjects study protocol was approved by the Institutional Review Board at University of California Santa Cruz (HS#299). Written consent for participating in the study was obtained from the parent and verbal assent was obtained from the child for each dyad prior to the study.

Results

The results are organized into three main sections that correspond with each set of research questions. The first set of research questions explores how parents responded to the interview question about how they discuss misconceptions with their child. The next set of research questions investigates parents' holistic approach to discussing misconceptions in the context of each topic in the prompted conversation activity, and then connects what parents reported in the interview to what was observed in the activity. The final set of research questions explores the specific talk that occurred during the activity and specifically parents' focus on accuracy in their discussions of the high- and low-stakes topics.

Parents' Reported Approach to Children's Misconceptions

Do More Parents Report Focusing on Correcting Their Children's Misconceptions or on Exploring Their Children's Ideas? (Research Question 1a)

Parents were asked how they responded to their children's scientifically incorrect misconceptions and why they responded the way they did. Forty-four percent of parents (*n* = 47) reported correcting their children when they expressed a scientifically incorrect belief. Twenty-three percent of parents (*n* = 25) expressed that they scaffold their child's understanding of the topic, but do not correct them. Only 8% of parents (*n* = 9) said they explore their children's ideas without correcting them, with a goal of helping them stay curious and imaginative. Other parents reported that their response to misconceptions varies depending on the topic (12%; *n* = 13) or the context in which the misconception has arisen (8%; $n = 8$). Parents that reported that their approach to misconceptions depends on the topic or the context were excluded from further analyses.

What Variables Predict Parents' Reported Approach to Misconceptions (E.g., Child Age, Parents' Attitude Towards Science or Failure Mindset, and Parent or Child Gender)? (Research Question 1b)

To investigate whether parents' reported approaches to misconceptions were predicted by child age, parents' attitude towards science or failure mindset, and parent or child gender, I performed two multinomial logistic regressions. These analyses exclude the two categories of parents who said their approach to misconceptions depends on either the topic or context. First, we analyzed the likelihood of parents reporting they take a correcting and scaffolding approach compared to an exploring approach as the dependent measure, predicted by the child's age, parent's attitude towards science and failure mindset, and parent and child gender. The overall model was statistically significant, indicating the ability to distinguish the likelihood of parents reporting different approaches to children's misconceptions by the predictor variables; χ^2 (10, $N = 81$) = 22.09, *Nagelkerke* $R^2 = 0.283$, $p = .015$. When comparing parents coded as taking a scaffolding approach versus an exploring approach, parents' scores on the failure mindset questionnaire were the only significant predictor. Higher positive views of failure mindset predicted a greater likelihood of parents reporting a scaffolding compared to an exploring approach ($B = 2.44$, $p < .004$, OR = 11.50, 95% *CI* [2.15, 61.44]. Child age, parents' attitudes toward science, parent gender, and child gender were not significant factors in distinguishing parents as correcting and scaffolding in comparison to exploring (see Table 5).

Next, we analyzed the likelihood of parents reporting they take a scaffolding and exploring approach compared to a correcting approach as the dependent measure, predicted by the child's age, parent's attitude towards science and failure mindset, and parent and child gender. The overall model was statistically significant, indicating the ability to distinguish the likelihood of parents reporting different approaches to children's misconceptions by the predictor variables; χ^2 (10, *N* = 81) = 22.09, *Nagelkerke* R^2 = 0.283, *p* = .015. When comparing parents coded as taking a scaffolding approach versus a correcting approach, parents' scores on the failure mindset questionnaire were the only significant predictor. Higher positive views of failure mindset predicted a greater likelihood of parents reporting a scaffolding compared to a correcting approach (*B* = 1.40, *p* = .004, OR = 4.07, 95% *CI* [1.57, 10.55]. Child age, parents' attitudes toward science, parent gender, and child gender were not significant factors in distinguishing parents as scaffolding and exploring in comparison to correcting (see Table 6). Taking the results from both of these analyses together, parents who viewed failure as a positive aspect of learning were more likely to report a scaffolding approach than either of the other approaches.

Parents' Observed Approaches to Discussing Misconceptions During the Prompted Conversation Activity

Do Parents Primarily Approach Misconceptions by Providing the Correct Answer, Scaffolding, or Exploring Their Children's Ideas? (Research Question 2a)

For each of the 10 topics, parents were coded as taking an approach that involved providing the correct answer, scaffolding, a mixed approach that used scaffolding but also explicitly provided the correct answer, or exploring their ideas. On average, parents provided their child with the correct answer on 3.37 (SD = 2.66) out of the 10 topics. A scaffolding approach was observed on 1.86 (SD = 1.95) of the topics. On average, a mixed approach that involved both scaffolding and providing the correct answer was observed on 3.51 (SD = 2.28) of the topics. An exploring approach was observed on only 0.25 (SD = 0.56) of the topics. The frequency of parent approaches in the prompted conversation activity did not vary based on the order of the topics in preliminary analyses, so order was excluded in the subsequent analyses (all ps > .05).

Do Parents' Observed Approaches to Misconceptions Vary with the Type of Topic (High-Stakes vs Low-Stakes)? (Research Question 2b)

One important component of this study is the prediction that parents' approaches would focus on correcting their children more often on high-stakes than on low-stakes topics in the prompted conversation activity. A 2 (Stakes: High vs. Low) x 4 (Approach: Providing the Correct Answer, Scaffolding, Mixed Scaffolding/Correct Answer, Exploring) repeated measures ANOVA was conducted with child age in years as a between-subjects variable to explore the patterns in how parents responded to the high-stakes and low-stakes topics in conversations with their 4-, 5-, and 6-year-old children. The sphericity assumption was violated and the Greenhouse-Geisser correction was used. A main effect of parent approach was found, $F(1.99, 161.20) = 35.54$, $p < .001$, $\eta^2_p = 0.31$, whereby parents used the approaches of providing the correct answer ($M = 1.67$, $SE = 0.15$) and the mixed approach ($M = 1.75$, $SE = 0.13$) significantly more often than the scaffolding approach ($M = 0.95$, $SE = 0.11$), *p*s < .05. The exploring approach ($M = 0.13$, $SE = 0.03$) occurred significantly less frequently than all other approaches (*p*s < .001). Parents' holistic approaches to misconceptions did not vary by children's age.

To test the prediction that parents' approaches would vary by type of topic, we must consider the main effect of parents' observed approaches to misconceptions in light of a significant Stakes x Approach interaction, $F(2.19, 177.64) = 5.03$, $p = .006$, $\eta^2_p = 0.06$ (see Figure 1). I predicted that parents would be more likely to provide children with the correct answer when they are talking about high-stakes topics that involve possible threats to personal health or safety, compared to low-stakes topics that are less consequential to everyday life and involve general knowledge about science topics. I also predicted that parents would be more likely to take an exploring approach for low-stakes topics than high-stakes topics. These hypotheses were confirmed. Follow-up pairwise comparisons revealed that parents were observed providing the correct answer for high-stakes topics ($M = 1.87$, $SE = 0.18$) significantly more frequently than low-stakes topics ($M = 1.47$, $SE = 0.15$), $p = .007$.

Parents took an exploring approach more frequently for low-stakes topics (*M* = 0.19, *SE* = 0.05) than high-stakes topics (*M* = 0.07, *SE* = 0.04), *p* = .049. There were no clear predictions about how parents might vary in the amount of scaffolding or mixed approaches for high- and low-stakes topics. Parents took the mixed approach significantly more frequently for low-stakes topics (*M* = 1.92, *SE* = 0.15) than high-stakes topics (*M* = 1.58, *SE* = 0.14), *p* = .022. Parents did not differ in their frequency of scaffolding for high-stakes topics (*M* = 1.02, *SE* = 0.14) or low-stakes topics (*M* = 0.87, *SE* = 0.11), *p* = .277. These reported *p*-values for the pairwise comparisons use a Bonferroni correction for multiple comparisons.

What Variables Predict Parents' Observed Approaches to Misconceptions (E.g., Child Age, Parents' Attitude Towards Science or Failure Mindset, and Parent or Child Gender)? (Research Question 2c)

The next set of analyses aimed to explore if the frequency of parents taking each of the observed approaches (providing the correct answer, scaffolding, mixed approach, and exploring) could be predicted by children's age, parents' attitude towards science, parents' failure mindset, parent gender, or child gender. First, we investigated if any factors predicted the observed frequency of parents taking an approach that provided the correct answer. The model was not significant. Table 7 shows the results of this regression analysis. I predicted that parents taking an approach that involves providing children with the correct answer would be predicted by: (1) older child age, and (2) parents' negative failure mindset. These hypotheses were not supported.

Next, we explored if any factors predicted the observed frequency of parents taking a scaffolding approach. This model was significant. Mothers were observed using a scaffolding approach more often than fathers. Child age, parents' attitude towards science, parents' failure mindset, or child gender were not related to the frequency of observing this approach. Table 8 shows the results of this regression analysis.

Then, we explored if any factors predicted the observed frequency of parents taking a mixed approach. This model was significant. Parents who had a more positive mindset about failure used a higher frequency of the mixed approach. Fathers were observed using the mixed approach more than mothers. To ensure the parent gender finding was not accounted for by a failure mindset difference, an independent samples *t*-test revealed fathers and mothers did not significantly differ in their scores on the failure mindset questionnaire, $t(70.68) = 1.05$, $p = .297$. Child age, parents' attitude towards science, and child gender were not related to the frequency of observing this approach. Table 9 shows the results of this regression analysis.

Finally, we explored if any factors predicted the observed frequency of parents taking an exploring approach. This model was not significant. Table 10 shows the results of this regression analysis.

How do Parents' Reported Approach to Children's Misconceptions Relate to How They Actually Approached Misconceptions with Their Children in the Prompted Conversation Activity? (Research Question 2d)

This analysis aimed to explore whether parents' reported approach to navigating misconceptions from the parent interview related to how frequently parents engaged in the different approaches in the prompted conversation activity. Table 11 shows how parents who reported different approaches differed in the distribution of their use of the observed approaches. Of the 84 families for whom data were available for both the interview and the conversation activity, 37 parents reported a correcting approach, 19 reported a scaffolding approach, and 6 reported an exploring approach in the interview. Parents who reported that their approach to misconceptions depends on the topic or context were not included in this analysis. Because there were few parents who reported an exploring approach in the interview, all of these data were analyzed nonparametrically using a series of Kruskal-Wallis tests. The significance levels for pairwise comparisons using Dunn's test report *p*-values with Bonferroni corrections.

Parents who reported correcting, scaffolding, and exploring approaches in the interview displayed significantly different patterns of approaches (providing the correct answer, scaffolding, and mixed approaches) in the prompted conversation activity, $ps < .05$. Parents' observed use of providing the correct answer varied by reported approach. Parents who reported a correcting approach in the interview actually provided the correct answer on marginally more topics than parents who reported a scaffolding approach in the interview, $p = .058$. Next, we considered the use of scaffolding in the activity; parents who reported an exploring approach were observed using scaffolding for significantly more topics than parents who reported a correcting approach, $p = .046$. Moving to the use of a mixed approach, parents who reported a scaffolding approach were observed using the mixed approach for significantly more topics than parents who reported a correcting approach, $p = .006$. Parents with different reported approaches did not vary in the observed frequency of exploring approaches in the prompted conversation activity (see Table 11).

Parents' Talk During the Prompted Conversation Activity

How Often do Parents Talk about Accuracy when Discussing Misconceptions with Their Children? (Research Question 3a)

The next set of analyses explored how parents talked to their children (at the utterance level) during the prompted conversation activity. On average, parents' conversations included 5.36 accuracy utterances, and this accuracy talk constituted 5% of the total talk. The most frequent type of utterance in the prompted conversation activity was information talk which, on average, occurred 41.24 times, or 35% of the total talk. Personal Connections utterances occurred an average of 4.27 times, or 3% of the total talk. Parents discussing Seeking External Information or Expressing Uncertainty occurred less than 1 time per discussion. The mean frequency and percentage of all talk categories can be found in Table 12. In preliminary analyses, the frequency and proportion of parents' talk in the prompted conversation activity did not vary based on the order of the topics, so order is excluded in the following analyses (all *p*s > .05).

Do Parents Talk More about Accuracy when Discussing High-Stakes Topics than Low-Stakes Topics? (Research Question 3b)

We next investigated if parents talked more about accuracy with high- or low-stakes topics. A 2 (Stakes: High vs. Low) x 3 (Age in years: 4-, 5-, and 6-year-olds) ANOVA was conducted to examine the patterns in parents' accuracy talk for high-stakes and low-stakes topics with the frequency of parents' accuracy talk (combined statements and questions) as the dependent variable. We did not find a significant difference in the frequency of parents' accuracy talk for high-stakes or low-stakes topics, $F(1, 81) = 1.67$, $p = .200$, $\eta^2_p = 0.02$. The frequency of accuracy talk for high-stakes and low-stakes topics also did not vary based on the child age group, $F(2, 81) = 0.99$, $p = .377$, $\eta^2_p = 0.02$.

We then checked to see if the same pattern would unfold for the proportion of accuracy talk. We did not find a significant difference in the proportion of parents' accuracy talk for high-stakes versus low-stakes topics $F(1, 81) = 0.05$, $p = .830$, $\eta^2_p = 0.001$. The proportion of accuracy talk for high-stakes and low-stakes topics also did not vary based on the child age group, $F(2, 81) = 1.44$, $p = .243$, $\eta^2_p = 0.03$. Estimated marginal means and standard errors for frequency and proportion of parent accuracy talk can be found in Table 13. The prediction that parents would talk more about accuracy when discussing high-stakes topics compared to low-stakes topics was not supported.

What Variables Predict Parents' Talk about Accuracy (E.g., Child Age, Parents' Attitude Towards Science or Failure Mindset, and Parent or Child Gender)? (Research Question 3c)

The next analysis aimed to examine if children's age, parents' attitude towards science and failure mindset, and parent and child gender predicted parents' frequency of accuracy utterances. Table 14 shows the results of the regression analysis with the frequency of talk. The prediction that parents would talk more about accuracy with older children than younger children was not supported. In the prompted conversation activity, fathers discussed accuracy more frequently than mothers. To ensure this difference in accuracy talk was a function of parent gender, an independent samples *t*-test revealed that fathers spoke more than mothers in the activity, $t(82) = 3.19$, $p < .001$. Thus, we repeated the regression with the proportion of parents' accuracy talk. In this analysis, the overall model was not significant (see Table 15). Children's age, parents' attitude towards science, parents' failure mindset, parent gender, or child gender did not relate to parents having a higher proportion of accuracy talk during the prompted conversation activity.

Discussion

This study explored how parents and children discuss factually incorrect science ideas. Parents and children completed a prompted conversation activity in which they discussed 10 different science misconceptions. Parents then reported how they usually respond to their children's science misconceptions and why they respond that way. Although numerous studies have investigated how parents and children discuss science in everyday conversations, no known studies to date have explicitly looked at how families discuss misconceptions comparing health and safety versus general science topics. I first discuss parents' views and approaches to misconceptions as they relate to the theoretical distinction between conceptual change and sense-making frameworks for understanding children's learning. Next, I summarize which factors predicted parents' views and approaches to their children's misconceptions. Then, I discuss how parent-child conversations about science misconceptions may relate to children's scientific thinking. Finally, I address the current challenges and future directions for my research.

How do Parents View and Approach Science Misconceptions?

Parents most often reported approaches to their children's misconceptions that aligned with the conceptual change perspective, mentioning that they wanted their children to have an accurate scientific understanding. This approach is reflected in previous research that has shown that parents often take on a teacher-like role and ask known-answer questions when interacting with their children about science (Yu et al., 2019). In the prompted conversation activity, parents most often provided their children with correct answers, with or without guiding their children to the correct answer. This aligns with previous research that has found that parents often assumed the role of "explainer" when they played with their children at a museum exhibit (Crowley et al., 2001b).

While parents' overall self-reported approach was consistent with a conceptual change approach, another key element of the current study was to investigate how parents actually talk with their children about misconceptions, and whether parents' reported approaches to their children's misconceptions from the interview aligned with how they approached misconceptions in the prompted conversation activity. One way parents endorsed a conceptual change approach in the interview was by reporting that they provide explanations when their children express their scientifically incorrect ideas. These parents were generally consistent in the interview and the activity, engaging in more instances of providing their children with the correct answer in the prompted conversation activity than parents who reported a scaffolding approach.

Another way parents took a conceptual change approach is when they reported that they scaffold their children's understanding by asking questions (Vygotsky, 1962; Wood & Middleton, 1975; Wood et al., 1976). These parents expressed that they want their child to have the correct scientific understanding, but that they prefer not to correct their child, rather to have their child come to the scientific understanding on their own. In the prompted conversation activity, however, the parents who reported this scaffolding approach actually tended to use a mixed approach that incorporated scaffolding with providing the correct answer; they used this mixed approach more often than parents who reported a correcting approach in the parent interview.

The families that reflected a conceptual change approach were in stark contrast to parents who reported that they prioritize exploring their children's ideas with curiosity. This approach is more aligned with a sense-making approach that focuses on how children reason about their ideas. These parents reported that they were not concerned about their child having the scientifically correct understanding and generally wanted their children to stay imaginative about the world. Parents who reported an exploring approach in the interview more frequently engaged in a scaffolding approach in the activity. These parents were consistent in that they did not frequently provide their child with the correct answer in the activity. However, their scaffolding conversations suggested more attention to correct answers than one might have expected from their interview response. Families very infrequently engaged in open-ended exploration of their children's ideas in the prompted conversation activity and there were no differences in the observed frequency of this approach from parents who reported a correcting, scaffolding, or exploring approach in the interview.

In general, there was some alignment between what parents reported and how they actually responded to misconceptions in the prompted conversation activity. Next it was important to investigate what other factors predicted parents' reported and observed approaches to misconceptions.

What Factors Impact How Parents View or Approach Science Misconceptions?

To better understand parents' approaches, we examined whether factors such as child age, parents' attitude towards science, parents' failure mindset, the gender of the parent or child, or the "stakes" of the topic impacted the reported or observed approaches to misconceptions. One factor that significantly impacted how parents actually approached conversations about misconceptions with their children was whether the topic was high- or low-stakes. As predicted, parents took an approach that provided their children with the correct answer more often for high-stakes topics than low-stakes topics. In contrast, parents took the mixed approach, involving scaffolding and providing the correct answer, more often for low-stakes than for the high-stakes topics. This suggests that parents felt it was more important to explicitly focus on the correct answer for topics that pertain to their children's health and safety, and were more likely to guide their children to the correct answer or focus on their curiosity for general science topics that are less consequential to their everyday life. Given the observed differences in parents' approaches for high- and low-stakes topics, it is interesting that only 12% of parents mentioned that their approach to correcting their children's science misconceptions varied based on the topic of the misconception. Some of these parents spontaneously mentioned that they felt it was more important to correct misconceptions that impact their children's safety than science topics they will learn later in school. The data suggest that parents are often adjusting their approaches to misconceptions although they infrequently report doing so. Future research should be mindful of this variation in how parents approach misconceptions when designing studies about science misconceptions. This difference in approaches for high- and low-stakes topics might relate to how parents view the purpose of learning and what skills and information are most important for children to learn (Rogoff et al., 2003).

Parents' mindset about failure was also significantly related to the ways parents reported and were observed engaging with their children about misconceptions. Previous research has found that parents' positive mindset about failure predicted children's growth mindset about intelligence (Haimovitz & Dweck, 2017). In the current study, parents were more likely to report themselves as taking a scaffolding approach to their children's misconceptions if they had a more positive mindset about failure than they were to report a correcting or exploring approach in the parent interview. In the prompted conversation activity, parents who had a more positive mindset about failure were also more likely to be observed using a mixed approach where they both scaffolded their children and provided them with the correct answer. This demonstrates that parents' mindset about failure and the possibility to learn from mistakes may relate to how families interact about misconceptions.

Previous research has found that both parent and child gender may impact family interactions about science (Crowley et al., 2001a; Leaper et al., 1998; Leech et al., 2023; Shirefley & Leaper, 2022; Short-Meyerson et al., 2016; Tenenbaum & Leaper, 2003). In the current study, we found that parents did not differ by gender in their reported approaches to misconceptions in the parent interview; however, in the prompted conversation activity we found that mothers engaged in a scaffolding approach, where they did not provide their child with the correct answer, more frequently than did fathers. On the other hand, fathers engaged in a mixed approach, that involved scaffolding their child as well as providing them with the correct answer, more frequently than mothers. This finding aligns with previous research that found that mothers and fathers had different strategies when problem-solving about science with their children (Short-Meyerson et al., 2016). Additionally, we found that fathers talked more about accuracy, and talked more in general, than did mothers in the prompted conversation activity. This is in contrast with previous research that found that mothers talk more with their children than fathers (Leaper & Anderson, 1998). When we examined the proportion of talk, we found that fathers and mothers did not differ in the proportion of accuracy talk during the prompted conversation activity. Interestingly, we also did not find any differences in how parents talked to their sons compared with daughters. While some research has found that parents have explained more to their sons than their daughters at children's museum exhibits (Crowley et al., 2001a), other research examining the context of book-reading has found that parents used more science talk with their daughters than their sons (Shirefley & Leaper, 2022). The current findings add to this complex body of evidence that parents' gender may relate to talk about science but not in simple ways.

Surprisingly, parents' attitudes towards science did not predict parents' observed or reported approaches to children's misconceptions. Previous research has shown that parents' attitude towards science was associated with families visiting more museum exhibits (Szechter & Carey, 2009). Other work investigating parents' attitude towards science found a positive association with children's science achievement (Perera, 2014). Given that parents' attitudes and beliefs can impact children's experiences, it is interesting that we did not find a relation between parents' attitude toward science and their reported or observed approaches to misconceptions.

Additionally, child age did not relate to parents' reported or observed approaches to misconceptions. Previous research has found that parents report their older children as having fewer misconceptions than their younger children (Nguyen & Rosengren, 2004). One might expect that given this view, parents might interact differently with their children, however, we did not find this to be true. In the current study, the age of the child did not relate to how parents reported addressing misconceptions in the interview or how they actually approached misconceptions in the prompted activity task.

Connecting Parent Approaches about Misconceptions to Children's Ideas about Science

Researchers have argued that science involves both content knowledge and thinking skills (Weisberg & Sobel, 2022). The Next Generation Science Standards highlight the idea that science instruction should emphasize practices instead of viewing science as a series of facts (Lehrer & Schauble, 2015; NGSS Lead States, 2013). Previous work has documented that three of the many ways parents define science is as hypothesis-testing, making inferences from observations, and knowing explanations for everyday phenomena (Setioko & Ding, 2023). By frequently providing their children with correct answers when scientifically incorrect ideas are expressed, parents may subtly be conveying that science is indeed a set of facts.

Parents may also be influencing their children's scientific thinking when they approach misconceptions by exploring their ideas with curiosity. Previous research has suggested that curiosity and wonder can support scientific thinking (Jirout, 2020).

Parents who take an exploratory approach to scientifically incorrect ideas might positively impact their children's curiosity and sense of wonder about the world. When children experience this approach to science it may impact their interest in science. Previous research found that students' curiosity related to their interest in science (Luce & Hsi, 2015). Because parents and children frequently engage in conversations about science, investigating how parents view science and approach misconceptions may be very important in understanding the development of children's curiosity and subsequent scientific thinking.

Scientific thinking is also suggested to involve reflection (Wardekker, 1998; Weisberg & Sobel, 2022) and is thought to be a sociocultural process that occurs when individuals are in dialogue with one another (Nelissen & Tomic, 1996; Vygotsky, 1962; Zimmerman & Klahr, 2018). Research on science educators has found that they often attempt to scaffold students' thinking with the goal of developing learners' skills (Lin et al., 2012). In the prompted conversation activity, some parents were prompting children's reflection by engaging in scaffolding. This scaffolding approach might prompt children to reflect, therefore supporting their scientific thinking.

Challenges and Future Directions

It is important to acknowledge that this study has several limitations that can be addressed in future research. Future research should consider how families from different backgrounds have conversations about science and misconceptions. One strength of the current study is that families came from a variety of different ethnic backgrounds, which are generally underrepresented in research; however, it is important to note that many parents reported a high level of education and income. Given the demographic background of the families in the current study, it is important to avoid over-generalizing the findings. Previous research has found that parents with different levels of schooling had different approaches when problem-solving about science with their children (Solis & Callanan, 2016). In particular, the focus on correcting and scaffolding in the current findings may be a feature of this highly educated sample. In future research I am interested in exploring how families of different backgrounds approach conversations about science misconceptions.

The current investigation centers on the ways that parents view and approach conversations about misconceptions, but future work could develop additional ways of investigating the conversational dynamics that unfold in the prompted conversation activity. Instead of looking only at parent talk, one could develop coding schemes to consider (1) how children respond when parents used the different approaches captured in this study, and/or (2) which science practices children engaged in, such as providing explanations or asking questions. This could allow future investigations that more explicitly connect parents' approaches to science misconceptions with the development of children's scientific thinking.

An alternative study design may also impact how families talk about science misconceptions. While this study did involve topics that are likely to arise in family conversation, it may have felt unnatural for families to discuss a set of 10 misconceptions that are relatively decontextualized and in a random order. Previous research has shown that families often have meaningful conversations about science through stories and storytelling (Haden et al., 2023). Future research can investigate how families discuss misconceptions with methodologies that are more relevant to families' everyday experiences. One way to do this would be to have families read a story about someone who has several scientifically incorrect ideas. This might be more engaging for families and might lead to deeper conversations where children and parents can get to know a particular character and understand their beliefs and perspectives.

Another way to naturally capture parent reflections about misconception conversations with their children would be through the use of a diary study (e.g., Callanan & Oakes, 1992). This would allow parents to reflect on what misconceptions generally arise in a two-week time span of everyday life instead of in an interview question with a researcher. Additionally, a diary component could be added to a prompted conversation activity study design or a book reading study. This would allow researchers to continue investigating if there is an alignment between the ways misconceptions are discussed in everyday life and how they are observed in research contexts.

Finally, future research should continue to consider how parents' mindset about failure relates to everyday science conversations and interactions. Researchers could also recode accuracy statements and questions, for example distinguishing parents' talk about accuracy that were used in a positive or negative context. Future work could investigate if parents' failure mindset relates to whether parents use more positive or negative accuracy talk when discussing misconceptions with their children. Using the failure mindset questionnaire is a good first step in investigating how parents' views of failure relate to how they interact with their children; however, in future work I am interested in interviewing parents more explicitly about the common narrative that "you learn from your mistakes." While this belief is commonly endorsed, it is unknown whether and how parents view science as a domain where this narrative is applicable. These differing views about the ability to learn from misconceptions may also relate to the messages parents convey about what is science and scientific thinking.

Conclusion

In summary, this study found that parents were more likely to endorse a conceptual change approach where children's misconceptions are thought to be addressed and corrected by hearing explanations. This reported approach to their children's science misconceptions was related to how parents actually interacted with their children about misconceptions. The current study also found differences in the ways parents approached conversations about health and safety misconceptions compared to general science topics, suggesting that research about children's science reasoning should take into account families' ideas about what topics are important for children to understand. Parents' mindset about failure was related to how they approached their children's misconceptions. Mothers and fathers also navigated conversations about misconceptions differently. Although there is still much work to be done in examining how parents perceive the science misconceptions that might arise in everyday life, this study provides an initial portrait of how families discuss science misconceptions. By being sensitive to the ways that parents navigate conversations about scientifically correct and incorrect ideas, researchers may begin to recognize how children learn and develop scientific thinking skills through culturally relevant and contextually embedded experiences.

Appendix A

Piloted Misconception Statements

1. I think you only need to brush your teeth when you eat sweets.
2. I think wind is caused by the earth spinning.
3. I think whales are big fish.
4. I think magnets stick to everything made of metal.
5. I think you can get a sunburn if it's cloudy outside.
6. I think the moon follows you around.
7. I think bears go to sleep for the entire winter.
8. I think heavy objects always sink in water.
9. I think humans are animals.
10. I think trees are still alive when they lose their leaves.
11. I think thunder is the sound of clouds crashing together.
12. I think the moon is only out at night.
13. I think the earth is flat.
14. I think food is only too hot to eat if you can see steam.
15. I think wood disappears after it burns in a fire.
16. I think it is important to sleep if you don't feel tired at bedtime.
17. I think the moon affects the ocean.
18. I think the earth moves around the sun.
19. I think all birds can fly.
20. I think fruits and vegetables have important vitamins that help our bodies.
21. I think all bacteria is bad for you.
22. I think every snake is dangerous.
23. I think you can still get sick from germs if you cover yourself in soap.
24. I think you can see germs with a microscope.
25. I think caterpillars and butterflies the same type of bug.

Appendix B

Parent Questionnaire

Attitudes Toward Science Questionnaire

Attitudes Toward Science (Szechter & Carey, 2009)

1	2	3	4	5	6	7
Mostly disagree	Somewhat disagree	Slightly disagree	Neither Agree nor Disagree	Slightly agree	Somewhat agree	Mostly agree

1. Scientists are among the most successful people.
2. Thinking like a scientist is only useful when taking a test in science class.*
3. Science is among the most useful school subjects.
4. There is no point to learning about science because everything we know will be wrong in 20 years.*
5. I would enjoy being a scientist.
6. Students who like science are the least popular.
7. Scientists are among the most honest people.
8. Science makes me feel like I am lost in a jumble of numbers and words. *
9. I enjoy visiting science museums.
10. Science is fun when compared to other school subjects.
11. If science shows that my belief is wrong, I consider changing my belief.
12. The world would be better off if people thought more like scientists.
13. Knowing science only means knowing facts and formulas.*
14. I can see myself becoming a scientist some day.
15. Scientists are among the smartest people.

Failure Mindset Questionnaire

Failure Mindset (Haimovitz & Dweck, 2016)

1	2	3	4	5	6
Strongly disagree	Somewhat disagree	Slightly disagree	Slightly agree	Somewhat agree	Strongly agree

1. Experiencing failure enhances performance and productivity.
2. Experiencing failure facilitates learning and growth.
3. The effects of failure are positive and should be utilized.
4. Experiencing failure debilitates performance and productivity.*
5. Experiencing failure inhibits learning and growth.*
6. The effects of failure are negative and should be avoided.*

Demographics Questionnaire

We hope that our research will include children from a wide variety of backgrounds. These questions are optional, but please answer all questions that you are comfortable answering. Your answers will be kept completely confidential.

Your child's gender: ______________________

Your child's age: ☐ 4 ☐ 5 ☐ 6 ☐ 7

Your gender: ______________________

Your age: ☐ Below 21 ☐ 21-35 ☐ 36-49 ☐ 50-65 ☐ Over 65

What is your household income:

☐ Below 30,000
☐ 31,000-50,000
☐ 51,000-70,000
☐ 71,000-90,000
☐ 91,000-120,000
☐ Over 120,000

What is the highest level of schooling you've completed? ______________________

If you attended college, what was your major? ________________________________

If you have an advanced degree, what field did you study? _____________________

What is your occupation? ___________________________

Would you consider your occupation related to STEM (Science, Technology, Engineering, Mathematics)? ___________________________

How would you describe your family's ethnicity? _____________________________

What language(s) does your family speak at home? ___________________________

How many children are in your family? ______________________

How old are your children? _____________________________________

Does the participating child attend school? ___________________________

What grade is your child in? ___________________________

How many hours a day/week do they attend? ___________________________

Appendix C

Parent Talk Coding Scheme

Talk Type & Form		Description	Example
Information	**Statement**	• Information about scenario statement concept • Example (or information about an example) that is in support/conflict with child's response or scenario statement • Definition to clarify a concept	• Even when birds have wings it doesn't mean they can fly. • Remember when you were leaving school last week and we saw the moon in the daytime. • Thunder is what we hear when there's lightning, right?
	Question	• Asking what child knows or general information about scenario statement concept • Asking child for or about an example that is in support/conflict with children's ideas or scenario statement	• What happens if you don't brush your teeth? • Can you think of any birds that don't fly?
Accuracy	**Statement**	• Identifying the accuracy of the child's response or scenario statement • Agreeing or disagreeing completely or partially • Most likely using "accuracy" words like right correct etc.	• That's not correct. • You're almost right. • I'm pretty sure that's right.
	Question	• Asking about the certainty of children's ideas or scenario statement • Questions usually have yes/no answers • Most likely using "accuracy" words like right correct etc.	• Are you sure? • Do you think that is right? • Do you agree?
Personal Connection	**Statement**	• Relating the scenario statement back to a previous experience or conversation	• We saw those birds at the zoo last week.
	Question	• Asking child to relate topic to a previous experience or conversation	• What's that biggest tree in our backyard?

Parent Talk Coding Scheme (continued)

Expressing Uncertainty	• Expressing uncertainty with parent's own or child's ideas	• I actually don't know what makes the sound of thunder.
Appreciating Child Thought Process	• Parent acknowledges and appreciates the child thought process • This does not include general praise for the child	• That's actually a good point. • Huh, I've never thought about it that way.
Seeking External Information	• Checking with an expert (human or Google) • Conducting own experiment	• Maybe we could look up more information about this later.
Definition Question	• Asking if child understands a word	• Do you know what bacteria is?
Rephrasing / Repeating Child	• Rephrasing or repeating what child said back to them • Does not add new information to the conversation	• So, you're saying germs can still get into your body from your nose? • Child says "Yeah" and then Parent says "Yeah"
Rephrasing / Repeating Prompt	• Reading the slide • Rephrasing or repeating the scenario statement • This can occur at any point in the conversation	• When you see steam coming out of food, only then is it too hot? • Is a tree dead if it doesn't have leaves?
On Task	• Talk that is on task but does not fit in the above categories (e.g., praise, talking about kid on the slide, talking about how many slides are left, etc.) • Asking child to repeat themselves • Ending the conversation about a topic and moves on to the next one	• Okay, mhm, alright • Good job! • Time for the next slide!
Off Task	• Talk that doesn't relate to the activity	• We can play in the ambulance when we're done. • Put down your snack for now.

Parent Talk Coding Scheme (continued)

No Code	• False starts, unintelligible, parent talking to researcher or other child, things like that. • Not a full thought.	• Do you thi- • We accidentally pressed the button too many times, can you help get it back?

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Table 1

Additional Participant Demographic Information

	N	Percent
Parental Schooling		
High School Graduate	2	1.9%
Some University	1	0.9%
Associate's Degree	1	0.9%
Bachelor's Degree	40	37.4%
Master's Degree	40	37.4%
Doctorate or Professional Degree	22	20.6%
Not Reported	1	0.9%
Household Income		
< 30K	5	4.7%
31-50K	2	1.9%
51-70K	1	0.9%
71-90K	3	2.8%
91-120K	12	11.2%
> 120K	82	76.6%
Not Reported	2	1.9%

Table 2

Set of Misconceptions for the Prompted Conversation Activity

High-Stakes Personal Health and Safety Misconceptions	Low-Stakes General Science Misconceptions
I think all bacteria is bad for you.	I think all birds can fly.
I think food is only too hot to eat if you can see steam.	I think the moon is only out at night.
I think you only need to brush your teeth when you eat sweets.	I think thunder is the sound of clouds crashing together.
I think it is important to sleep even if you don't feel tired at bedtime.*	I think humans are animals.*
I think you can still get sick from germs if you cover yourself in soap.*	I think trees are still alive when they lose their leaves.*

Note. The asterisk identifies items that were phrased in a scientifically accurate way, but that children were likely to disagree with.

Table 3

Accuracy Results from Piloting Final Set of Misconceptions

	High-Stakes Misconceptions % Correct	**Low-Stakes Misconceptions % Correct**
Children (*N* = 50)	37.2%	39.2%
Parents (*N* = 30)	87.9%	85.3%

Table 4

Coding Schemes for Parents' Holistic Approach to Discussing Misconceptions

Code	Description
Providing Correct Answer	• Parent provides child with a full or partial explanation of scenario statement • Parent provides child with a brief example or personal connection about the scenario statement • Parent provides child with a quick answer to the scenario statement
Scaffolding	• Parent begins by guiding child to their understanding of the correct idea, or asking questions to support their child and make their own connections • Parent may embed information in questioning • Scaffolding generally includes a logical progression towards factual understanding • Does not provide child with an explanation or quick answer
Mixed Scaffolding / Correct Answer	• Parent begins by guiding child to their understanding of the correct idea, or asking questions to support their child and make their own connections • Parent may embed information in questioning • Scaffolding generally includes a logical progression towards factual understanding • Parent provides child with correct answer at some point in the topic discussion
Exploring	• Parent asks their child questions or engages in conversation that explores the ideas without the goal of getting the child to the right answer • Conversation seems exploratory without a clear logical progression towards factual understanding
No Discussion	• Parent reads prompt, child answers, parent says a one-word answer or nothing and then they move on to the next topic
Skip	• Parent reads prompt, child does not answer, they move on to the next topic

Table 5

Multinomial Logistic Regression Predicting Reported Correcting and Scaffolding Approaches compared to an Exploring Approach

Predictor	**Exploring vs.**	***B***	***OR***	***p***
Child Age (in months)	Correcting	0.00	1.00	.925
	Scaffolding	-0.05	0.96	.262
Attitudes Toward Science	Correcting	-1.11	0.33	.138
	Scaffolding	-1.25	0.29	.127
Failure Mindset	Correcting	1.04	2.83	.180
	Scaffolding	**2.44**	**11.50**	**.004**
Parent Gender	Correcting	-0.81	0.44	.307
	Scaffolding	-0.69	0.50	.438
Child Gender	Correcting	0.68	1.98	.435
	Scaffolding	-0.05	0.95	.961

Note. Significant predictors are bolded.

Table 6

Multinomial Logistic Regression Predicting Reported Scaffolding and Exploring Approaches compared to a Correcting Approach

Predictor	Correcting vs.	*B*	*OR*	*p*
Child Age (in months)	Scaffolding	-0.04	0.958	.123
	Exploring	0.00	1.00	.925
Attitudes Toward Science	Scaffolding	-.014	0.87	.751
	Exploring	1.11	3.04	.138
Failure Mindset	**Scaffolding**	**1.40**	**4.07**	**.004**
	Exploring	-1.04	.035	.180
Parent Gender	Scaffolding	0.13	1.13	.827
	Exploring	0.81	2.26	.307
Child Gender	Scaffolding	-0.73	0.48	.207
	Exploring	-0.68	0.51	.435

Note. Significant predictors are bolded.

Table 7

Multiple Regression Predicting Observed Parent Approach – Providing Correct Answer

Predictor	***B***	***SE***	***β***	***t***	***p***
Child Age (in months)	-0.01	0.03	-.03	-0.29	.773
Attitude Towards Science	-0.51	0.55	-.13	-0.93	.353
Failure Mindset	0.08	0.49	.02	0.17	.865
Parent Gender	-0.23	0.64	-.11	-0.36	.719
Child Gender	-0.59	0.63	-.04	-0.93	.354
Model Statistics					
R^2	2.3%				
F	0.36				
p	.875				

Note. Significant predictors are bolded.

Table 8

Multiple Regression Predicting Observed Parent Approach – Scaffolding

Predictor	***B***	***SE***	***β***	***t***	***p***
Child Age (in months)	0.03	0.02	.14	1.32	.191
Attitude Towards Science	0.45	0.38	.15	1.19	.240
Failure Mindset	-0.41	0.34	-.16	-1.22	.224
Parent Gender	**1.01**	**0.44**	**.25**	**2.30**	**.024**
Child Gender	0.64	0.44	.16	1.47	.146
Model Statistics					
R^2	13.4%				
F	2.41				
p	.043				

Note. Significant predictors are bolded.

Table 9

Multiple Regression Predicting Observed Parent Approach – Mixed Scaffolding/Correct Answer Approach

Predictor	***B***	***SE***	***β***	***t***	***p***
Child Age (in months)	-0.02	0.02	-.10	-1.01	.315
Attitude Towards Science	-0.50	0.42	-.14	-1.19	.239
Failure Mindset	**0.95**	**0.37**	**.31**	**2.55**	**.013**
Parent Gender	**-1.93**	**0.49**	**-.41**	**-3.96**	**< .001**
Child Gender	0.32	0.48	.07	.66	.510
Model Statistics					
R^2	47.6%				
F	4.58				
p	.001				

Note. Significant predictors are bolded.

Table 10

Multiple Regression Predicting Observed Parent Approach – Exploring

Predictor	*B*	*SE*	*β*	*t*	*p*
Child Age (in months)	0.01	0.01	.13	1.18	.243
Attitude Towards Science	0.18	0.11	.21	1.62	.110
Failure Mindset	-0.10	0.10	-.14	-1.01	.317
Parent Gender	0.17	0.13	.15	1.30	.196
Child Gender	-0.02	0.13	-.02	-0.16	.870
Model Statistics					
R^2	5.6%				
F	0.925				
p	.469				

Note. Significant predictors are bolded.

Table 11

Descriptive Statistics for Observed Approaches across Reported Approaches to Misconceptions

	Correcting (N = 37)		Scaffolding (N = 19)		Exploring (N = 6)		Difference among reported approaches (Kruskal-Wallis Test)
Observed Approach	M	SD	M	SD	M	SD	
Providing Correct Answer	4.22_a	2.81	2.42_b	1.87	$2.33_{a,b}$	2.58	$H(2) = 6.71, p = .035$
Scaffolding	1.43_a	1.76	$1.74_{a,b}$	1.48	3.33_b	1.97	$H(2) = 6.13, p = .047$
Mixed Scaffolding/Correct Answer	2.95_a	2.05	4.74_b	1.88	$3.67_{a,b}$	1.51	$H(2) = 9.90, p = .009$
Exploring	0.16	0.44	0.32	0.58	0.00	0.00	$H(2) = 2.74, p = .254$

Note. Different subscripts indicate significant differences with Bonferroni adjusted alpha level.

Table 12

Descriptive Statistics for Parent Utterances during Prompted Conversation Activity

	Frequency		**Percent**	
	M	*SD*	*M*	*SD*
Information Talk	41.24	27.38	35%	9%
Accuracy	5.36	3.95	5%	4%
Personal Connections	4.27	4.93	5%	3%
Expressing Uncertainty	0.61	1.06	1%	1%
Appreciating Child's Thought Process	0.35	0.83	< 1%	1%
Seeking External Information	0.32	0.73	< 1%	1%
Definition Question	0.60	0.71	< 1%	1%
Repeating/Rephrasing the Child	17.44	10.86	15%	7%
Repeating/Rephrasing the Prompt	14.57	4.41	15%	6%
Miscellaneous On Topic	29.98	22.04	25%	10%

Table 13

Descriptive Statistics for High- and Low-Stakes Parent Accuracy Talk during Prompted Conversation Activity

	Frequency		**Percent**	
	M	*SE*	*M*	*SE*
High-Stakes Accuracy Utterances	2.50	0.21	5%	0.01
Low-Stakes Accuracy Utterances	2.80	0.28	5%	0.01

Table 14

Multiple Regression Predicting the Frequency of Parent Accuracy Talk

Predictor	*B*	*SE*	*β*	*t*	*p*
Child Age (in months)	-0.03	0.04	-.07	-0.67	.507
Attitude Towards Science	0.29	0.76	.05	0.38	.704
Failure Mindset	-0.02	0.67	.00	-0.03	.973
Parent Gender	**-2.80**	**0.88**	**-.34**	**-3.19**	**.002**
Child Gender	-1.03	0.87	-.13	-1.19	.238
Model Statistics					
R^2	16.3%				
F	3.05				
p	.015				

Note. Significant predictors are bolded.

Table 15

Multiple Regression Predicting the Proportion of Parent Accuracy Talk

Predictor	***B***	***SE***	***β***	***t***	***p***
Child Age (in months)	0.00	0.00	.14	1.23	.224
Attitude Towards Science	0.01	0.01	.23	1.78	.078
Failure Mindset	0.00	0.01	-.08	-0.60	.553
Parent Gender	-0.01	0.01	-.09	-0.85	.399
Child Gender	-0.01	0.01	-.11	-0.94	.348
Model Statistics					
R^2	8.9%				
F	1.53				
p	.189				

Note. Significant predictors are bolded.

Figure 1

Average Frequency of Observed Approach Use by Topic Stakes