# The influence of exposure to scientific inaccuracies in children's educational television on the science explanations of children and parents

By

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## Abstract

Study 1 analyzed 11 children's science programs. Consistent with research on children's storybooks, science information was often presented in a manner that might be confusing for children. Specifically, one-third of science lessons were presented alongside scientific misconceptions, only half of which were explicitly refuted. Additionally, one-quarter of lessons depicted or described science concepts in an anthropomorphized manner. These lessons mainly occurred during animated program segments and were often taught by non-human characters.

Study 2 examined the effects of exposure to these inaccuracies on children's science learning. A total of 78 3- to 5-year-old children watched two clips about two different science topics. Children were randomly assigned to one of three exposure conditions that varied the presence and type of inaccuracy embedded in the show, or to a no-exposure control condition where children answered all post-test questions prior to watching the show. Results indicated that children in the anthropomorphic condition provided the most accurate open-ended science explanations and close-ended endorsements. Children in the factual condition showed some improvements over the no-exposure condition, though these improvements were less consistent across all outcomes than those in the anthropomorphic condition. Children in the refutation condition did not differ from children in the no-exposure condition on any outcome. No condition modified children's tendency to include anthropomorphic statements in their explanations.

Study 3 examined the effects of exposure to these same clips on the accuracy of parents' science explanations to their children. An online Mechanical Turk sample of 141 parents of preschoolers were randomly assigned to the same four conditions used in Study 2. Afterward, they were asked to imagine that their preschool child had posed a series of questions about the content and to respond as they normally would. Results indicated that exposure to science television (regardless of condition) improved parents' science explanations to their children by increasing the number of facts they mentioned and reducing the number of misconceptions they mentioned (relative to no-exposure). Path analyses indicated that these effects were largely driven by parents' higher endorsements of science facts as accurate and their lower ratings of misconceptions as informative to children.

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# CHAPTER 1

## General Introduction

Although decades of research have focused on improving the effectiveness of science education in schools (McFarlane, 2013), informal science learning remains the single greatest source of new science knowledge acquisition among the general U.S. population (Bell, Lewenstein, Shouse, & Feder, 2009). Media sources in particular are the primary (and often only) source from which U.S. adults derive new science information and learn about new scientific discoveries (Brossard & Nisbet, 2007). Given this impact, a wealth of research has examined how people create, consume, understand, and are influenced by exposure to science media. For example, survey research has assessed the changing landscape of science journalism (Yi-Fan Su, Akin, Brossard, Scheufele, & Xenos, 2015), the contribution of news exposure to science knowledge (Takahasia & Tandoc, 2016), and the influence of entertainment media on science attitudes (Nisbet et al., 2002). Additionally, experimental work has examined how the framing of news stories can influence the way in which people attend to science information (Knobloch-Westerick, Johnson, Silver, & Westerick, 2013), as well as their feelings of uncertainty about scientific controversies (Corbett & Durfree, 2004).

Most of this work, however, has studied adults. Although some research exists on young children's exposure to media that teaches about science, technology, engineering, or mathematics (STEM) concepts, these studies have mainly documented their responses to researcher-created STEM storybooks (Geerdts, 2015; Ganea et al., 2014) and simple STEM video games (Aladé, Lauricella, Beaudoin-Ryan, & Wartella, 2016; Schroeder & Kirkorian, 2016). The few experimental studies that have centered on STEM television have examined school-aged children (Mares, Cantor, & Steinback, 1999; Fisch et al., 1997; Rockman et al., 1996), while the few published studies examining preschool-aged children's responses to STEM television have used quasi-experimental designs (Schlesinger, Flynn, & Richert, 2016; Bachrach et al., 2010) or focused only on children's learning of mathematics concepts (e.g., seriation; Gola, Richard, Lauricella, & Calvert, 2013; Lauricella, Gola, & Calvert, 2011) rather than other science concepts considered crucial for school readiness (Greenfield et al., 2009).

Somewhat surprisingly, no studies have experimentally manipulated the types of pedagogical strategies used within preschool children's science programs to assess their effectiveness in transmitting science knowledge to preschool audiences. This a noteworthy gap, given that children under age 8 spend almost twice as much time watching television than they do engaging with other media (Rideout, Saphir, Tsang, & Bozdech, 2013), and recent longitudinal research suggests that children's science achievement by as late as eighth grade is largely predicted by their science knowledge in kindergarten (Morgan et al., 2016). Relatedly, parents spend more time watching science television with their children than they do engaging in any other science-related activities (e.g., visiting museums, reading books; Pattinson, 2014), but no research has sought to understand how exposure to such programs impacts the manner in which parents interact with their children around science topics.

This dissertation sought to fill these gaps by fulfilling three core goals:

1) Describe the characteristics that typify children's science television.
2) Test the effects of exposure to prototypical exemplars of science television shows on the science explanations of children and parents.
3) Discuss the implications of these findings for research on children's early science learning.

To achieve these goals, the current project included three studies. Study 1 was a content analysis that described the characteristics of 11 science television programs geared toward preschoolers, specifically emphasizing the presence of scientific inaccuracies (i.e., misconceptions and anthropomorphism) in these shows. Building on these results, Study 2 experimentally manipulated two episodes of a popular, commercially-available science program to include different types of scientific inaccuracies, and it examined the impact that exposure to these different versions of the show had on the accuracy of children's science explanations. Similarly, Study 3 examined the impact that exposure to these same programs had on parents' science explanations in response to questions presumably posed by their preschool child.

To guide the development of these studies and their hypotheses, the following literature review contains three sections, each describing a separate realm of research. The first section details research examining the characteristics of children's science media; the second section details research examining the factors that influence children's science learning; and the third section details research examining factors that influence parents' science explanations to their children.

## The Characteristics of Children's Media

Most research describing the nature of science content for young audiences has focused on children's books, and only one unpublished study has examined children's science television.

**Children's picture books.** Research on children's picture books has noted two chief characteristics of the typical presentation of science information: (1) the presence of scientific misconceptions, and (2) the presence of anthropomorphism. Generally, misconceptions are defined as attitudes or ideas that conflict with current scientific explanations or beliefs (Braasch, Goldman, & Wiley, 2013; Tippett, 2010), while anthropomorphism refers to the attribution of humanlike characteristics to nonhuman animals or things (Kallery & Psillos, 2003).

Both of these types of inaccuracies are prevalent in children's books, including those books meant to educate as well as those meant to entertain. For example, Trundle, Troland, & Pritchard (2008) analyzed 80 books about the different phases of the moon. They found that many books misrepresented the depictions of the moon's phases and often incorrectly credited these phases to shadows cast by the Earth (rather than the angle of the moon relative to the sun's light). Similarly, Sackes et al. (2009) found inaccuracies present in books spanning a variety of sciences, including physical science (e.g., shadows positioned in unrealistic ways relative to light sources), life science (e.g., all trees have flowers; trunks are the "legs" of a tree), and astronomy (e.g., inaccurate cloud shapes; personification of the moon). Moreover, in a qualitative analysis of 99 science-based picture books, Broemmel and Rearden (2006) found that life science books often depicted talking animals. Similarly, Marriot (2002) demonstrated that children's storybooks often imbue animals with humanlike properties (e.g., talking, going to school, etc.), and they depict animals in their real habitats only about a quarter of the time that they are shown.

**Depictions of science in children's television.** Only one study (an unpublished master's thesis) has examined representations of science in children's TV programming. Charpentier (2007) analyzed three episodes each from 38 popular children's TV programs from 2006 to 2007, coding every instance where science content was mentioned or taught. The majority of scientific presentations focused on life sciences (50.8%) and Earth/space science (30.9%). Results indicated that the majority of these programs were meant to entertain, not to educate. Indeed, only four shows contained most of the segments defined as science "lessons," or relatively long presentations that explained multiple facets of a single concept, while the remaining 60% of segments were categorized as “exposures,” or incidental science facts embedded in non-scientific narratives.

When scientific information was presented, it was often introduced alongside misconceptions or embedded within fantasy material. For example, in an episode of Nickelodeon’s *Jimmy Neutron, Boy Genius*, Jimmy used rubies to power a robot and claimed that rubies are aluminum oxide minerals that make great conductors. Although rubies are, indeed, aluminum oxides, they are insulators rather than conductors. Similarly, an episode of FOX’s *Archie’s Weird Mysteries* depicted characters worrying that an evil potato was controlling the zombie-like residents of their town. They later conclude that microwave transmissions from a TV station were exerting mind control, and they increased the frequency of those microwaves to destroy the potato. In fact, microwaves only work this way in enclosed spaces and, of course, they cannot be used for mind control — or, presumably, to destroy evil potatoes.

Although Charpentier’s analysis paints a bleak picture of the quality of science lessons in children’s television, her analysis was conducted at a time when few TV shows explicitly aimed to educate children about science concepts. Most of the programs in her analysis were shows primarily meant for entertainment. Additionally, there are theoretical reasons to presume that thoughtfully incorporating scientific inaccuracies as a pedagogical tool within children’s programs might have beneficial effects on children’s learning under certain circumstances.

**Theoretical Frameworks for Understanding Children’s Learning from Science Television**

The majority of research on children’s learning from television draws on Fisch’s (2000) Capacity Model, which provides a broad framework for understanding how children attend to and extract meaning from media content. The model posits that children’s learning from media is constrained by their limited cognitive resources. Because most educational television shows for young audiences are designed as narrative stories with embedded educational material, children must divide their cognitive resources between comprehending both narrative and educational information. When these two sources of information are intertwined (i.e., the educational material is integral to the narrative), learning improves; when these two sources are distinct (i.e., the educational material is tangential to or obscured by the narrative), learning diminishes. As such, the model presumes that educational narratives with simple storylines that guide children's attention to relevant educational information and scaffold their understanding of that material will generally facilitate learning.

This model provides useful insights by illuminating circumstances in which children might learn from media most effectively. Additionally, a broad realm of research already exists on how science can be taught most effectively to adults, adolescents, and children, as well as on how scientific inaccuracies (i.e., misconceptions and anthropomorphism) might improve or impede these learning processes. In the following two sections, research on science learning across different formal and informal contexts is described. The first section describes the tenets of Conceptual Change Theory, with a specific focus on reasons why educational television might be an ineffective tool for addressing misconceptions held by preschool viewers. The second section details children's development and maintenance of anthropocentric reasoning, with a specific focus on reasons why exposure to anthropomorphic media might exacerbate these processes. Each of these sections concludes by considering the implications of the reviewed research within the framework of the Capacity Model.

**Scientific misconceptions and Conceptual Change Theory.** Given differences in children's early life experiences, children vary in the frameworks that they use to interpret the world (Allen, 2014). Notably, when children's early experiences lead them to inaccurate conclusions or conceptions about the world (e.g., the Earth is flat), these inaccuracies can impede the extent to which they are able to understand and assimilate new information related to those ideas (e.g., gravity). Indeed, research suggests that children do not enter educational scenarios "tabula rasa," primed to absorb accurate knowledge (Pine, Messer, & St. John, 2001, p. 91). Rather, the process of learning requires gradual restructuring of children's pre-existing knowledge structures to align with more culturally accepted views of scientific thought (Pine et al., 2001). Although new information that does not conflict with previously-held conceptions can be easily assimilated into existing structures for conceptual growth, children react in a variety of ways to information that is inconsistent with their views, including rejection (i.e., ignoring that information), sequestration (i.e., simultaneously maintaining both new and old information), or accommodation (i.e., replacement of old views with new ideas; Hynd, Alverman, & Qian, 1997; Tippett, 2010).

This lattermost reaction underscores Conceptual Change Theory, which describes the process by which nonscientific knowledge structures are supplanted by more scientifically accurate ones (Hynd et al., 1997; Tippet, 2010). To date, much of the research in this area has focused on the use of refutation texts, or texts that identify and explicitly refute readers' misconceptions about a particular science concept. As reviewed below, the majority of research on the effectiveness of this approach has been conducted with adolescents and adults exposed to written refutation texts. Thus it is unclear what the effects of refutations in science TV would be for younger, preschool-aged viewers.

***Conceptual change among adults and adolescents.*** Refutation texts generally contain three components: (1) a description of a misconception (e.g., "some people believe camels store water in their humps"), (2) a statement of refutation (e.g., "but this idea is not true"), and (3) the correct explanation (e.g., "camels store fat in their humps") (Tippet, 2010; Braasch et al., 2013). In experimental studies, these texts are typically compared to other non-refutation texts, which do not mention a misconception but might instead present related information about the topic or repeat the same correct information twice (e.g., Braasch et al., 2013). The general notion behind refutation texts is that by making salient one's own misconceptions and then explicitly refuting that misconception, a state of cognitive dissonance is induced that intrinsically motivates learners to reduce this dissonance by revising their inaccurate knowledge structures (Braasch et al., 2013).

Research with adults and adolescents has generally supported the idea that refutation texts are more effective than texts that do not address misconceptions in making inaccurate knowledge obsolete and in imparting scientifically accurate information to learners (Tippett, 2010; Braasch et al., 2013; Kendeou, Braasch, & Braten, 2016; van Loon, Dunlosky, van Gog, van Merrienboer, & de Bruin, 2015). However, more recent work has suggested that the success of a refutation text hinges on the nature of a reader's prior misconceptions—specifically, whether the misconception presented in text corresponds to a relatively coherent, well-established knowledge structure in the reader's mind that produces consistent predictions across a set of phenomena, or is instead a set of fragmented, unstructured pieces of knowledge that generates inconsistent predictions over time (Braasch et al., 2013).

Across three experiments, Braasch et al. (2013) found that undergraduates with fragmented misconceptions about airflow (i.e., those who did not consistently apply the same misconception across different contexts about airflow) benefitted less from refutation texts than learners with more coherent misconceptions. Similarly, van Loon et al. (2015) found that refutation texts were only useful for inducing conceptual change in eighth graders for misconceptions they held with high levels of confidence (and were thus more strongly represented in memory), while misconceptions held with low levels of confidence were no more impacted by refutation texts than by non-refutation texts. Thus researchers have concluded that the experience of dissonance resulting from the juxtaposition of correct and incorrect information is more "surprising" when the incorrect information is more confidently or strongly held in memory than when it is adhered to with less confidence (van Loon et al., 2015, p. 45).

***Conceptual change among younger children.*** Because elementary- and preschool-aged children have limited reading comprehension skills, refutation texts have not been used with them. However, studies where adults elicit and correct an individual child's unique misconceptions during a face-to-face classroom lesson have provided encouraging results regarding the use of refutation-type strategies with younger audiences. For example, in a series of studies, Kloos and her colleagues worked to modify children's misconception that large items sink faster than smaller items by replacing this inaccurate notion with the notion that *dense* items sink faster than *less dense* items (Kloos & Somerville, 2001; see also Kloos et al., 2010). Pretests indicated that almost all 5- to 7-year-old children held the same inaccurate notion that size influences sinking. In line with prior work on refutation, children who then received a demonstration lesson where their mistaken beliefs were explicitly refuted and corrected by a live adult were more likely to express accurate notions about density on a post test than children who received a similar lesson without first having their misconceptions labeled as incorrect.  Similar results were obtained for studies that included teaching 4- and 5-year-old children about balance; on pretests, almost all children made the same mistakes when trying to balance asymmetrical beams on a fulcrum (i.e., they believed everything should be balanced at their center), and these mistaken beliefs were effectively dealt with through in-person refutation demonstrations (Pine et al., 2002).

However, other research casts doubt on the effectiveness of this strategy for more complicated topics. Indeed, for many science concepts, children's early science knowledge is oftentimes of questionable accuracy, and they rarely begin to connect disparate pieces of science knowledge into coherent theoretical structures until they enter more formal schooling (Kambouri, 2015). Given this limitation, young children's knowledge about many science concepts tends to be relatively weak and fragmented in memory (Black & Lucas, 1993). Similar to research on adolescents' weakly held misconceptions (Braasch et al., 2013; van Loon et al., 2015), this fragmentation of children's knowledge sometimes limits the effectiveness of face-to-face refutation lessons among this age group.

For example, although early research characterized children's initial theories about the Earth as relatively coherent and theory-like (Vosniadou & Brewer, 1992), more recent work has questioned this conclusion, finding that individual children can simultaneously possess a variety of incompatible notions about the Earth (e.g., the Earth is hollow/fat; there are two Earths; Hannust & Kikas, 2007). Additionally, children use different beliefs to make predictions about related phenomena (like gravity) depending on how questions are asked, and they do not follow similar lines of reasoning when asked the same questions over different periods of times (Hannust & Kikas, 2010).

Consistent with this fragmentation of knowledge, interventions meant to refute children's misconceptions about characteristics of the Earth/gravity tend to show limited effectiveness. Hannust and Kikas (2007) taught 5- to 7-year-old children 10-15 minute lessons about the Earth to children seven times over the course of one month. These lessons were designed to elicit and correct some of children’s inaccurate ideas about gravity. Although children in the experimental group showed significant gains in knowledge compared to a control group (who did not receive these lessons), these were meager improvements: 11 percent of children held scientifically accurate views of the Earth on pre-tests, and this number increased to only 15 percent of children on post-tests. Although other researchers have demonstrated more potent effects of refutation lessons on other abstract topics (i.e., the cause of the day/night cycle), these interventions tend to result in children extracting straightforward scientific facts (i.e., the Sun and Earth are both spheres) rather than more abstract ideas that require integration of these facts (i.e., day and night are caused by the rotation of the Earth on its axis; Valanides et al., 2000).

Taken together, these studies question the effectiveness of using refutation strategies with preschoolers. In the context of using science media as a potential intervention for correcting these misconceptions, such mixed results are important to consider, especially because children are often left to engage with media on their own without adult oversight (Rideout et al., 2013).

***Media as a possible intervention for children’s misconceptions.*** To date, only one small-scale study has examined the effectiveness of a media refutation intervention (i.e., a children’s storybook) on children’s science learning. Mayer (1995) read 16 children (between Kindergarten and third grade) a book designed to refute misconceptions about whales. Although she did not pre-test children to assess their misconceptions prior to reading, she suggested that exposure to the book actually led five children to learn new misconceptions (e.g., whales jump from ponds to oceans; whales eat shrimp and fish; etc.). Over half the children said they learned nothing new from reading the book, and only one child gleaned a new piece of accurate knowledge (i.e., whales live in salt water.) Mayer concluded that refutations should be limited in science media because children do not seem to possess adequate cognitive resources to navigate the complexities inherent to the juxtaposition of factual and fictional information. Additionally, misconceptions included in this media might not relate to actual misconceptions children hold in real life, thus undermining the structure of an effective refutation text.

Indeed, it would appear that children are relatively poor judges when it comes to distinguishing factual from fictional information in TV narratives. For example, over the course of three days, Fisch et al. (1997) assigned second-, fourth-, and fifth-graders to see two episodes of *Cro* (Day 1 and 2) and one episode of *The Flintstones* (Day 3). Both shows were humorous, 30-minute cartoons on commercial television that featured both human and anthropomorphic characters in a prehistoric setting; however, *Cro* was designed to teach basic science concepts and simple machines, while *The Flintstones* depicted many instances of “pseudo-science,” or unrealistic devices that do not obey physical laws. After exposure, when asked to make comparisons between the shows, children mainly focused on describing features of the plot—they rarely ever mentioned anything about the differences in educational content. Additionally, there were no differences in their belief that the shows accurately depicted examples of “science.” However, when asked to provide specific examples of science content that they learned after watching each show, children were more likely to identify realistic science/technology concepts after watching *Cro* (e.g., how to build a glider), whereas they inevitably pointed to unrealistic depictions in *The Flintstones* (e.g., people use animals as machines, like elephants for showers) because no realistic depictions were present.

Consistent with the notion that children struggle to differentiate between accurate and inaccurate information, unpublished formative research on early *Sesame Street* content showed that preschoolers sometimes extract inaccurate knowledge even from well-designed media content. Specifically, Truglio, Scheiner, Seguí, and Chen (1999) assigned 150 preschoolers to view a series of *Sesame Street* segments about a variety of science concepts. Although children learned some accurate information from exposure to these clips (e.g., how shadows form), they also endorsed ideas that directly conflicted with the intended lessons embedded in these segments. For example, after viewing a segment in which plants, animals, and inanimate objects were identified as living or non-living things, many children classified plants as non-living things. The researchers argued that children were overburdened by the amount of information embedded in the show, and they recommended that future segments distinguish inanimate objects from plants *or* animals separately (rather than simultaneously).

***Considering misconceptions in the framework of Fisch's Capacity Model.*** In summary, Conceptual Change Theory suggests that refutation narratives are effective because they activate existing inaccurate knowledge networks and motivate revision (Braasch et al., 2013), especially for misconceptions that are strongly represented in memory (van Loon et al., 2015). Among younger children, this strategy has only been tested in situations where adults directly elicit and correct children's misconceptions about relatively straightforward science concepts during face-to-face science lessons (Kloos et al., 2010; Pine et al., 2002; Kloos & Somerville, 2001). However, research shows that children's misconceptions are often weakly represented in memory (Kambouri, 2015), they are often left alone to engage with media content (Rideout et al., 2013), and they have difficulty weighing the relative accuracy of factual versus fictional information in science TV narratives (Truglio et al., 1999; Fisch et al., 1997).

Because Fisch's (2000) Capacity Model suggests that children have limited working memory to attend to and comprehend media messages, the process of extracting meaning from an educational show that follows a refutation narrative would require children to split their attention between the entertainment portion of the narrative (e.g., characters posing a science question and searching for the answer) as well as the rather complex educational portion (e.g., the refutation narrative, which is naturally embedded with false information that is later corrected). Children's fragmented prior knowledge should complicate this process, making it less likely that they would correctly identify the accurate science lesson and revise their knowledge accordingly. Three possibilities exist: children might (1) learn very little from exposure to these narratives, (2) learn inaccurate (rather than accurate) information, or (3) learn both accurate *and* inaccurate information, given prior research showing that children can simultaneously believe contradictory scientific ideas (e.g., there are two Earths: one that is round and one that is flat; Hannust & Kikas, 2010; Hannust & Kikas, 2007).

**Anthropomorphism and children's learning from media.** The use of anthropomorphism to teach children about the biological and natural world is a hotly debated topic within the science education literature. For some, it represents a "fundamentally flawed way to describe nonhuman animal behavior" that "has long endured" (Horowitz & Bekoff, 2007, p. 24), despite being an "incurable disease" that has "no place in academic study" (Kennedy, 1992). For others, it represents a "useful aid" that can benefit students' understanding of science via metaphor (Kallery & Psillos, 2003, p. 292). It only becomes dangerous when the user is unaware of its metaphorical nature, which might "direct thinking in ways the user does not realize" (Taber, 1995, p. 92).

Similar debates characterize the current literature on children's anthropomorphic media. Although some studies suggest that exposure to such media diminishes children's learning and enhances their tendency to apply humanlike characteristics to the natural world, other studies suggest that anthropomorphic images can actually attract children's attention and scaffold their learning of complex topics, allowing them to describe science topics in more sophisticated ways than they otherwise would (for a review, see Geerdts, 2016). Each of these perspectives is considered in turn.

***Detrimental effects of anthropomorphic media.*** A review of the research suggests that young children do not appear to hold an anthropocentric view of the world; rather, such a viewpoint develops over the preschool years (Geerdts, 2016). In a pair of experiments, Hermann, Waxman, and Medin (2010) discovered that 3-year-olds were unlikely to attribute human characteristics to nonhuman animals and inanimate objects, but 5-year-olds did. Related research has found that 5-year-olds in rural environments are less likely than 5-year-olds from urban environments to maintain anthropocentric ideas (Waxman & Medin, 2007), and, similarly, children with pets at home are less likely to anthropomorphize animals than children without pets (Geerdt et al., 2015). Taken together, these findings suggest that anthropocentrism is a developed (rather than innate) tendency.

On the surface, anthropomorphism might seem harmless. However, research suggests there are detrimental effects when anthropomorphism is used as a way to interpret scientific phenomena. One illustrative example is the manner in which evolution and natural selection is understood. Legare, Lane, and Evans (2013) taught 5- to 12-year-olds about natural selection using one of three different sets of narratives, including “need-based,” “desire-based,” and “scientifically accurate” narratives. For example, brownbirds were described as evolving to have tougher beaks because they needed (need-based) or wanted (desire-based) to eat tough seeds; conversely, current-day brownbirds were described as descendants of tough-beaked brownbirds who were able to survive on tough seeds after soft seeds died away, causing the soft-beaked brownbirds to die as well (scientifically accurate). They then assessed children on the accuracy of their retellings of why brownbirds had tough beaks, as well as their endorsement of different explanations other children gave for how biological change occurs. They found that those children who were read the need-based and scientifically accurate narratives identified more accurate explanations about natural selection than those children receiving desire-based stories, while those who were read desire-based narratives were more likely to endorse desire-based (or anthropomorphic) explanations for evolution.

Similarly, recent studies suggest that exposure to certain types of media content can lead preschool children to begin developing anthropocentric cognitive frameworks. For example, Ganea et al. (2014) randomly assigned preschool children to hear three storybooks about novel animals (i.e., handfish, oxpeckers, and cavies) with realistic photographs and either anthropomorphic (e.g., "cavies like to spend the afternoon in the sun") or realistic descriptions (e.g., "cavies spend the afternoon in the sun") of animal behavior. They found that children in both conditions were equally likely to learn factual information about the animals (e.g., handfish eat worms and move slowly), but children hearing anthropomorphic descriptions were more likely to also attribute human-like behaviors to the animals (e.g., handfish get excited and feel proud; cavies talk and take baths.) These effects were worsened in a subsequent study that paired anthropomorphic language with anthropomorphic pictures (Ganea et al., 2014). Children were still more likely to attribute human-like characteristics to real images of the animals after hearing an anthropomorphic story, and the addition of anthropomorphic pictures also made them *less* likely to learn intended factual information about the animals.

***Beneficial effects of anthropomorphic media.*** Despite this previous work on the drawbacks of anthropomorphism, scholars have recently argued that visual anthropomorphism is only problematic when it is paired with anthropomorphic language (Ganea et al., 2014; Ganea et al., 2011) and when it involves extreme forms of anthropomorphism (e.g., animals engaging in patently false humanlike behaviors, like living in houses and eating at dinner tables) rather than more subtle depictions (e.g., animals with humanlike faces but otherwise engaged in a natural habitat; Geerdts et al., 2015).

For example, Geerdts et al. (2015) exposed preschoolers to storybooks about camouflage that varied the type of language (factual vs. anthropomorphic) and images (realistic vs. subtle anthropomorphism) used. Unlike the findings for extreme anthropomorphic in Ganea et al.'s (2014) study, children exposed to subtle anthropomorphic visuals were not more likely to attribute humanlike qualities to these animals. Even though children's retellings of the story included more anthropomorphic language after they were told a story using anthropomorphic (rather than factual language) language, children across all conditions recalled an equivalent number of facts about camouflage, and children's open-ended explanations about camouflage were more sophisticated and detailed when they were read a book with anthropomorphic pictures.

In fact, detrimental effects of anthropomorphism have only been found in prior research when children were exposed to stories that combined both anthropomorphic language and extreme anthropomorphic visuals. When only language is manipulated (e.g., Ganea et al., 2011), children exposed to anthropomorphic language learn equally well as children exposed to realistic storybooks. Similarly, when only visuals are manipulated, children exposed to anthropomorphic visuals learn as well as (Ganea et al., 2014) or better (Geerdts et al., 2015) than children exposed to realistic storybooks, presumably because such visuals attract children's attention to the content (Parker & Lepper, 1992) without imparting patently false information.

***Considering anthropomorphism in the framework of Fisch's Capacity Model.*** In summary, research findings on the impact of anthropomorphic visuals in children's media are mixed (Geerdts, 2016). Although extreme visual depictions paired with anthropomorphic language can impart factually inaccurate information to children and disrupt their learning of embedded educational material in storybooks (Ganea et al., 2014), books that contain more subtle forms of visual anthropomorphism but otherwise lack verbal anthropomorphism can actually enhance children's learning (Geerdts et al., 2016). Scholars have proposed that the fantasy nature of this type of content might operate by drawing children's attention and increasing their motivation to learn (Parker & Lepper, 1992).

However, no studies have yet examined children's responses to anthropomorphic visuals in television. Indeed, it might be that these dynamic depictions (i.e., actively moving, speaking) more closely resemble the types of problematic, unrealistic images present in storybooks that impede children's learning. Considering again the tenets of the Capacity Model — which suggest that children's attention to educational material underscores their learning of that content — it is possible that anthropomorphic visuals would either (1) attract children's attention and improve their comprehension of underlying narrative/educational information (Geerdts et al., 2015), or (2) serve as a distraction for children that directs their attention toward the fantasy aspects of the visuals and away from the educational lessons embedded within that content (Ganea et al., 2014).

**Parents' Science Explanations to their Children**

Although preschoolers are the primary audience for children's science programming, these programs are also created with the intent to make adults more comfortable and effective at discussing science with their children (Bachrach et al., 2012). However, no studies have examined whether they are effective at achieving this goal. In fact, research has only recently examined how adults alter their language when speaking to children about science in general, despite the fact that science learning often occurs by hearing testimony from others (Harris & Koening, 2006). Specifically, Vlach and Noll (2016) found that adults include more information to children (relative to adults) when explaining science concepts, but this information is characterized by an increase in both accurate (e.g., definitions, descriptions) and inaccurate (e.g., references to magic) information. Moreover, prior research on parent-child interactions in informal learning environments has found that parent science explanations are often low in quality and easily influenced by external factors. For example, when describing science museum exhibits to their children, parents' explanations are typically shallow and brief (Crowley, Callanan, Tenenbaum, & Allen, 2001) and largely based on explanatory information readily available at those exhibits (Tare, French, Frazier, Diamond, & Evans, 2011).

The remainder of this section details the types of questions children pose to adults about the natural world, as well as research on adults' ability to provide accurate responses to those questions.

**Children's search for causal information.** Although children learn most effectively about the world through naturalistic exploration, Canfield and Ganea (2014) argue that there are many types of knowledge that children cannot garner through direct experience. This is particularly relevant for science knowledge, which often centers on unobservable entities (e.g., microscopic beings), abstract concepts that children cannot directly experience (e.g., the rotation of the Earth), or differentiation of fact from fantasy (e.g., the nonexistence of unicorns) (Canfield & Ganea, 2014; Harris & Koening, 2006). In such circumstances, children are left to rely on the testimony of others. Indeed, both qualitative and quantitative research suggests that children utilize "why" and "how" questions to actively request explanations from adults to acquire new knowledge about the world (Bova, 2011; Bova & Arcidiacono, 2013; Frazier et al., 2009; Harris

& Koening, 2006). By the age of three, children are able to use such questions to probe responsive adults about the world, and they most often do so in the home during routine daily activities, like watching television (Callanan & Oakes, 1992).

Frazier et al. (2009) have identified a three-step process that typically occurs during such conversational exchanges: (1) child's question, (2) parent's response, and (3) child's reaction to that response. These roughly coincide with three steps in learning: an initial state, an informational input, and a revision in knowledge. In one study, Frazier et al. (2009) analyzed language diary data to understand the prevalence of children's why/how questions and the quality of parent responses. Corresponding to the first step in learning, they found that children often posed why/how questions to adults, and the prevalence of these questions did not change over the course of the preschool years. However, corresponding to the second step in learning, adults provided high-quality explanations less often (36.7%) than they provided non-explanations (63.3%) (i.e., circular reasoning, re-stating the question without providing more information, etc.) Additionally, the likelihood that adults provided explanations decreased as children aged. In their study, 2-year-olds received explanations in response to their questions 40% of the time, while 4-year-olds received explanations only 30% of the time — perhaps because children's questions got more complex with age.

In a second study, Frazier et al. (2009) experimentally manipulated whether or not children received an explanation or non-explanation in response to their why/how questions, and they examined how this receipt impacted the final step of learning: the child's reaction and their revision in knowledge. They found that children who received explanations in response to their why/how questions expressed more satisfaction with adult answers (i.e., smiling and laughing) than they did in response to non-explanations, which they often met with disagreement.

Additionally, children were more likely to ask follow-up questions in response to explanations, while they were more likely to re-ask their original question or provide their own (often erroneous) explanation in response to non-explanations. These findings fit with other work suggesting that children are sensitive to the quality of parent explanations (Canfield & Ganea, 2014) and that they decide how to gather new information in the future based on their prior satisfaction with reliable and unreliable sources (Mills, Legare, Grant, & Landrum, 2011; Corriveau & Kurkel, 2014).

**Adults' science knowledge and science explanations.** Despite children's curiosity, surveys indicate that adults often lack knowledge to accurately explain the causal mechanisms underlying a number of everyday scientific phenomena (National Science Board, 2012). These findings have been replicated across cultures for general adult populations, where (for example) only 74 percent of U.S. adults have an accurate conception of the day/night cycle (compared to 66 percent in Europe, 70 percent in India, and 86 percent in South Korea) (National Science Board, 2012). More generally, national surveys assessing basic science knowledge find that Americans answer, on average, only 65 percent of questions in scientifically accurate ways (National Science Board, 2012).

Even preschool teachers (who are tasked with imparting accurate knowledge to children) seem to lack adequate science knowledge. Survey research suggests that they sometimes avoid teaching science because they do not feel as competent with science topics as they do with other subjects they feel more pressured to cover, like literacy (Greenfield et al., 2009). In fact, studies have shown that preschool teachers actually harbor a number of scientific misconceptions (Trumper, 2003). For example, 51 percent of a sample of pre-service elementary school teachers in Israel incorrectly believed that the day/night cycle is caused by Earth's revolution around the sun (Trumper, 2003); conversely only 54 percent of a sample of pre-service elementary teachers in France understood that day/night are caused by the rotation of the Earth on its axis (Frede, 2006).

This lack of knowledge appears to influence the manner in which adults choose to explain science concepts to children. Although research in this area is relatively scarce, recent work suggests that parents make important modifications in their explanatory strategies when presenting science information to children rather than other adults. Across two studies, Vlach and Noll (2016) posed "why" questions to undergraduates (e.g., "why are there seasons?"), who were told to direct their explanation to another college student or to a 5-year-old child. They then coded the quality of the explanations for statements beneficial to learning (i.e., defining new terms, making connections to prior knowledge, etc.) or detrimental to learning (including inaccurate information, referencing magic/mythic forces, use of anthropomorphism, etc.).

Results showed that participants, in general, provided more information to children than to adults; however, their explanations to children included a significantly greater amount of both beneficial *and* detrimental information. Furthermore, participants rated their explanations to children as more accurate than their explanations to adults, despite the fact that these explanations also tended to include misleading or inaccurate information (e.g., "electricity is lazy.") The authors suggest that adults might believe science needs to be made more fun and engaging for young children, which leads them to incorporate interesting (yet inaccurate) information that they presume will make otherwise boring content more accessible or relatable. This notion fits with similar research suggesting that preschool teachers are less concerned with their students learning accurate science knowledge than they are with ensuring that children have fun while learning (Lee, 2006).

Relatedly, several studies have shown that adults resort to anthropomorphic explanations for natural phenomena when they lack content knowledge to properly explain natural processes to more mechanistic terms (Kallery & Psillos, 2003). Although this satisfies the immediate curiosity of the child, doing so imparts potentially misleading information and removes any impetus for the adults to improve their knowledge about that content, potentially creating a "vicious cycle" of reinforced inaccuracies for both parties (Kallery & Psillos, 2003, p. 309). In fact, preschool children tend to initially resist anthropomorphic explanations from adults (Gustavsson & Pramling, 2014; Thulin & Pramling, 2009). For example, Thulin and Pramling (2009) documented cases of preschool teachers introducing children to new animals (e.g., woodlice) embedded with anthropomorphic explanations of animal behavior (e.g., "do you think they have a preschool to go to?") Although children initially rejected such notions (e.g., "No!), it was found that they later started responding to adult questions with their own anthropomorphic language (e.g., "You wonder why [the woodlouse] does that in his house? … "maybe because he wants to play a lot every day!") (p. 143-147).

**Summary.** Taken together, these findings suggest that children are curious about the world and are sensitive to the quality of adult responses to their questions. Adults, however, seem somewhat unconcerned with the quality of responses they provide to preschool-aged children and, in some cases, seem to actively contribute to preschoolers' nascent misunderstandings about the world. It remains an open question whether exposure to children's science television programming helps or hinder the adults' ability to provide science explanations to children.

## Chapter Overview

This dissertation proceeds as follows. The first task was to describe the characteristics of educational lessons in children's science television. Accordingly, Chapter 2 presents the results of a content analysis of preschool children's science programs (Study 1). The study examined 11 popular children's science television shows, quantified the number of educational segments included in those programs, and described the extent to which those educational segments included scientific misconceptions and anthropomorphic descriptions or depictions.

The second task was to examine the effects of exposure to scientific inaccuracies on children's science explanations. Accordingly, Chapter 3 presents the results of experiment that randomly exposed to children to different versions of a popular educational science television show that contained misconceptions, anthropomorphic visuals, or were otherwise purified of any scientific inaccuracies (Study 2). After exposure, children's science explanations were assessed.

The third task was to examine the effects of exposure to educational science television on parents' science explanations to their children. Accordingly, Chapter 4 presents the results of an online experiment that randomly exposed parents to the same versions of the educational science show used in the previous experiment (Study 3). After exposure, parents were presented with a sequence of questions presumably posed by their preschool child, and their science explanations in response to those questions were assessed.

The final task was to synthesize and review the findings of the project. Chapter 5 contains a summary of how this project addressed the three main goals identified at the beginning of this chapter. Limitations are also highlighted and directions for future research are proposed.

# CHAPTER 2

## Study 1: The Characteristics of Science Lessons in Children's Educational Television

Many new television programs have been developed since Charpentier (2007) conducted her analysis of children's television in 2005 and 2006. Indeed, numerous children's TV networks have designed shows with the explicit aim to teach science to young viewers. Additionally, her analysis described (but did not quantify) the prevalence of scientific inaccuracies (e.g., misconceptions and anthropomorphism). As such, Study 1 aimed to extend her description of the science content in children's educational TV.

## Method

### Sample of Television Shows

Programs were selected from five major children's networks: PBS, Sprout, Nick Jr., Disney Jr., and Discovery Kids. Descriptions of each program were drawn from network websites. Shows were included in the current analysis if they were geared toward 3-6 year old children and the show's description indicated that the curriculum included science content. These criteria resulted in a selection of 15 programs. However, initial viewing revealed that four shows did not contain any educational lessons as defined in the current study (see below): *The Lion Guard*, *Miles from Tomorrowland*, *Curious George*, and *Maya the Bee*. Generally, these shows focused on socio-emotional lessons (e.g., the importance of being kind or inclusive) but took place in natural or futuristic settings (e.g., the forest, outer space) with animal characters (e.g., lions, honeybees). Although it is possible that children might extract some incidental new knowledge about animal characteristics from these types of shows, no verbal scientific lessons were identified in the episodes analyzed. As a result, these four shows were dropped from the current analysis, leaving 11 programs.

**Units of analysis.** Four episodes were randomly selected from the available corpus of each show, which provided 44 total episodes ranging from 11 minutes to 30 minutes. Each episode was viewed, and educational segments in each program were identified. Educational segments began whenever a science topic was first mentioned, and they endured as long as characters continued to discuss that same subject. For example, a character asking about the characteristics of Komodo dragons was considered the start of an educational segment, and that segment endured as long as characters continued to elaborate on those characteristics (i.e., physical attributes, habitat, etc.). Any time a character interjected new, lesson-irrelevant information (i.e., something that advanced the narrative in a new direction, including information on a new science topic or something related to the plot itself), that particular educational segment was considered terminated. The number of educational segments within each episode varied, ranging from 1 to 14 segments.

### Coding Scheme Categories

Each educational segment was coded on a number of dimensions (described below). A research assistant trained on the coding scheme coded a random selection of educational segments (25% of the sample). Inter-coder reliability was assessed using the KALPHA macro in SPSS to calculate Krippendorf's alpha (Hayes & Krippendorf, 2007). The agreement coefficients ranged from .82 to 1.0 for all coded dimensions, with the average alpha at .93; this agreement was satisfactory, given previous recommendations for an alpha of at least .67 (Krippendorf, 2004).

**Type of science.** Based on Charpentier's (2007) analysis, each segment was coded for the type of science content that was taught: life/animal science, Earth/space science, physical science, engineering/technology, and scientific inquiry/history of science.

**Presence of animation.** Each segment was coded as animated or live-action.

**Types of teachers.** The character responsible for delivering the factual information during each segment was characterized as nonhuman or human.

**Presence of misconceptions.** For each educational segment, coders assessed the accuracy of the science information included in that segment by researching the topic on Encyclopedia Britannica's website. A segment was coded as one that contained a misconception if characters made any statement about the focal science concept taught within that segment that could not verified as accurate using this method. For example, if characters wondered whether Komodo dragons breathe fire during a segment about the attributes of Komodo dragons, that segment was coded as one that contained a misconception. Each segment that contained a misconception was further coded for whether or not that misconception was explicitly refuted (i.e., identified as incorrect), either immediately (during the same segment) or later in the episode.

To ensure that concepts identified as misconceptions were actually inaccurate (and not simply a result of incomplete or outdated information in the online encyclopedia), the final list of misconceptions (as determined by the coders) was submitted for review by two scientists. One was a university biology instructor with a bachelor's degree of science in biology and a master's degree in public health; the other was a senior scientist at a pharmaceutical research organization with a bachelor's degree of science in biology. Both scientists first reviewed the lists individually and were encouraged to consult any resources they deemed appropriate to verify the information. Afterward, both scientists met and discussed the list, including any issues they had identified individually.

This process led to the removal of one misconception, which was identified during an educational segment describing the characteristics of meteorites. Because one of the primary lessons of that particular episode was that meteorites have many characteristics that make them distinct from rocks on earth, coders had initially identified an early segment in that episode (which described meteorites as identical to rocks on earth) as one that contained misconceptions. However, both scientists agreed that meteorites share enough in common with earth rocks to make this statement correct. As such, it was removed from the list of misconceptions. Neither scientist lodged any other concerns with the list.

Example misconceptions can be found in Table 1.

**Presence of anthropomorphism.** A segment contained anthropomorphism if the focal science concept taught within that segment was visually or verbally anthropomorphized. This did not include anthropomorphic characters that were merely present during the segment — it only pertained to explicit, visual representations or verbal references to the focal science concept taught during that segment. Each instance of anthropomorphism was coded as involving a living thing (e.g., butterfly) or a non-living thing (e.g., car).

Examples of verbal anthropomorphism can be found in Table 2. Given research suggesting that visual anthropomorphism can have differential effects on children's learning depending on how it is incorporated into media content (Geerdts, 2016), visual anthropomorphism was further coded as subtle or extreme (Geerdts et al., 2016). Subtle depictions included instances where focal science concepts were shown with humanlike facial expressions but otherwise engaging in realistic behaviors or functions (e.g., snails talking and smiling, but living in a child's aquarium). Extreme depictions included instances where focal science concepts were depicted engaging in unrealistic humanlike behaviors (e.g., iguanas roller-skating) that might impart patently false information about the characteristics or behaviors of those science concepts (See Figure 1).

## Results

Across all 44 episodes, 252 educational segments were identified for analysis.

### Science Topics

Figure 2 displays a breakdown of all types of science topics taught. Consistent with Charpentier's (2007) findings, life sciences (e.g., dinosaurs, caterpillars) were taught most often, followed by Earth/space science (e.g., Mars, the moon), physical sciences (e.g., friction, buoyancy), technology/engineering (e.g., function of underwater excavators; structural engineering) and scientific inquiry/history of science (e.g., making predictions; Jane Goodall's ape studies). Additionally, programs varied widely in the number of educational segments they contained, ranging from a low of 15 segments across all four episodes of *Octonauts*, to a high of 42 segments across all four episodes of *Wild Kratts* (see Figure 3).

### General Characteristics of Science Programs

Most of the 11 shows included in this analysis were animated. Although five programs did contain some live-action segments (i.e., *Peep*, *Dinosaur Train*, *Sid the Science Kid*, *Wild Kratts*, and, to a lesser extent, *Go Diego Go*), these were most often relatively shorter segments included at the beginning or end of the show.

Additionally, six programs contained casts of main characters comprised of almost entirely animated anthropomorphic creatures (i.e., *Doki*, *Peep*, *Dinosaur Train*, *Cat in the Hat*, *Octonauts*, and *Blaze*). Although the five other programs contained primarily human casts, one program depicted some of these human characters with unrealistic colors and hairstyles (i.e., with yellow skin in *Sid the Science Kid*), while others contained anthropomorphic secondary characters (i.e., a talking ferret in *Earth to Luna*).

**Characteristics of Educational Segments**

**Presence of animation.** The majority of educational segments (218 segments, 86.51%) occurred during animated (rather than live-action) portions of each show.

**Types of teachers.** The characters teaching new science concepts were almost evenly split between human (143 segments, 56.75%) and nonhuman characters. During animated segments, human teachers occurred at an equal rate to nonhuman teachers (109 segments each). All live-action educational segments contained human teachers (34 segments).

**Prevalence of scientific inaccuracies** Although misconceptions and anthropomorphism within educational segments are examined separately, it should be noted that they occasionally co-occurred within the same segment. Indeed, of the 252 educational segments identified in the current analysis, 102 segments (40.48%) contained either misconceptions or anthropomorphism, while another 28 segments (11.11%) contained some combination of both. Considering these co-occurrences, some type of scientific inaccuracy was present in over half of all educational segments identified (130 segments, 51.59%).

***Prevalence of misconceptions.*** Consistent with research on children's books (Broemmel & Rearden, 2006; Sackes et al., 2009; Trundle et al., 2008), misconceptions were relatively prevalent, occurring over a third of the time (91 segments, 36.11%) that scientific information was presented (e.g., weathermen have superpowers to control the weather; toy dinosaurs turn into fossils). As seen in Figure 3a, some shows included more misconceptions than others, and the proportion of misconceptions relative to the total number of educational segments within each show varied widely (i.e., no segments in *Blaze and the Monster Machines* contained misconceptions, while over two-thirds of the segments in *Earth to Luna* contained at least one). The tendency for misconceptions (in general) to be included in shows varied: some episodes contained none or only one misconception, while others contained up to five unique misconceptions. Of the 91 educational segments that contained a misconception, only 19 instances (20.89%) involved repetitions of a misconception presented earlier in the same episode; the rest were all novel misconceptions. Additionally, the most that any one particular misconception was repeated within the same episode was three times (i.e., the possibility that Komodo dragons breathe fire and fly in the *Doki* episode *Brave Knight Fico).*

Of the 91 educational segments that contained a misconception, only 31 segments (35.23%) featured an immediate refutation of that misconception (i.e., during that same segment, like when characters tell Doki that Komodo dragons do not breathe fire after he asks if they do). The misconceptions featured within another 15 segments (25.86%) were refuted at some point later in the show (e.g., Doki and his friends initially wonder if rainbows need rain and sunshine to form, and they later find out that rainbows can form anytime a light source shines through water in the air). Finally, the remaining 45 instances (46.87%) were never explicitly corrected (e.g., the impossibility of time travel is never addressed in *Wild Kratts*; the impossibility of Sid's "chat hat" that allows him to talk to animals is never clarified in *Sid the Science Kid*).

A clear distinction arose when examining the presence of misconceptions between animated and live-action educational segments: of the 34 live action educational segments identified, only one of these segments contained a misconception. In other words, 98.90% of the total educational segments that contained a misconception occurred during animated program segments.

***Prevalence of anthropomorphism.*** Anthropomorphism occurred during about one quarter of educational segments (67 segments, 26.59%). Living things (e.g., frogs, octopi; 53 segments, 79.10%) tended to be anthropomorphized more often than nonliving things (e.g., viruses, shooting stars; 14 segments, 20.90%). Of the segments that contained anthropomorphism, verbal examples (21 segments, 31.34%) were less common than visual examples (46 segments, 68.66%), and in no cases did these two types of anthropomorphism occur during the same educational segment. Additionally, the prevalence of anthropomorphism across shows varied (i.e., it never occurred in *Ready Jet Go*, but was incorporated in more than three-fourths of segments in *Go Diego, Go;* see Figure 3b).

All but one instance of visual anthropomorphism was categorized as subtle, both for living and non-living things. For example, in one episode of *The Cat in the Hat*, reindeer are depicted talking and smiling while in the forest eating moss; similarly, in *Blaze and the Monster Machines*, the main character Blaze (a car that has eyes and a mouth) sometimes transforms into other forms of technology (e.g., a rocket) and describes his features. The only example of an extreme depiction occurred in *Go Diego Go,* which displayed a brief still image of a cartoon iguana roller-skating (see Figure 1). However, this image occurred during an episode recap and remained on screen for less than ten seconds.

As with misconceptions, a clear distinction arose when examining the presence of anthropomorphism between animated and live-action educational segments: of the 34 live action educational segments, only four of these segments contained anthropomorphism, all of which were verbal in nature. In other words, 94.03% of the total educational segments that contained anthropomorphism occurred during animated segments (and, unsurprisingly, all instances of visual anthropomorphism occurred during animated segments).

## Discussion

Study 1 sought to describe the characteristics of educational lessons in contemporary children's science television shows. In general, these were animated programs that largely featured anthropomorphic casts of characters. However, consistent with prior work in this area (Charpentier, 2007), these programs were replete with factual science information. Indeed, across the 11 programs analyzed, the current study identified 252 instances where science information was presented. Lessons about life sciences and Earth/space science dominated these shows, accounting for nearly 90% of the factual information presented to children. However, over half of the educational segments identified taught science concepts in potentially problematic ways.

Specifically, misconceptions were introduced in over one-third of educational segments, and only about half of those misconceptions featured a corresponding refutation or correction at some point during the same episode (e.g., realizing that his shoes no longer fit, Sid wonders if his shoes are shrinking; his parents correct him and explain that he's actually growing in *Sid the Science Kid*). As such, misconceptions appeared to be incorporated with underlying educational intent almost just as often as they are used for entertaining or humorous purposes (e.g., the Kratt brothers' magical transformations into super-powered creatures in *Wild Kratts*).

Additionally, anthropomorphism occurred in about one-quarter of educational segments, with visual instances occurring almost twice as often as verbal instances. Only one instance of visual anthropomorphism was categorized as "extreme" (i.e., an iguana roller-skating), and visual and verbal anthropomorphism never co-occurred during the same educational segment. These findings are noteworthy, given that prior research has deemed anthropomorphic visuals detrimental only when they are of the extreme variety and when they co-occur with verbal anthropomorphism (Ganea et al., 2014).

Although it is true that the majority of educational segments occurred during animated portions of these shows, only five of the educational segments that contained misconceptions and anthropomorphism occurred during live-action portions of these shows. However, even though these live-action segments contained relatively "pure" educational content, it is possible that children pay less attention to the material included in these segments. Despite the fact that no studies have directly compared children's learning from live-action and animated program segments, formative research of early *Sesame Street* content found that children paid less attention to live-action content relative to content containing some fantasy elements (e.g., puppets or animation; Fisch & Truglio, 2001). Such inattention spurred *Sesame Street*'s producers to reject recommendations from child psychologists, who had advised them to refrain from mixing realistic and fantasy content in the show. This decision led to *Sesame Street*'s well-known mixture of live-action and muppet characters (Fisch & Truglio, 2001).

It is important, then, to consider what children might extract from these animated educational program segments, which are presumably more attention-grabbing than live-action content but simultaneously rife with scientific inaccuracies. As outlined in chapter 1, the implications of including misconceptions (both refuted and non-refuted) and anthropomorphism (both verbal and extreme/subtle visual) in children's television remain a mystery. Indeed, no studies have assessed the impact of children's exposure to refutation narratives or anthropomorphic visuals in children's science television on their science knowledge. Study 2 addresses this gap.

# CHAPTER 3

## Study 2: The Influence of Exposure to Scientific Inaccuracies in Children's Educational Television on Children's Science Explanations

Despite hopes that science television can embolden young minds and sow the seeds for scientific literacy across the lifespan (Stockmayler, Rennie, & Gilbert, 2010), the findings of Study 1 suggest that children's science television shows sometimes contain scientific inaccuracies. Given concerns that media exposure might actually contribute to children's development and maintenance of scientific misconceptions (Sackes et al., 2009; Marriot, 2002), research on the impact of this content is required.

Study 2 addresses this gap by testing the effects of preschoolers' exposure to depictions of science in children's television both with and without embedded scientific inaccuracies. Seventy-eight preschool children viewed two 3.5-minute clips from a popular, commercially-available children's science program. Because Study 1 found that the most common lessons taught in children's science programs center on earth/space and life sciences, one clip relevant to each of these two types of science was selected. The earth/space science clip taught about the cause of the day/night cycle, while the life science clip taught about the characteristics of butterfly feet.

Children were randomized into one of four conditions. Children in the *factual* condition viewed versions of these clips with all scientific inaccuracies edited out. Children in the *refutation* condition saw these same clips edited to follow the original refutation structure of the show, whereby characters first mentioned and refuted three scientific misconceptions before introducing the same factual lessons included in the factual condition. Children in the *anthropomorphic* condition viewed the same clips as children in the factual condition, but they were edited to retain some of the original anthropomorphic visuals from the show. Finally, children in the *no-exposure* condition answered all post-test questions before viewing two randomly selected clips from the other three conditions, thus serving as a control condition for the other three groups.

Five outcome variables were measures. Children's *science explanations* were assessed by examining (1) children's mentions of scientific facts and misconceptions in their open-ended science explanations and (2) their close-ended endorsements of scientific facts and misconceptions as accurate. Additionally, children's *anthropomorphic ideas* were assessed by examining (3) their mentions of anthropomorphic statements in their open-ended science explanations and (4) their close-ended endorsements of anthropomorphic statements as accurate. Finally, (5) children's enjoyment of the show was measured.

**Children's science explanations.** The primary outcome of interest in the current study centered on children's open-ended science explanations. Prior research suggests that children generate causal explanations as a mechanism of self-discovery (Legare, Gelman, & Wellman, 2010). That is, when faced with information that is incompatible with their prior knowledge, children will produce causal explanations in attempt to accommodate or reconcile new information with their existing theories. As such, assessing the quality of children's self-generated science explanations after exposure to science media can illuminate the extent to which new information is accurately represented in memory. Additionally, prior research on the impact of exposure to science television among school-aged children suggests that their ability to explain science concepts reflects higher-order learning than factual recognition tasks (Rockman et al., 1996). From a more practical point of view, preschoolers' self-generated explanations should typify the ideas that they might spontaneously produce on their own during their everyday lives.

As an additional test of learning, the current study also assessed children's close-ended endorsements of science explanations as accurate or inaccurate. Children were presented with a series of explanations rooted in either scientific facts or scientific misconceptions, and they were asked to judge that accuracy of those explanations. Although such a test is less reflective of the types of explanations children might construct on their own, it can still shed light on the extent to which exposure to science media leads children toward more or less accurate scientific knowledge frameworks.

***Open-ended explanations: Mentions of facts and misconceptions.*** Children's open-ended science explanations were examined for their inclusion of scientific facts and scientific misconceptions both before and after they viewed the show. With regard to scientific facts, prior research suggests that school-aged children can learn scientific facts from exposure to high-quality children's science television (Fisch et al., 1997; Mares et al., 1999). It was expected that children would learn new factual content in each of the three exposure conditions and thus be more likely to include this information when providing science explanations for the focal science phenomena. It was predicted,

**H1:** Children in each of the three exposure conditions will mention more scientific facts in their science explanations after viewing the show compared to before viewing.

In the current study, the clips used in the anthropomorphic condition depicted focal science concepts with subtle anthropomorphism (e.g., human-like faces and speech) similar to the types of images used in previous studies that found beneficial effects for learning (Geerdts et al., 2016). However, because this was the first study to examine children's responses to anthropomorphic depictions in television, it was unclear whether such images would function similarly to storybooks, or if the dynamic nature of these depictions would more closely resemble the types of extreme anthropomorphism found to degrade learning in prior research (e.g., Ganea et al., 2014; Ganea et al., 2011). A research question was posed,

**RQ1:** Will children in the anthropomorphic condition mention more scientific facts in their science explanations at post-test compared to the other two exposure conditions?

With regard to scientific misconceptions, the clips used in the refutation condition were designed to refute and correct misconceptions about each topic. As a result, children in this condition should (in theory) be most likely to eject misconceptions from their science explanations. However, research examining conceptual change theory has only tested refutation texts with children over age 8 (Tippett, 2010), and as outlined in Chapter 1, there are many reasons to believe that these narratives would actually *degrade* preschoolers' ability to identify misconceptions as erroneous, given the cognitive constraints of this audience (e.g., lack of adult scaffolding, fragmented knowledge frameworks, and difficulty distinguishing factual and fictional information). It was predicted,

**H2:** Children in the refutation condition will mention more scientific misconceptions in their science explanations after viewing the show compared to before viewing.

What about children in the other two exposure conditions, who see factual information with no misconceptions? On the one hand, offering children a coherent explanation of science concepts might induce them to provide those factual explanations at a higher rate than they provide alternative misconceptions. On the other hand, they might continue to incorporate misconceptions even after providing factual explanations, given their willingness to tolerate contradictory scientific ideas (Hannust & Kikas, 2012; Hannust & Kikas, 2007). Thus a research question was posed,

**RQ2:** Will children in the factual and anthropomorphic conditions mention fewer misconceptions in their science explanations than children in the refutation condition?

***Close-ended endorsements of facts and misconceptions.*** Children were also assessed on their ability to discern the relative accuracy of explanations rooted in scientific facts from those rooted in scientific misconceptions. These measures were assessed only at post-test (rather than pre-test). An additional set of hypotheses and research questions was proposed, which paralleled the predictions regarding the effects of exposure to science television on children's science explanations:

**H3:** Children in each of the three exposure conditions will endorse more scientific facts as accurate compared to children in the no-exposure condition.

**RQ3:** Will children in the anthropomorphic condition endorse more scientific facts as accurate than children in the other two exposure conditions?

**H4:** Children in the refutation condition will endorse more scientific misconceptions as accurate compared to children in the no-exposure condition.

**RQ4:** Will children in the factual and anthropomorphic conditions endorse fewer scientific misconceptions as accurate than children in the no-exposure condition?

**Children's anthropomorphic ideas.** Mirroring the logic of these predictions, the current study also assessed children's spontaneous inclusion of anthropomorphic statements in their science explanations (at pre- and post-test), as well as their close-ended endorsements of anthropomorphic statements about each science topic (at post-test). Again, these measures are meant to reflect the extent to which anthropomorphic ideas are integrated into children's existing knowledge frameworks (open-ended), as well as children's ability to discern the relative accuracy of those ideas (close-ended).

***Open-ended science explanations: Mentions of anthropomorphic statements.*** Prior research has found that children are unlikely to mention anthropomorphic statements spontaneously when describing scientific phenomena unless adults encourage them to do so (Thulin & Pramling, 2009; see also Gustavsson & Pramling, 2014). That is, children do not often generate anthropomorphic explanations for natural phenomena spontaneously on their own, but they will mimic adults who use such language as a teaching mechanism during formal and informal learning scenarios. Even though no adults in the current study modeled anthropomorphic explanations, it is possible that exposure to anthropomorphic media might serve as an implicit form of encouragement for children to incorporate such ideas into their science explanations. It was predicted,

> **H5:** Children in the anthropomorphic condition will include more anthropomorphic statements in their science explanations compared to children in the other three conditions.

***Close-ended endorsements of anthropomorphic statements.*** Prior experimental work has found that exposure to anthropomorphic media can lead children to endorse inaccurate anthropomorphic beliefs about novel animals (e.g., handfish feel excitement and pride; Ganea et al., 2014). The current study focused on children's beliefs about the applicability of three different sets of human traits to the focal science phenomena discussed in the experimental clips: physical (e.g., talking, dancing), emotional (e.g., feeling happiness, love), and social (e.g., having friends, playing games with others). Consistent with prior work on children's responses to anthropomorphic media content (Ganea et al., 2014), it was predicted,

**H6:** Children in the anthropomorphic condition will endorse more anthropomorphic statements as accurate compared to children in the other three conditions.

**Children's enjoyment of the show.** The final hypothesis focused on children's enjoyment of the show. Prior research suggests that children prefer educational media that utilizes fantasy content compared to educational media devoid of such content (Parker & Lepper, 1992). Although all the clips used in this study contained many of the fantastical characteristics common in popular educational television (e.g., animated characters; Mares & Acosta, 2008), the anthropomorphic clips departed the most from the relatively more realistic depictions inherent to the portrayals in the other two conditions. It was predicted,

**H7:** Children will enjoy the anthropomorphic clips more than the factual or refutation clips.

# Method

## Participants

Participants were 78 children between the ages of 3 and 5 ($M$ = 58.36, $SD$ = 7.50); 56.4% male. Parent reports indicated 62 White, 14 Asian, 8 Hispanic, and 4 Black participants (parents could select more than one race). Children were recruited from local preschools and email listservs for local community groups.

## Design

This was a 4 (condition: factual vs. refutation vs. anthropomorphic vs. no-exposure) x 2 (age: older vs. younger) x 2 (topic: day/night vs. butterflies) mixed design. Condition and age were between-subjects factors, while topic was a within-subjects factor. Children were randomized into one of four conditions: *factual* ($n$ = 20), *refutation* ($n$ = 20), *anthropomorphic* ($n$ = 19), and *no-exposure* ($n$ = 19).

**Procedure**

Children were interviewed individually. Children recruited from preschools were interviewed in a quiet room at their school, while children recruited from the community were brought to campus by their parents and interviewed in a small study room. Children received $10 for participating.

Interviews lasted approximately 20 minutes. Clips and questions were posed to children on a Mac laptop. The interview began by having children in the three exposure conditions answer two open-ended science questions (in counterbalanced order) that were the focus of the two TV programs that they would later watch. The first dealt with the day/night cycle: “I don’t know much about day and night. Can you tell me — why does day turn into night?” The second dealt with butterflies: “I don’t know much about butterflies, or what they do with their feet. Can you tell me — why do butterflies wiggle their feet?” The researcher typed children’s responses. Whenever the child fell silent, the researcher asked “What else?” until the child stopped responding or ceased providing new information.

Next, children in the three exposure conditions watched two 3.5-minute clips (in counterbalanced order) of the educational Sprout show *Earth to Luna*. One clip dealt with the causes of the day/night cycle, while the other dealt with butterfly feet. After each clip, the child responded to a series of post-test questions before moving on to the second clip. Children in the no-exposure condition participated in these activities in reverse order. That is, they first responded to all post-test questions about both topics (with topic counterbalanced between children), and then watched both clips in sequence. This allowed for assessment of children’s knowledge and beliefs prior to viewing the show while still ensuring that all children benefitted from exposure to the program.

**Materials**

The two 3.5-minute clips were edited versions of the *Earth to Luna* episodes "Nighty Night, Sun" and "Butterfly Feet." Each clip depicted 6-year-old Luna, her 4-year-old brother Jupiter, and their pet ferret Clyde posing a science question, learning the answer to that question, and singing a song that reiterated that lesson. To assess the impact of scientific inaccuracies on children's science knowledge, the factual clip was manipulated in two separate ways to create the refutation and anthropomorphic clips.

In the *refutation* clip, children witnessed the characters exploring their backyard and posing a series of three misconceptions that seemed like plausible answers to their science question (e.g., "Maybe the sun hides at night.") Each misconception was repeated three times. After children learned the correct answer to their question (but before the educational song), these misconceptions were each explicitly refuted by the characters twice (e.g., "So the Sun doesn't hide!") during a brief, 10-second segment. Children in the other two conditions saw the same scenes with the initial misconceptions and refutations edited out. To equate the length of this segment for children in the factual and anthropomorphic conditions, children in those conditions also saw a non-educational musical number, which is included at the beginning of every *Earth to Luna* episode and focuses on the characters' enthusiasm about finding the answer to their question (i.e., "What's Happening Here?").

In the *anthropomorphic* clip, children heard the same educational songs as children in the other two conditions, but they instead saw anthropomorphic visuals. These included a singing sun/earth or butterfly, as well as the main characters magically transformed into singing satellites or butterflies (see Figure 4). This manipulation was possible because each episode of *Earth to Luna* contains two musical numbers — one with animated, human versions of the main characters, and one with animated, anthropomorphized versions. For the day/night clip, children heard the song "Spinning All Around." For the butterfly clip, heard the song "Butterfly Feet." The clips were edited so that the total time spent depicting scientific inaccuracies was the same for the two conditions: either 70 seconds of misconceptions/refutations, or 70 seconds of anthropomorphic visuals.

## Measures from Child Interviews

Children's science learning (i.e., open-ended explanations and close-ended endorsements), anthropomorphic ideas (i.e., open-ended explanations and close-ended endorsements), and enjoyment were assessed during the interview session. Children were assured that they could skip or say, "I don't know" to any question without penalty.

**Children's science learning.** Measures of children's science learning included their mentions of scientific facts and misconceptions in their open-ended science explanations, as well as their close-ended endorsements of scientific facts and misconceptions.

***Open-ended science explanations: Mentions of facts and misconceptions.*** As previously described, children provided open-ended explanations in response to the main science question of each clip (i.e., "Why does day turn into night?" and "Why do butterflies wiggle their feet?"). Children in the three exposure conditions answered these questions both before and after viewing the show.

Children's explanations were coded for their mentions of three facts and three misconceptions introduced in the show. An example fact about the day/night cycle was: "The earth turns round and round." An example fact about butterflies was: "They use their feet to taste stuff." An example misconception about the day/night cycle was: "The sun goes down, down, down, and then up, up up." An example misconception about butterflies was: "They're itchy sometimes.” The presence of each fact or misconception was only counted once, so if a child repeated the same fact or misconception in different ways (i.e., “the sun moves,” and “the sun goes across the sky”), that child received only one point. Thus children could receive a score between 0 and 3 for both their *mentions of facts* and their *mentions of misconceptions.*

All coding was conducted by the first author. To assess reliability, a research assistant trained on the coding scheme also coded all children’s responses. Inter-coder reliability was assessed using the KALPHA macro in SPSS to calculate Krippendorf’s alpha (Hayes & Krippendorf, 2007). Reliability was achieved for both facts (alpha = .95), CI [.90, 1.00], and misconceptions (alpha = .94), CI [.89, .99]. Where ratings differed by 1 point or less, discrepancies between the two coders were resolved by averaging the two scores. Where ratings differed by more than 1 point, discrepancies were resolved through discussion.

Preliminary analyses revealed that there were very few occasions ($n$ = 12) where a child mentioned more than 1 fact or misconception in their explanations across all questions. Thus for each outcome children were coded as 0 (did not provide at least one fact or misconception) or 1 (provided at least 1 fact or misconception).

***Close-ended endorsements of facts and misconceptions.*** Children’s perception of the accuracy of three science explanations rooted in facts and three explanations rooted in misconceptions was assessed with six close-ended yes/no questions (for each topic). Although the intent was to ask children these questions before and after exposure to the show, preliminary interviews indicated a testing effect: children seemed to change their endorsements simply because they were asked the same question more than once. As such, these questions were only asked at post-test.

Children first received instructions for the task. For the day/night clip, children were told: "Some kids have different ideas about why day turns into night. I'm going to read you some of their ideas, and I want you to tell me if *no*, that's not what happens at night, or *yes*, that is what happens at night." For the butterfly clip, children were told: "Some kids have different ideas about why butterflies wiggle their feet. I'm going to read you some of their ideas, and I want you to tell me if *no*, that's not why butterflies wiggle their feet, or *yes*, that is why butterflies wiggle their feet." Children could respond verbally or by pointing to a red X (for no) or a green check mark (for yes) depicted on screen. To prevent response biases, the yes/no response options were randomized.

After these instructions, the researcher read children each of the three facts and three misconceptions in random order (for each clip). Thus, children's scores for both *endorsements of facts* and *endorsements of misconceptions* could range from 0 to 3 for both topics.

**Children's anthropomorphic ideas.** Measures of children's anthropomorphic ideas included their mentions of anthropomorphic statements in their open-ended science explanations, as well as their close-ended endorsements of anthropomorphic statements about focal science concepts.

***Open-ended explanations: Mentions of anthropomorphic statements.*** Children's science explanations were also coded for the presence of anthropomorphic statements. Anthropomorphic statements were those that applied any human-like qualities to the focal science concepts of each clip that those concepts themselves did not naturally possess. Building on work from Ganea et al. (2014), three categories of anthropomorphism were coded: physical, emotional, and social. However, examination of children's explanations revealed only two cases of verbal anthropomorphism across both topics. As such, this measure was dropped from further analysis.

***Close-ended endorsements of anthropomorphism.*** Consistent with prior work on children's anthropomorphic beliefs (Ganea et al., 2014), children were asked a series of six close-ended yes/no questions (for each topic).

Children first received instructions for the task. For the day/night clip, children were told: "Some kids have different ideas about the sun. I'm going to read you some of their ideas, and I want you to tell if *no*, that's not true about the sun, or *yes*, that is true about the sun." For the butterfly clip, children were told: "Some kids have different ideas about butterflies. I'm going to read you some of their ideas, and I want you to tell me if *no,* that's not true about butterflies, or *yes*, that is true about butterflies." Response options and scoring were the same as for children's endorsements of facts/misconceptions.

Consistent with work by Ganea et al. (2014), two questions asked about physical qualities (e.g., "the sun talks"), two questions asked about emotional qualities (e.g., "the sun loves daytime"), and two questions asked about social qualities (e.g., "the sun plays games with the Earth") (see Table 3). Thus children's scores could range from 0 to 2 for each type of anthropomorphism across both topics.

**Enjoyment.** For each clip, children were first asked if they liked or disliked the clip (illustrated by a smiling and frowning emoticon, respectively). After their selection, children were asked if they "just liked/disliked it," "really liked/disliked it," or "really really liked/disliked it" (illustrated by one, two, and three stacked smiling/frowning emoticons, respectively). Scores were recoded to range from -3 to +3, with higher scores reflecting higher enjoyment.

**Measures from Parent Reports**

**Age.** Age in months was calculated from parent reports of their child's birthday. A median split (59 months) was conducted in order to separate children into younger (coded as 0) and older (coded as 1) groups.

**Gender.** Parents indicated if their child was male (coded as 0) or female (coded as 1).

**Race.** Parents were asked to select as many categories that described their child's race (White, Asian, Hispanic, Black, Native American, or other). Children were categorized as White (coded as 1) or non-White (coded as 0).

**Experience with pets.** Consistent with research suggesting that children's experience with pets influences their anthropomorphic beliefs (Geerdts et al., 2015), parents were asked if their family owns (or ever owned) a dog or a cat. For families who did own a cat or a dog, they were asked to estimate the number of years of their child's life that they have owned that pet, as well as the extent to which the child helped care for that pet on a 7-point scale (1 = *almost never*, 7 = *very frequently*). Experience with pets was calculated by multiplying numbers of years by the extent the child helped care for the pet ($M$ = 8.30, $SD$ = 11.99). Children with no pet experience received a 0.

**Science TV exposure.** Parents were asked to indicate the extent to which their child watches (or watched) a series of 16 science-focused children's programs (e.g., *Sid the Science Kid, Octonauts, The Magic School Bus,* etc.) Parents responded on a 5-point scale (1 = *never*, 5 = *very often*) ($M$ = 1.71, $SD$ = .48).

**Parents' science attitudes.** Given research suggesting that parents' attitudes about science can influence children's interest in science (Pattinson, 2014), parents were asked a series of 12 questions about their science attitudes on a 7-point scale (1 = *strongly disagree*, 7 =

*strongly agree*). Four questions assessed their attitudes about the importance of science (e.g., "It is important to have good scientific knowledge and skills in order to get any good job in today's world;" $M = 5.20$, $SD = 1.29$, $\alpha = .89$); four questions assessed their attitudes about the personal value of science (e.g., "There are many opportunities for me to use science in my everyday life;" $M = 5.66$, $SD = 1.28$, $\alpha = .92$); and four questions assessed their level of enjoyment of science (e.g., "I generally have fun when I am learning science topics;" $M = 5.75$, $SD = 1.32$, $\alpha = .97$). However, a principal components factor analysis indicated that these items all loaded on to one factor. As such, they were combined into one measure of parents' science attitudes ($M = 5.54$, $SD = 1.09$, $\alpha = .93$).

# Results

## Analytic Strategy

Preliminary analyses indicated that age, gender, race, experience with pets, science TV exposure, and parents' science attitudes did not significantly differ between conditions. Gender, race, science TV exposure, and parents' science attitudes were examined as possible covariates in all analyses, and experience with pets was considered as an additional covariate in analyses of children's endorsements of anthropomorphism. In no case did any of these variables significantly predict any outcomes, so they were dropped from analyses.

Age (younger vs. older) was included as a main effect in all analyses to account for developmental differences between children. Topic was also included as a main effect in all analyses to account for differences in children's answers between episodes.

## Effects of Condition on Children's Science Learning

Hypotheses regarding children's science learning concerned the effect of exposure to different versions of science content on children's science explanations (pre- vs. post-test) and their endorsements of scientific facts and misconceptions as accurate (post-test).

**Pre-vs. post-test mentions of facts and misconceptions in explanations.** Because children's mentions of facts and misconceptions were dichotomized (absent vs. present), McNemar's tests were used to assess whether the proportion of children mentioning at least one fact or misconception at post-test was significantly different from the proportion of children mentioning at least one fact or misconception at pre-test. These tests were conducted separately within each exposure condition for both topics (see Figure 5 for mentions of facts and Figure 6 for mention of misconceptions). The no-exposure condition was excluded from this analysis because children in this condition were not asked these questions.

H1 stated that children in the three exposure conditions would mention more scientific facts at post-test compared to pre-test, while H2 stated that children in the refutation condition would mention more scientific misconceptions at post-test compared to pre-test. In partial support of H1, more children in the anthropomorphic condition mentioned a fact about the day/night cycle ($p < .05$) and about butterflies ($p < .001$) at post-test relative to pre-test, and more children in the factual condition mentioned a fact about butterflies at post-test relative to pre-test ($p < .01$). The number of children in the refutation condition who mentioned at least one fact about either topic did not differ between pre- and post-test. Contrary to H2, the number of children who mentioned a misconception about the either topic did not differ between pre- and post-test. Unexpectedly, fewer children in the anthropomorphic condition mentioned a misconception about the day/night cycle ($p < .05$) at post-test relative to pre-test. Very few children ($n = 5$) mentioned a misconception about butterflies at pre- or post-test.

**Post-test comparisons between experimental conditions.** RQ1 asked whether children in the anthropomorphic condition would mention more facts at post-test than children in the other two other exposure conditions. This question was examined using logistic regression. Two separate analyses were conducted: one on children's post-test mention of facts about the day/night cycle, and one on children's post-test mention of facts about butterfly feet. Predictors included children's age (in months) and exposure condition (dummy-coded with the anthropomorphic condition as the reference group).

Results indicated that children in the refutation condition were less likely than children in the anthropomorphic condition to mention a fact about the day/night cycle ($B$ = -2.11, $SE$ =.91, $p < .05$, $OR$ = .12, Nagelkerke-$R^2$ = .36) and about butterfly feet ($B$ = -1.85, $SE$ =.73, $p < .05$, $OR$ = .16, Nagelkerke-$R^2$ = .20). Children in the anthropomorphic condition did not differ from children in the factual condition, nor did age significantly predict their mention of facts about either topic.

RQ2 asked whether children either the factual or anthropomorphic conditions would mention fewer misconceptions at post-test than children in the refutation condition. This question was also examined using logistic regression. Two separate analyses were conducted: one on children's post-test mention of misconceptions about the day/night cycle, and one on children's post-test mention of misconceptions about butterfly feet. Predictors included children's age (in months) and exposure condition (dummy-coded with the refutation condition as the reference group). However, results indicated no significant effects of age or condition.

***Summary.*** The refutation condition appeared to be least successful at improving children's science explanations. The number of children mentioning at least one fact or misconception in this condition did not change from pre- to post-test for either topic, and children in this condition were significantly less likely than children in the anthropomorphic condition to mention a fact about both topics. The factual condition was next most successful. More children in this condition mentioned a fact about butterfly feet at post-test than at pre-test, but the number of children mentioning a fact about the day/night cycle did not change from pre- to post-test; additionally, the number of misconceptions they mentioned about either topic did not change from pre- to post-test. However, children in this condition did not significantly differ from children in the anthropomorphic condition. The anthropomorphic condition was most successful. Children in this condition mentioned more facts at post-test (compared to pre-test) about both topics, and they mentioned fewer misconceptions about the day/night cycle at post-test (compared to pre-test). Almost no children in this condition mentioned a misconception about butterfly feet, so there were floor effects for that outcome.

**Close-ended endorsements of facts and misconceptions.** Children's close-ended endorsements of facts and misconceptions were analyzed using a repeated-measures ANOVA. Condition (no-exposure vs. factual vs. refutation vs. anthropomorphic) and age (younger vs. older) were between-subjects factors, while topic (day/night vs. butterfly feet) and information type (fact vs. misconception) were within-subjects factors. Post-hoc comparisons between the no-exposure condition and the three exposure conditions were assessed using Dunnett's t-tests, which are recommended when comparing multiple treatment groups against a single control group. For comparisons among the three exposure conditions, Sidak corrections were used to correct for multiple comparisons.

H3 stated that children in each of the three exposure conditions would endorse more scientific facts as accurate than children in the no-exposure condition, while RQ3 asked whether children in the anthropomorphic condition would endorse more scientific facts as accurate than children in the other two exposure conditions. H4 stated that children in the refutation condition would endorse more scientific misconceptions as accurate than children in the no-exposure condition, while RQ4 asked if children in the factual and anthropomorphic conditions would endorse fewer scientific misconceptions as accurate than children in the no-exposure condition.

Results indicated a significant effect of information type, $F(1,70) = 56.80$, $p < .001$, $\eta p^2 = .45$. Across all conditions, children endorsed facts as more accurate ($M = 2.27$, $SE = .08$) than misconceptions ($M = 1.30$, $SE = .09$). Additionally, there was a significant interaction between information type and condition, $F(3,70) = 6.21$, $p < .001$, $\eta p^2 = .21$ (see Figure 7). In partial support of H3 (and with regard to RQ3), children in the anthropomorphic condition endorsed more facts as accurate than children in the no-exposure condition ($p < .01$), while no other condition differed from the no-exposure condition. Contrary to H4 (and with regard to RQ4), children in both the factual ($p < .01$) and anthropomorphic ($p < .05$) conditions endorsed fewer misconceptions as accurate than children in the no-exposure condition, while children in the refutation condition did not differ from children in the no-exposure condition.

There was an additional, unexpected interaction between information type and age, $F(1,70) = 5.75$, $p < .05$, $\eta p^2 = .08$. There were no age differences in children's endorsement of facts as accurate, but younger children endorsed more misconceptions as accurate ($M = 1.55$, $SE = .11$) than older children ($M = 1.04$, $SE = .13$). In no instance did topic interact with any other variable.

***Summary.*** With regard to children's endorsements of scientific facts and misconceptions, only children in the anthropomorphic condition endorsed more scientific facts as accurate compared to children in the no-exposure condition, while children in both the factual and anthropomorphic endorsed fewer scientific misconceptions as accurate compared to children in the no-exposure condition. Children in the refutation condition did not differ from children in the no-exposure condition in their endorsements of facts or misconceptions.

**Effects of Condition on Children's Anthropomorphic Ideas**

Additional measures focused on children's mentions and endorsements of anthropomorphic statements about the focal science concepts taught by the show.

**Open-ended science explanations: Mentions of anthropomorphic statements.** H5 stated that children in the anthropomorphic condition would be more likely to include anthropomorphic statements in their science explanations compared to children in the other three conditions. However, because virtually no children made anthropomorphic statements (see Method section), H5 was not supported.

**Close-ended endorsements of anthropomorphic statements.** H6 stated that children exposed to the anthropomorphic clips would endorse the accuracy or more anthropomorphic statements about the focal science concepts in each clip compared to children in the other three conditions. This prediction was tested using a repeated-measures ANOVA with condition and age (younger vs. older) as between-subjects factors, and topic (day/night vs. butterfly feet) and anthropomorphic trait (physical vs. emotional vs. social) as within-subjects factors.

Contrary to H6, there were no main or interaction effects of condition. Thus the anthropomorphic clip did not lead children to endorse more anthropomorphic statements as accurate. However, there was a main effect of topic, $F(1,70) = 31.86$, $p < .001$, $\eta p^2 = .31$, trait, $F(2,140) = 164.61$, $p < .001$, $\eta p^2 = .70$, and a significant interaction between trait and age, $F(2,140) = 4.64$, $p < .05$, $\eta p^2 = .06$. Children were more likely to endorse the accuracy of anthropomorphic statements about butterflies ($M = 1.23$, $SE = .05$) than about the sun $M = .91$, $SE = .06$). Additionally, children were most likely to endorse the accuracy of statements about emotional anthropomorphism (*M* = 1.68, *SE* = .05), followed by statements about social anthropomorphism (*M* = 1.08, *SE* = .07), followed by statements about physical anthropomorphism (*M* = .45, *SE* = .06), all *p*'s < .001. These main effects held for both younger and older children, though younger children were significantly more likely to endorse the accuracy of statements about physical anthropomorphism (*M* = .59, *SE* = .09) than older children (*M* = .31, *SE* = .08), *p* < .05.

**Summary.** Contrary to predictions, children rarely mentioned anthropomorphic statements in their science explanations. Additionally, condition did not impact children's tendency to endorse anthropomorphic statements as factual. However, consistent with prior work in this area, children were more likely to anthropomorphize a living (rather than non-living) entity, and children were more likely to extend social and emotional traits to focal science concepts than they were physical traits (Ganea et al., 2014). There was an unexpected interaction between trait and age, such that younger children were more likely to physically anthropomorphize than older children.

### Enjoyment

H7 stated that children would enjoy the clips mentioned in the anthropomorphic condition more than the clips used in the other two exposure conditions. Results of a repeated-measures ANOVA with condition (factual vs. refutation vs. anthropomorphic) and age (younger vs. older) as between-subjects factors and topic (day/night vs. butterfly feet) as a within-subjects factor indicated no significant main or interaction effects of condition, topic, or age. Children's enjoyment ratings were high (i.e., above 5 on a 7-point scale) across all conditions.

**Summary.** Children enjoyed all the clips equally.

## Discussion

**Impacts of Exposure**

Across all learning outcomes, children in the anthropomorphic condition showed the most consistent, beneficial shifts in learning from pre- to post-test. Relative to pre-test, they mentioned significantly more facts (about both topics) and fewer misconceptions (about the day/night cycle) in their science explanations. Additionally, relative to the no-exposure group, children in the anthropomorphic condition endorsed the accuracy of more scientific facts and fewer scientific misconceptions about both topics.

Although children in the factual condition also demonstrated beneficial shifts in learning, the effects across all outcomes were not as consistent or pronounced as they were for children in the anthropomorphic condition. Despite mentioning more facts about butterflies at post-test compared to pre-test, children in the factual condition did not shift in the number of facts they mentioned about the day/night cycle, and they mentioned the same number of misconceptions across both times of testing. Although they endorsed the accuracy of fewer misconceptions than children in the no-exposure condition, they did not differ in their endorsements of facts.

It should be noted that children were relatively unlikely to mention any relevant misconception about butterfly feet at either pre- or post-test, but far more children mentioned at least one misconception about the day/night cycle at pre- or post-test. This suggests that children are naturally likely to hold prior misconceptions about certain topics. Still, only the anthropomorphic condition was successful at reducing children's mention of misconceptions about the day/night cycle. Taken together, these findings suggest that the anthropomorphic clips were more effective than the factual clips at improving children's mentions and endorsements of facts, and also at correcting their mentions and endorsements of misconceptions. These results are consistent with recent research showing that children learn more effectively from storybooks that use subtle forms of visual anthropomorphism relative to storybooks that use more realistic images (Geerdts et al., 2015; Geerdts, 2016). Although it is presumed that the benefits of anthropomorphism operate as a result of children's increased attention to fantasy material (Parker & Lepper, 1992), the mechanism that underscores these results has yet to be identified empirically. It is possible that the shift in visuals from human to anthropomorphic characters explicitly provided children with varied practice (i.e., rehearsal of the same material in a new visual context), which has been found to promote learning (Fisch et al., 2005). Future research should continue to investigate these possibilities.

Interestingly, the refutation condition did not consistently degrade or improve children's performance on measures of learning. In general, children in this condition differed very little from children in the no-exposure condition. Thus, while children in this condition did not appear to learn anything correct from exposure to the refutation clips, they also did not extract inaccurate information. If anything, they simply appear to have learned nothing new at all. These results are consistent with research showing that children struggle to extract educational lessons from cognitively burdensome narratives (Piotrowski, 2014; Mares & Acosta, 2010; Mares & Acosta, 2008). Future research should continue to examine characteristics of science TV narratives that support, impede, and degrade children's attention and processing.

**Children's anthropomorphic ideas.** Despite the benefits of exposure to the anthropomorphic clips for learning, it was hypothesized that exposure to such depictions would lead children to mention more anthropomorphic statements in their science explanations and to endorse the accuracy of more anthropomorphic statements about focal science concepts than children in the other conditions. However, children were generally unlikely to include anthropomorphic statements in their science explanations. This finding is consistent with prior research suggesting that children do not often spontaneously mention anthropomorphic statements without adult encouragement (Thulin & Pramling, 2009; see also Gustavsson & Pramling, 2014).

Additionally, contrary to predictions, children in the anthropomorphic condition (relative to children in the other three conditions) did not endorse the accuracy of more anthropomorphic statements about either science topic examined in the current study. Again, this is consistent with recent research suggesting that subtle anthropomorphism does not increase children's tendency to anthropomorphize animals (Geerdts et al., 2015), at least for those that are relatively familiar (e.g., frogs, butterflies). As previously mentioned, research demonstrating detrimental effects of anthropomorphic media have used extreme depictions of animals (e.g., living in houses) that are unfamiliar to most children (e.g., cavies, oxpeckers; Ganea et al., 2014). While the current study extends this realm of research to televised depictions, it will be important for future work to directly compare children's responses to familiar and unfamiliar animals across varying degrees of anthropomorphism.

**Influence of topic and age.** Importantly, the effects of condition noted above were consistent across age groups and both science topics examined in the current study. Although main effects of topic and age were not explicitly hypothesized, differences in children's responses between topics and age groups were assessed for all outcomes.

Consistent with prior research suggesting that children harbor a variety of misconceptions about the causes of the day/night cycle (Valanides et al., 2000; Venville, 2004), the current study showed that children were more likely to mention misconceptions about the day/night cycle than about butterflies in their science explanations at both pre- and post-test. Given the relative novelty of the information taught to children about butterfly feet, children mentioned few misconceptions about butterfly feet at pre-test, and they mentioned and endorsed the accuracy of more facts about butterfly feet than about the day/night cycle at post-test. Taken together, these findings suggest that science television might be more effective at imparting knowledge to children about topics where they hold few prior misconceptions. Indeed, the lack of learning in response to the refutation clips implies that attempting to address and correct their prior misconceptions in this context might actually impede (rather than promote) learning.

Additionally, in the current study, children were more likely to endorse the accuracy of anthropomorphic statements about butterflies than about the sun. These findings suggest that children considered (to some degree) the sentience of the target science concept when deciding whether or not to extend anthropomorphic traits to it. Indeed, prior research has shown that children are capable by age 3 of distinguishing between living and non-living entities (Anggoro, Waxman, & Medin, 2008). Future research should continue examine the boundary conditions of children's tendency to anthropomorphize both living and non-living things, as well as the impact of media depictions on their tendency to do so.

With regard to age, there was one notable effects: younger children endorsed more misconceptions as accurate than older children. However, even though younger children endorsed the accuracy of more misconceptions than older children, they were not more likely to actually include that information in their open-ended science explanations. It is unclear if this finding simply reflects their limited verbal skills, or whether their close-ended endorsements of misconceptions do not reflect actual commitment to those inaccurate ideas. Future research should continue to examine the relationship between children's open- and close-ended responses as they progress through the preschool years.

**Theoretical and Practical Implications**

These results have implications for Fisch's Capacity Model and Conceptual Change Theory, as well as for the design of children's educational science media.

**Implications for Fisch's Capacity Model.** Comparing the results between the three exposure conditions, it is evident that the anthropomorphic clips were most effective at imparting new knowledge to children, the factual clips were slightly less effective, and the refutation clips were ineffective (but not detrimental). These findings are understandable in the context of the Capacity Model. The clips used in the factual and anthropomorphic conditions followed equivalent, simplistic storylines that posed a science question and answered that question. However, the anthropomorphic clips contained attractive visuals during a key educational sequence (i.e., a song that reiterated the primary science lesson), which likely drew children's attention and enhanced their learning to a greater degree than the factual clips, which were identical in all respects except for the inclusion of anthropomorphic images.

This finding comes with an important caveat: it's possible that these visuals only improved learning because they coincided with the presentation of accurate educational information. It will be important for future research to vary the use of anthropomorphism over the course of an educational narrative to examine when (and how) it might have detrimental effects. That is, if the anthropomorphic visuals occurred while characters proposed scientific misconceptions, would children learn that inaccurate information more effectively? Moreover, it will be important to examine the impact that these visuals have on the way children represent this material in memory. Indeed, it is possible that these fantastical visuals would motivate children to reject the relevance of this information to reality in novel real-world contexts (Bonus & Mares, 2015). If this were the case, then the learning boost demonstrated in the current study might backfire in transfer contexts.

Children's lack of learning in the refutation condition is also understandable in the context of the Capacity Model. That is, given children's limited cognitive resources (i.e., limited attention; fragmentation of knowledge) to make sense of the complexity of the refutation narrative (i.e., inaccurate information followed by a refutation followed by accurate information), it is unsurprising that children in this condition resembled children in the no-exposure condition on most learning outcomes. This result suggests that when left alone to engage with refutation narratives, children struggle to comprehend their narrative intricacies. Future research should examine more closely the characteristics of these narratives that burden children, and how improvements could be made to facilitate their understanding.

**Implications for Conceptual Change Theory.** This was the first study to apply the study of refutation narratives to preschool children in an experimental context. As such, it is the first to examine the limitations of conceptual change theory among this age group. Although refutation strategies have been deemed successful with preschool children in prior research (Kloos et al., 2010; Pine et al., 2002 Kloos & Somerville, 2001), these interventions generally involve face-to-face encounters between a child and a teacher or some other adult who is able to elicit the child's unique misconceptions and provide corrective feedback. Unlike this previous work, the current study demonstrated that children struggle to make sense of refutation narratives when left alone without feedback or adult guidance. Future research should examine ways to more effectively design media-based refutation lessons for young children.

Despite the ineffectiveness of the refutation narrative, these findings should not be taken as indication that misconceptions should be purified from all children's science media. On the contrary, a wealth of evidence suggests that attempting to educate young children without first addressing their misconceptions is a somewhat fruitless endeavor that can sometimes strengthen their misconceptions (Kambouri, 2015; Black & Lucas, 1993). However, the current findings do suggest that simply teaching children accurate information can sometimes reduce their tendency to mention and endorse misconceptions, at least in the short-term. In contexts where no adults are available to explain complex material and correct children's confusions, this might be the most conservative strategy.

However, recent research has shown that interactive touchscreens that engage children with narrative content and provide corrective feedback on children's confusions can enhance their learning of key narrative moments (Peebles, Bonus, & Mares, in preparation). Future research should examine the possibilities that interactive TV shows and games hold for eliciting and correcting children's misconceptions about science concepts. It is possible that refutation narratives presented on touchscreens that are designed to assess and correct children's inaccurate ideas could enhance learning over and above the effects of the anthropomorphic clips documented here. Unfortunately, similar caveats apply: research on children's learning from touchscreens has noted that children typically struggle to transfer lessons extracted from those experiences even more than they struggle to do so from non-interactive media, despite improvements in learning (Peebles et al., under review; Aladé, et al., 2016; Schroeder & Kirkorian, 2016). Striking an adequate balance between learning and transfer remains an elusive goal.

**Implications for media producers.** On the surface, these results suggest fairly straightforward advice: anthropomorphism is good for learning, refutations are bad, and depictions purified of either inaccuracy rest somewhere in between. As previously, noted, however, this interpretation is overly simplistic. Anthropomorphic visuals are likely beneficial for learning, but potentially only for concepts that are relatively familiar to children and when they do not coincide with inaccurate or misleading information. Refutation narratives do not seem to improve children's learning, but it's possible they could if they are designed with greater awareness of children's limited cognitive capacity. Indeed, it is too early to provide sweeping generalizations about the (in)effectiveness of either of these strategies. However, one takeaway remains clear: preschool children are a unique audience, and the techniques used to educate adults about science topics cannot necessarily be co-opted for children and expected to work without additional considerations. Future research is needed to clarify these considerations.

**Limitations**

As with any one-shot experimental study, there are many limitations to consider. First, only one children's program was used. Although the results of Study 1 suggest that these characteristics are common in most science TV for preschoolers, research on other shows, where these types of inaccuracies might manifest in slightly different ways, is necessary.

Second, the clips used in this study were short (i.e., about one-third of the length of a normal episode). This was done to ensure that children could watch and respond to more than one clip without fatigue. However, it is possible that children's learning outcomes will differ in response to longer episodes. Indeed, none of the experimental clips used in this study directly mirrored the structure of the regular version of the show, which is typically a conglomeration of all three experimental conditions. Even though the use of misconceptions and anthropomorphism rarely coincide during the same educational segments within a science program (Study 1), both strategies are occasionally used at different moments during the same episode of a show. Future research should assess the ramifications of including different combinations of these inaccuracies over the course of a show.

Third, only two science topics were used in the current study (i.e., the day/night cycle and butterfly feet). While these topics were meant to represent two broad categories of science (i.e., earth/space and life science) that reflect the most common lessons taught in children's science television (Study 1), it will be important to assess other topics within these categories, as well as other categories of science. Indeed, children's early science education is not entirely rooted in children's learning of science facts, but also hinges on their learning of science process skills (e.g., asking questions, using evidence, etc.; Kloos et al., 2012). How effective science television is at honing these skills remains an open question.

Finally, children's learning was assessed during one experimental session by only one researcher. Future research is needed to examine how children's immediate learning predicts their knowledge over the course of days, weeks, and months, as well as over repeated viewings. It is possible that the effects seen in this study would be relatively short-lived without further repetition or elaboration of the content, or that children would be unlikely to use this information in other real-world situations with other children or adults, regardless of how much they learned. Longitudinal research can better illuminate the impact of exposure to science television over time.

# CHAPTER 4

## Study 3: The Influence of Exposure to Children's Science Television on Parents' Science Explanations to their Preschool Children

A wealth of research suggests that adults purposefully alter their manner of speech when speaking to children rather than other adults, often as a way to promote children's learning. For example, mothers teaching language to their young infants will use a higher pitch and alter the duration of their vowels (Werker et al., 2007), and they will use general (rather than specific) nouns when categorizing objects in their child's environment (Blewitt, 1983). When teaching children early numerical concepts, adults focus their efforts on rehearsing numbers (Durkin, Shire, Riem, Crowther, & Rutter, 1986), and they give more directed feedback to children with low (relative to high) mathematical competence (Saxe, Guberman, & Gearhart, 1987).

To date, only one study has examined how adults discuss science with preschool-aged children (Vlach & Noll, 2016), despite the fact that science learning in early childhood often occurs by hearing testimony from others (Harris & Koening, 2006). Given that parents report watching science TV programs more often than they engage in any other science-related activities with their children (e.g., reading books, visiting museums, etc.; Pattinson, 2014), Study 3 investigates how parents' science explanations to their children are influenced by exposure to children's science television. Indeed, such programs are created with the intent to make adults more comfortable and effective at discussing science (Bachrach et al., 2012). This is a particularly important finding to consider, given that fewer parents believe their children actually learn about science from educational media than they do other academic topics, like math and reading (Rideout, 2014). Despite these beliefs, contemporary children's science programs are actually replete with scientific lessons, though these lessons are sometimes characterized by scientific inaccuracies (Study 1) that can impede children's learning (Study 2). While it is possible that these depictions might improve parents' explanations by exposing them to factual scientific information, it is also possible that they might motivate parents to incorporate more scientific inaccuracies in their explanations.

Study 3 tested these possibilities with an experiment that assessed the impact of exposure to science television on parents' science explanations to their preschool-aged children. A Mechanical Turk sample of 141 parents of preschoolers viewed the same two 3.5-minute educational science clips used in Study 2, and they were randomized into the same four conditions: *factual*, *refutation*, *anthropomorphic*, and *no-exposure*. The main outcomes of interest were (1) the types of knowledge and attitudes that are likely to influence the content parents include in their science explanations to their children, (2) the actual content parents' include in their science explanations, and (3) parents' perceptions of the virtues of educational science television.

**Factors that influence parents' science explanations.** The current study focused on two variables that might impact the types of information parents' include in their explanations: parents' endorsements of scientific facts and scientific misconceptions as accurate, and parents' ratings of those facts and misconceptions as informative to children's learning about new science concepts.

***Endorsements of scientific facts and misconceptions.*** As previously noted, national surveys have demonstrated that adults sometimes lack knowledge about basic, everyday scientific concepts, like the day/night cycle (National Science Board, 2012). Thus there is potential for children's science media content to enlarge even adults' knowledge base. It was predicted,

**H1:** Parents in each of the three exposure conditions will endorse more scientific facts as accurate compared to parents in the no-exposure condition.

Because prior research has shown that refutation narratives are effective at correcting adults' misconceptions (see Study 2: van Loon et al., 2015; Braasch et al., 2013), it was possible that exposure the refutation clips could correct adults' misconceptions, even for the rather basic topics taught in the show. It was also predicted,

**H2:** Parents in the refutation condition will endorse fewer scientific misconceptions as accurate compared to parents in the no-exposure condition.

***Ratings of scientific facts and misconceptions as informative.*** Ideally, parents' explanations of science concepts to their children would be rife with relevant, accurate information and relatively void of misconceptions. How might exposure to educational media influence parents' tendency to provide potentially confusing or otherwise disadvantageous information to children? Given that the clips used in every condition highlight the accuracy of scientific facts in a child-friendly context, then exposure to these clips should increase parents' belief that such factual information is informative to children. It was predicted,

**H3:** Parents in each of the three exposure conditions will rate facts as more informative for children compared to parents in the no-exposure condition.

However, research has shown that adults adjust their science explanations to children (relative to adults) by incorporating inaccurate (though possibly "fun") information (e.g., "electricity is lazy," or "magic makes it happen;" Vlach & Noll, 2016). Because the refutation clips explicitly refute and correct scientific misconceptions, it seemed possible that exposure to those clips might reduce parents' beliefs that misconceptions are informative to young children learning science. It was predicted,

**H4:** Parents in the refutation condition will rate misconceptions as less informative for children compared to parents in the no-exposure condition.

**Parents' mentions of scientific facts, misconceptions, and refutations.** Considering the previous hypotheses, how might exposure to science television influence the types of information that parents say they would include in their science explanations to their children? Given that H1 and H3 predicted that parents in each of the three exposure conditions would endorse more scientific facts as accurate and rate scientific facts as more informative to children, it was predicted,

**H5:** Parents in each of the three exposure conditions will mention more facts in their science explanations to their children compared to parents in the no-exposure condition.

Because H2 and H4 also predicted that parents in the refutation condition would endorse fewer scientific misconceptions as accurate and rate misconceptions as less informative to children, it was also predicted,

**H6:** Parents in the refutation condition will mention fewer misconceptions in their science explanations to their children compared to parents in the no-exposure condition.

Beyond the effects of exposure to the refutation clips on parents' endorsements and ratings of misconceptions, it is possible that the refutation structure of those clips might encourage parents to directly model their own explanations using a similar format. That is, they might first introduce a misconception as a means to refute and explicitly correct it. It was predicted,

**H7:** Parents in the refutation condition will mention more refutations (e.g., misconceptions followed by corrections) in their science explanations to their children compared to parents in the no-exposure condition.

***Mediation hypotheses.*** The causal processes implied by H5 and H6 were formalized into two mediation hypothesis regarding the beneficial effects of exposure → parents' endorsement/ratings of facts and misconceptions → science explanations (see Figure 8):

**H8:** The positive effects of each of the three exposure conditions (relative to the no-exposure condition) on parents' mention of facts in their science explanations will be mediated by their higher endorsement of scientific facts as accurate **(H8a)** and their higher ratings of scientific facts as informative to children **(H8b)**.

**H9:** The positive effect of the refutation condition (relative to the no-exposure condition) on parents' mention of misconceptions in their science explanations will be mediated by their lower endorsement of misconceptions as accurate **(H9a)** and their lower rating of misconceptions as informative to children **(H9b)**.

**Parents' mentions of anthropomorphic statements.** A separate question of interest was whether or not exposure to science TV would influence parents' tendency to anthropomorphize science concepts in their science explanations. Given prior research suggesting that adults sometimes encourage anthropomorphic reasoning among children (Thulin & Pramling, 2009), it is possible that exposure to anthropomorphic media might serve as implicit endorsement of those strategies. It was predicted,

**H10:** Parents in the anthropomorphic condition will be more likely to mention anthropomorphic statements in their science explanations to their children compared to parents in the no-exposure condition.

**Parents' ratings of the virtues of science TV.** No research has examined parents' perceptions about the value of children's science TV. However, prior research has shown that parents' beliefs about the value of media influence the type of media selections that parents make (and avoid making) for their children. For example, studies have shown that parents' beliefs about the educational value (Vandewater et al., 2006) and entertainment value (Vaala, 2014) of educational screen media positively predict their intent to expose their children to that content, as well as how much they actually expose their children to it. Thus the current study focused on the extent to which parents' perceptions of these two characteristics predicted their intent to expose their child to the show used in this study. It was predicted,

**H11:** Controlling for demographic and attitudinal factors (e.g., religious beliefs, attitudes about science), parents' ratings of perceived child learning from **(H11a)** and child enjoyment **(H11b)** of science TV will predict their intent to expose their child to that content.

However, it was unclear whether the experimental manipulations used in this study might modify parents' perceptions of the show. Indeed, prior research has shown that children are more attracted to fantastical media content than they are to content devoid of such material (Parker & Lepper, 1992). If parents recognize this affinity, then they might believe their children would enjoy the anthropomorphic clips more than the clips used in the other conditions. Moreover, it was also unclear if parents might perceive the educational value of the refutation clips differently than the clips in the other two conditions, given that the refutation narrative explicitly highlighted and corrected scientific misconceptions in addition to providing accurate scientific facts. Due to this lack of clarity, a research question was posed,

**RQ1:** Will condition influence parents' perception that their child would learn from or enjoy science TV **(RQ1a)**? Will condition influence parents' intent to expose their child to science TV **(RQ1b)**?

**Effects of parent and child gender.** Prior research suggests gender differences in the ways that parents explain science to children. For example, when parents engage in informal science activities with their children (e.g., visiting museums), both mothers and fathers provide science explanations to their sons more often than to their daughters, and these differences are exacerbated during father-child interactions (Crowley et al., 2001). Although such studies have not been conducted on parents' explanations of science content in response to viewing science media, it was possible that such gender differences would be replicated in this context. However, it was unclear whether condition might modify these tendencies. A final research question was posed,

**RQ2:** Will parent or child gender moderate the effects of condition on any outcome?

# Method

## Participants

Participants included 141 parents of preschoolers recruited online from Amazon's Mechanical Turk (MTurk). Parents ranged in age from 19 to 56 years old (M = 32.61, SD = 7.10). Their children's ages ranged from 3 to 6 years old (M = 4.44, SD = 1.07); 51.77% male. The majority of respondents were fathers (53.19%) and non-Hispanic Caucasian (72.34%), with the remaining sample composed of parents who were African-American (12.06%), Hispanic/Latino (11.35%), Asian (5.67%), or Native American (1.42%).

Compared to 2010 U.S. Census data, this sample over-represented non-Hispanic Caucasian (69% nationally) and under-represented African-American (12.6% nationally) and Hispanic (16% nationally) populations. In terms of education, the sample was more educated relative to the national 2010 population: 30.50% had an associate's degree or some college (vs. 28% nationally), 48.20% had a bachelor's degree (vs. 27% nationally), 9.20% had a higher degree (i.e. master's, professional, or doctorate degree vs. 10% nationally) and 2.10% had a high school degree or less (vs. 45% nationally).

**Design**

This was a 4 (condition: factual vs. refutation vs. anthropomorphic vs. no-exposure) x 2 (topic: day/night vs. butterflies) mixed design. Condition was a between-subjects factor, and topic was a within-subjects factor. Parents were randomized to condition: *factual* (*n* = 32), *refutation* (*n* = 38), *anthropomorphic* (*n* = 34), and *no-exposure* (*n* = 37).

**Procedure**

Participants on MTurk were invited to answer an online survey about how they would explain content from science TV to their preschool-aged child. Participants first filled out a screener survey to ensure that they fit the required criteria (i.e., parent of a child between the ages of 3 and 6). Extra questions regarding parents' media use were also included to disguise the intended eligibility requirements. All eligible participants provided informed consent prior to beginning the survey.

Parents were then randomized into one of four conditions. Parents in the three exposure conditions watched a clip about each of the two topics (order counter-balanced). After each clip, they answered questions about what they saw. Parents in the no-exposure group answered all of the same questions without viewing any clips. The final set of questions asked about demographics. Parents received $2 in their MTurk accounts in exchange for participating. The survey took approximately 20 minutes (for the exposure conditions) and 13 minutes (for the no-exposure conditions).

**Materials**

Parents saw the same *Earth to Luna* clips used in Study 2.

**Measures**

Parents' endorsements of facts and misconceptions as accurate, their ratings of those facts and misconceptions as informative to children, their mentions of facts, misconceptions, refutations, and anthropomorphic statements in their science explanations, and their perceptions of the experimental clips were assessed in the online survey. Although parents' endorsements of facts and misconceptions and their ratings of those facts and misconceptions were conceptualized as mediators of the relationship between exposure to the show and the content of parents' science explanations, parents' endorsements and ratings were assessed after they provided their open-ended explanations. This was done to ensure that parents did not consider the content of their explanations in uncharacteristic ways. This also seemed to be a more ecologically valid survey structure, given that the reverse order (endorsements/ratings followed by open-ended explanations) might cause parents to invest more effort in providing higher-quality explanations than they otherwise would.

**Close-ended endorsements of facts and misconceptions.** Parents' endorsements of the same three explanations rooted in facts or misconceptions used in study 2 were assessed using the same six close-ended yes/no questions, modified for use with adults (e.g, "Here are ideas that some people have about why day turns to night. Please indicate if you think yes, that is what happens at night, or no, that's not what happens at night.")

**Ratings of scientific facts and misconceptions as informative to children.** Parents were given a randomized list of the three facts and three misconceptions introduced in the show. They were given the entire list regardless of which statements that had previously endorsed as accurate or inaccurate, given prior research suggesting that adults will use inaccurate information in their explanations to children despite knowing that such information is false (Vlach & Noll, 2016). They were asked to read each statement and consider how informative that statement would be for teaching children about the day/night cycle or about butterfly feet (1 = *very uninformative*, 5 = *very informative*).

**Open-ended science explanations.** After each clip, parents were instructed: "Imagine that you watched this clip with your child. After watching it, your child asks you the following questions. Please respond as you naturally would." The two questions posed for the day/night clip were: "Why does day turn into night?" and "What happens to the sun at night?" The two questions posed for the butterfly clip were: "Why do butterflies wiggle their feet?" and "What is special about butterfly feet?" Question order was randomized. Parents typed their responses, and each explanation was coded for parents' mentions of facts, misconceptions, refutations, and anthropomorphism.

***Mentions of facts, misconceptions, and refutations.*** Parents' explanations were coded for the same three facts and misconceptions coded in Study 2. The presence of each fact or misconception was only counted once, so if parents repeated the same fact or misconception in different ways (i.e., "the sun moves," and "the sun goes across the sky"), they received only one point. An example fact about the day/night cycle was: "Day turns into night because the world is constantly spinning." An example fact about butterflies was: "Butterflies feet wiggle to pollinate flowers to make them grow." An example misconception about the day/night cycle was: "The sun goes to the other side until it comes back around to our side." An example misconception about butterflies was: "They wiggle their feet to relieve the itch on their body." Parents' scores were collapsed across both questions for each topic, so their scores could range from 0 to 3 for both their *mentions of facts* and their *mentions of misconceptions.*

This measure of parents' mentions of misconceptions only included instances where those misconceptions remained uncorrected (e.g., " the sun hides at night"). Cases where parents mentioned a misconception for the purposes of identifying it as inaccurate (e.g., "the sun doesn't hide") were included in a separate measure of parents' *mentions of refutations*. An example refutation about the day/night cycle was: "The sun doesn't go anywhere at night, it keeps shining where it is." Parents never provided any refutations about butterflies. Parents' scores were collapsed across both questions for each topic.

***Mentions of anthropomorphic statements.*** Anthropomorphic statements were those that applied any human-like qualities to the focal science concepts in each clip that those concepts did not naturally possess. Building on work from Ganea et al. (2014), three categories of anthropomorphism were coded: physical behaviors (e.g., talking), emotional experiences (e.g., feel love), and social experiences (e.g., having friends). Unlike facts and misconceptions, the presence of each unique occurrence of anthropomorphism was counted. Parents' scores were collapsed across both questions for each topic for each type of anthropomorphism.

***Reliability coding.*** All coding was initially conducted by the first author. To assess reliability, a research assistant trained on the coding scheme also coded all parents' responses. Inter-coder reliability was assessed using the KALPHA macro in SPSS to calculate Krippendorf's alpha (Hayes & Krippendorf, 2007). Reliability was achieved for facts (alpha = .86), CI [.81, .91]; misconceptions (alpha = .88), CI [.80, .96]; refutations (alpha = .89 CI [.79, .95]; physical anthropomorphism (alpha = .95), CI [.70, 1.00]; emotional anthropomorphism (alpha = .86), CI [.73, .97]; and social anthropomorphism (alpha = .90), CI [.76, 1.00]. Where ratings differed by 1 point or less, discrepancies between the two coders were resolved by averaging the two scores. Where ratings differed by more than 1 point, discrepancies were resolved through discussion.

**Parent perceptions of the show.** For each clip, parents responded to two statements on a 7-point scale (1 = *completely disagree*, 7 = *completely agree*) that gauged *perceived child learning* (i.e., "My child would learn something new from watching this episode," and "This episode would teach my child about the main science concept in the episode," $r = .78$, $p < .001$), *perceived child enjoyment* (i.e., "My child would enjoy watching this episode" and "This episode would be fun for my child to watch," $r = .81$, $p < .001$), and *intent to show their child* (i.e., "I would show this episode to my child" and "I would show my child other episodes of this show," $r = .76$, $p < .001$).

**Covariates.** A number of variables were measured as possible covariates.

***Age.*** Parents reported their age and their child's age (in years).

***Gender.*** Parents separately indicated their gender and their child's gender as male (coded as 0) or female (coded as 1).

***Race.*** Parents were asked to select as many categories that described their race (White, Asian, Hispanic, Black, Native American, or other). Parents were categorized as White (coded as 1) or non-White (coded as 0).

***Level of education.*** Parents indicated the highest level of education they achieved, including "some high school or less," "High school/GED," "some college/associate's degree," "college graduate," and "professional/graduate degree or training."

***Religious beliefs.*** Based on measures used by Braswell et al. (2013), parents were asked to rate whether they believed in six religious figures and concepts (i.e., God, faith healing, angels, prayer, spirits, and miracles) on a 7-point scale (1 = *definitely no*, 7 = *definitely yes*) ($M$ = 3.71, $SD$ = 2.15, $\alpha$ = .97).

***Magic beliefs.*** Based on measures used by Braswell et al. (2013), parents were asked to rate whether they believed in three magical concepts (i.e., astrology, good luck charms, and magic) on a 7-point scale (1 = *definitely no*, 7 = *definitely yes*) ($M$ = 2.52, $SD$ = 1.61, $\alpha$ = .80).

***Parent science attitudes.*** Parents responded to the same 12 questions used in Study 2. Consistent with Study 2, a principal components factor analysis indicated that these items all loaded on to the same factor, so they were collapsed into the same measure ($M$ = 5.50, $SD$ = 1.26, $\alpha$ = .96).

## Results

Preliminary analyses indicated that parent age, child age, parent gender, child gender, parent race, level of education, religious beliefs, magic beliefs, and science attitudes did not significantly differ between conditions. In an effort to systematically address RQ2 (which asked whether parent or child gender would moderate the effects of condition), parent and child gender were included in all analyses. Other covariates were not included in the MANOVA analyses that focused on the effects of condition (given their lack of variation between conditions), but they were included in subsequent path analyses examining the mediating processes by which condition affected parents' science explanations.

**Initial analyses examining effects of topic.** Although effects of topic were not explicitly hypothesized, it was initially included as a within-subjects main effect in all analyses. Results indicated that topic never interacted with condition to predict any outcome. Thus the current analyses are collapsed across topic.

### Parents' Science Explanations

The first set of hypotheses dealt with the effects of condition on parents' close-ended endorsements of scientific facts and misconceptions as accurate, their ratings of those facts and misconceptions as informative to children, and their mentions of facts, misconceptions, and refutations in their science explanations to their children. These hypotheses were tested using a multivariate analysis of variance (MANOVA). Condition (factual vs. refutation vs. anthropomorphic vs. no-exposure), parent gender (male vs. female), and child gender (male vs. female) were included as main effects. The seven outcomes (listed above) were included as dependent variables. Post-hoc comparisons between the no-exposure condition and the three exposure conditions were assessed using Dunnett's t-tests, which are recommended when comparing multiple treatment groups against a single control group. For comparisons among the three exposure conditions, Sidak corrections were used to correct for multiple comparisons.

Results of this MANOVA indicated a significant multivariate effect of condition, $F(21,342) = 2.06$, $p < .01$, Wilks $\Lambda = .71$, $\eta p^2 = .11$, and a significant multivariate effect of child gender, $F(7,119) = 2.15$, $p < .05$, Wilks $\Lambda = .89$, $\eta p^2 = .11$. There was no multivariate effect of parent gender, nor any significant multivariate interactions between condition and gender. Given the significant multivariate effect of condition, hypotheses were assessed by inspecting the univariate effects of condition on each outcome.

**Parents' endorsements of facts and misconceptions.** H1 stated that parents in each of the three exposure conditions would endorse more scientific facts as accurate compared to parents in the no-exposure condition. Examination of the univariate effects of condition indicated a significant effect on parents' endorsements of facts as accurate, $F(3,125) = 8.22$, $p < .001$, $\eta p^2 = .17$. Consistent with H1, parents in each of the three exposure conditions endorsed more scientific facts as accurate compared to parents in the no-exposure condition (see Figure 9).

H2 stated that parents in the refutation condition would endorse fewer scientific misconceptions as accurate compared to parents in the no-exposure condition. However, the univariate effect of condition on parents' endorsements of misconceptions as accurate was not significant, and H2 was not supported. Parents' endorsements of misconceptions as accurate were relatively low across all conditions (see Figure 9).

The univariate effect of child gender was not significant for either outcome.

**Ratings of facts and misconceptions as informative to children.** H3 stated that parents in each of the three exposure conditions would rate scientific facts as more informative to children compared to parents in the no-exposure condition. Examination of the univariate effects of condition indicated a significant effect on parents' ratings of facts as accurate, $F(3,125) = 3.33$, $p < .05$, $\eta p^2 = .07$. Consistent with H3, parents in each of the three exposure conditions rated facts as more informative to children compared to parents in the no-exposure condition (see Figure 10).

H4 stated that parents in the refutation condition would believe that scientific misconceptions are less informative for children compared to parents in the no-exposure condition. However, the univariate effect of condition on parents' ratings of misconceptions was marginally significant ($p = .07$), and H4 was not supported (see Figure 10).

The univariate effect of child gender on parents' ratings of misconceptions as informative was significant, $F(1,125) =7.61$, $p < .01$, $\eta p^2 = .06$. Parents of daughters rated misconceptions as more informative to children ($M = 2.51$, $SE = .13$) than parents of sons ($M = 1.98$, $SE = .14$). The univariate effect of child gender on parents' ratings of facts was not significant.

**Mentions of facts, misconceptions, and refutations.** H5 stated that parents in each of the three exposure conditions would mention more facts in their science explanations to their children compared to parents in the no-exposure condition. Examination of the univariate effects of condition indicated a significant effect on parents' mentions of facts in their science explanations, $F(3,125) = 9.00$, $p < .001$, $\eta p^2 = .18$. Consistent with H5, parents in each of the three exposure conditions mentioned more facts in their science explanations than parents in the no-exposure condition (see Figure 11).

H6 stated that parents in the refutation condition would mention fewer misconceptions in their science explanations compared to parents in the no-exposure condition. Examination of the univariate effects of condition indicated a significant effect on parents' mentions of misconceptions in their science explanations, $F(3,125) = 2.69$, $p < .05$, $\eta p^2 = .06$. Consistent with H6, parents in each of the three exposure conditions mentioned fewer misconceptions in their science explanations than parents in the no-exposure condition (see Figure 11).

H7 stated that parents in the refutation condition would mention more refutations in their science explanations compared to parents in the no-exposure condition. However, the univariate effect of condition on parents' mentions of refutations was not significant, and H7 was not supported. Parents mentioned relatively few refutations in their explanations across all conditions (see Figure 11).

Additionally, the univariate effect of child gender on parents' mentions of refutations was significant, $F(1,125) =3.76$, $p < .05$, $\eta p^2 = .03$. Parents of daughters were more likely to mention refutations ($M = .06$, $SE = .01$) than parents of sons ($M = .02$, $SE = .01$). The univariate effect of child gender on parents' mentions of facts and misconceptions was not significant.

**Summary.** Compared to parents in the no-exposure group, parents in each of the three exposure conditions endorsed more scientific facts as accurate, rated those facts as more informative to children, and mentioned more facts in their science explanations. In general, parents endorsed few misconceptions as accurate, and their tendency to do so did not differ by condition; additionally, parents across all conditions rated misconceptions as equally informative to children. Despite this lack of effects on parents' ratings of misconceptions, parents in each of the three exposure conditions were less likely than parents in the no-exposure condition to mention misconceptions in their open-ended science explanations. Finally, although parent gender did not influence any outcome, child gender did play a role. Parents of daughters were more likely than parents of sons to rate misconceptions as informative to children and to mention refutations in their science explanations to their children.

## Path Analysis

Mediation hypotheses were tested using path analysis with the lavaan package in R (see Figure 8). The independent variable was condition (with each exposure condition dummy-coded in reference to the no-exposure condition). The mediators were parents' endorsements of facts and misconceptions as accurate and their ratings of those facts and misconceptions as informative to children. The outcomes were parents' mentions of facts and misconceptions in their science explanations.

**Fitting the model.** A number of covariates representing background characteristics of parents and their children were included in the model to assess their impact on each outcome variable, as well as to examine whether the condition effects identified in the previous MANOVA analysis would remain significant even after accounting for these variables. These covariates were parent and child age and gender, parent race (white vs. non-white), parents' religious beliefs, parents' magic beliefs, and parents' science attitudes.

Although parents' mentions of refutations in their science explanations was not included as an outcome variable in the model tested, this variable was also included as a covariate in the portion of the analysis predicting those two outcomes. Given that parents' ratings of facts and misconceptions as informative to children are likely rooted to some degree in their belief that such information is accurate, the residuals were correlated between parents' endorsements and ratings of facts, as well as between their endorsements and ratings of misconceptions.

Model fit was tested using maximum likelihood estimation, and four indices were used to assess fit (see Hu & Bentler, 1999): relative chi-square ($\chi^2$/df ratio; < 3.0 acceptable; Kline, 2005), comparative fit index (CFI; > .90 acceptable, > .95 excellent), root-mean-square error of approximation (RMSEA; < .08 acceptable, < .05 excellent), and the standardized root-mean-square error residual (SRMR; < .08 acceptable, < .05 excellent).

Although there was some indication that this model fit the data, one statistic (RMSEA) suggested a lack of fit, $\chi^2(12) = 31.68$, $p < .01$, $\chi^2$/df ratio = 2.64, CFI = .94, RMSEA = .11, 95% CI [.06, .15], $p < .05$, SRMR = .04. Assessment of the parameter estimates indicated that child age never emerged as a significant covariate for any outcome, so it was removed from further analyses. Additionally, inspection of the modification indices suggested that model fit could be improved by adding an additional path linking parents' ratings of misconceptions with their mentions of facts in their science explanations. Although this path was not explicitly hypothesized, it made conceptual sense (i.e., parents who rate misconceptions as less informative to children might be more likely to mention facts in their explanations relative to parents who rate those misconceptions as more informative). Thus this path was included in the model.

This revised model demonstrated acceptable to excellent fit on all four fit indices, $\chi^2(11) = 18.18$, $p = .08$, $\chi^2$/df ratio = 1.65, CFI = .98, RMSEA = .07, 95% CI [.00, .12], $p = .26$, SRMR = .03. Hypotheses were assessed using this model (see Figure 12). The indirect effects of condition on parents' mentions of facts and misconceptions are reported in Table 4.

**Path analysis results.** H8 stated that the positive effect of each of the three exposure conditions (relative to the no-exposure condition) on parents' mentions of facts in their science explanations would be mediated by their higher endorsement of scientific facts as accurate and their higher ratings of scientific facts as informative to children. In partial support of H8, results indicated a significant indirect effect of each of the three exposure conditions on parents' mentions of facts via their endorsements of those facts as accurate. That is, parents in each of the three exposure conditions mentioned more facts in their science explanations as a result of their increased endorsement of those facts as accurate. Contrary to H8, although each of the three exposure conditions positively predicted parents' ratings of facts as informative, this variable was not significantly related to parents' mentions of facts.

H9 stated that the effect of the refutation condition (relative to the no-exposure condition) on reducing parents' mentions of scientific misconceptions in their science explanations would be mediated by their decreased endorsements of scientific misconceptions as accurate and their lower ratings of those misconceptions as informative to children. Contrary to H9, no condition produced any changes in parents' endorsements of misconceptions as accurate, nor did parents' endorsements of misconceptions predict how many misconceptions they mentioned in their science explanations. However, in partial support of H9, results indicated a significant indirect effect of the refutation condition on parents' mentions of misconceptions via their ratings of those misconceptions as accurate. That is, parents in the refutation condition (relative to parents in the no-exposure condition) mentioned fewer misconceptions in their science explanations as a result of their lower ratings of those misconceptions as informative to children.

There was an additional indirect effect for parents in the refutation condition via the same mediator on their inclusion of facts in their science explanations. That is, parents in the refutation condition (relative to parents in the no-exposure condition) mentioned more facts in their science explanations as a result of their decreased ratings of misconceptions as accurate.

Unexpectedly, these same two indirect effects (i.e., on parents' mentions of facts and misconceptions via their ratings of those misconceptions) were significant for parents in the anthropomorphic condition, but not for parents in the factual condition. This lack of indirect effects in the factual condition is likely due to the marginally significant negative effect of the factual condition on parents' ratings of misconceptions relative to the no-exposure condition ($\beta$ = -.16, $p$ = .08).

**Covariate effects.** The effects of the covariates on each mediator and outcome variable are reported in Table 5. Regarding scientific facts, white parents (relative to parents of others races and ethnicities) and mothers (relative to fathers) rated more facts as accurate. Similarly, parent age emerged as a positive predictor of parents' endorsements of facts, while parents' belief in magic emerged as a negative predictor. Additionally, mothers (relative to fathers) rated facts as more informative to children, and parent age, science attitudes, and mentions of refutations emerged as positive predictors of their mentions of facts in their science explanations.

Regarding scientific misconceptions, parent age emerged as a negative predictor of their endorsements of misconceptions as accurate, while parent religious beliefs emerged as a positive predictor of their ratings of misconceptions as informative to children. Consistent with the previous MANOVA analyses, parents of daughters (relative to parents of sons) were more likely to rate misconceptions as informative to children. However, despite this finding, parents of daughters (relative to parents of sons) were less likely to mention misconceptions in their science explanations.

**Summary.** Consistent with the previous MANOVA analyses, each of the three exposure conditions increased parents' endorsements and ratings of facts relative to the no-exposure condition. However, contrary to the previous MANOVA analysis, inclusion of covariates and the covariance between conceptually related variables revealed an additional (hypothesized) direct effect of condition on parents' ratings of misconceptions. That is, exposure to the refutation and anthropomorphic clips (relative to no-exposure) decreased parents' ratings of misconceptions as informative. Moreover, there were significant indirect effects of condition on parents' increased mentions of facts (via their higher endorsements of those facts as accurate and their lower ratings of misconceptions as informative to children), as well as on parents' reduced mentions of misconceptions (via their lower ratings of those misconceptions as informative).

**Mentions of Anthropomorphic Statements**

H10 stated that parents in the anthropomorphic condition would be more likely to anthropomorphize science concepts in their science explanations than parents in the no-exposure condition. This prediction was tested used a repeated-measures ANOVA with Sidak corrections for multiple comparisons. Condition, parent gender (male vs. female), and child gender (male vs. female) were between-subjects factors, while anthropomorphic trait (physical vs. emotional vs. social) was a within-subjects factor. Results indicated a significant effect of condition, $F(3,125) = 7.01$, $p < .001$, $\eta p^2 = .14$. Contrary to H10, parents in each of the three exposure conditions (factual, $M = .01$, $SE = .01$; refutation, $M = .03$, $SE = .01$; anthropomorphic, $M = .01$, $SE = .01$) mentioned fewer anthropomorphic statements in their science explanations than parents in the no-exposure condition ($M = .09$, $SE = .01$). However, across all conditions, anthropomorphic statements were relatively rare (i.e., mean scores neared zero in all conditions).

There was an additional significant interaction between anthropomorphic trait and parent gender, $F(2,250) = 3.90$, $p < .05$, $\eta p^2 = .03$. Although there were no differences between mothers' and fathers' mentions of physical and social anthropomorphism, fathers were significantly more likely to mention emotional anthropomorphism ($M = .07$, $SE = .02$) than mothers ($M = .02$, $SE = .02$) $p < .05$.

**Post hoc-analysis of parents' mentions of anthropomorphic statements.** To assess the impact of covariates on parents' mentions of anthropomorphic statements (and whether inclusion of those covariates modified the effects of condition), three sets of regression analyses were conducted (one for each type of anthropomorphism). Step 1 included demographic information about the parent and their child (i.e., race, age, and gender). Step 2 included parents' religious/magic beliefs and science attitudes. Step 3 included each of the three exposure conditions (dummy-coded in reference to the no-exposure condition). In no cases were the first two steps these analyses significant, and no covariates individually predicted parents' mentions of anthropomorphic statements. However, even after accounting for these covariates, each of the three conditions continued to significantly (and negatively) predict parents' use of all three types of anthropomorphic statements in their science explanations relative to the no-exposure condition.

**Parents' Perceptions of the Show**

H11 predicted that parents' intent to expose their children to the show would be associated with their perceptions that their child would learn from and enjoy the show. This hypothesis was addressed using a regression analysis predicting parents' intent to expose their child to the show. Step 1 included demographic information about the parent and their child (i.e., race, age, and gender). Step 2 included parents' religious/magic beliefs and science attitudes.

Step 3 included parents' perception that their child would learn from and enjoy the show. Step 4 included the interaction term between these variables (see Table 6).

Consistent with H11, parents' perception that their child would learn from and enjoy the show positively predicted their likelihood of exposing their child to the show, even after controlling for demographic and other attitudinal variables. Notably, the effect of perceived child enjoyment was over twice as strong as the effect of perceived child learning. There was no interaction between these variables. Additionally, mothers (compared to fathers) reported greater intent of exposing their child to the show, and parents' science attitudes positively predicted parents' intent to expose their child to the show.

RQ1 asked if condition would modify these perceptions of the show. This question was addressed using a MANOVA. Condition, parent gender (male vs. female), and child gender (male vs. female) were included as main effects. The three outcomes were perceived child learning and enjoyment, as well as parents' intent to expose their child to the show. Sidak corrections were used to correct for multiple comparisons. Results indicated no multivariate effect of condition. However, there was a multivariate effect of parent gender, $F(3,90) = 4.07$, $p < .01$, Wilks $\Lambda = .88$, $\eta p^2 = .12$. Examination of the univariate effects indicated a significant effect of parent gender on all three outcomes: child learning, $F(1,92) = 8.28$ $p < .01$, $\eta p^2 = .08$, child enjoyment, $F(1,92) = 10.39$, $p < .01$, $\eta p^2 = .10$, and intent to show child, $F(1,92) = 12.25$, $p < .001$, $\eta p^2 = .12$. Although parents' ratings were high across all outcomes, mothers' ratings were consistently higher than fathers' ratings across all three outcomes (see Figure 13).

**Effects of Parent and Child Gender.**

RQ2 asked whether parent or child gender would moderate the effects of condition on any outcome. In no case did such interaction effects occur. However, as previously noted, mothers were more likely than fathers to endorse scientific facts as accurate, and they were more likely than fathers to rate scientific facts as informative to children. Additionally, parents of daughters rated misconceptions as more informative to children than parents of sons, and parents of daughters were more likely to refute misconceptions in their explanations than parents of sons. Although it is plausible that these findings could be interrelated (i.e., parents of daughters believe misconceptions are more informative *because* they believe they should be refuted), bivariate correlations indicated no relationship between these two variables. Additionally, parents of daughters (relative to parents of sons) were actually *less* likely to mention misconceptions in their science explanations.

## Discussion

Given prior research suggesting that adults often provide low quality science explanations to children during informal learning experiences (Crowley et al., 2001) that are influenced by external factors (Tare et al., 2011), Study 3 examined whether exposure to science television could enhance or degrade parents' science explanations to their preschool children.

### Parents' Science Explanations

**Parents' mentions of facts and misconceptions.** A path model was proposed that predicted the characteristics of parents' science explanations. Exposure to science television was expected to increase parents' endorsements of scientific facts as accurate, as well as their ratings of those facts as informative to children; it was also expected to decrease parents' endorsements of scientific misconceptions as accurate and their ratings of those misconceptions as informative to children. In turn, these effects were expected to increase parents' mentions of facts and decrease their mentions of misconceptions in their science explanations.

Initial MANOVA analyses indicated that condition had a direct effect on two of these mediators. Specifically, parents in each of the three exposure conditions (relative to parents in the no-exposure condition) endorsed more facts as accurate and rated those facts as more informative to preschoolers. A follow-up path analysis (which accounted for covariate effects and the covariance between mediators) also indicated that parents in the refutation and anthropomorphic conditions rated misconceptions as less informative to children than parents in the no-exposure condition.

In partial support of the predicted path model, two indirect effects of exposure on parents' mentions of facts and misconceptions were significant. First, each of the three exposure conditions increased parents' endorsements of scientific facts as accurate, which, in turn, increased their mentions of facts in their science explanations. Second, the refutation and anthropomorphic conditions decreased parents' ratings of misconceptions as informative to children, which, in turn, increased their mentions of facts and decreased their mentions of misconceptions in their science explanations. It is important to note that this model fit the data, despite a relatively small sample size.

Taken together, these findings suggest that exposure to science programming can enhance the quality of parents' science explanations. They also illuminate two key mechanisms by which these effects occur: by teaching parents new science information, as well as by reducing their belief that misconceptions are informative to children. Importantly, these effects were mostly consistent across all exposure conditions. Except for the marginal effect of the factual condition on parents' ratings of misconceptions as informative, parents' knowledge and explanations benefitted regardless of the type of depiction they viewed.

Interestingly, exposure to science television had no impact on parents' mentions of refutations in their science explanations, even for parents exposed to refutation narratives that explicitly modeled this type of explanation. However, parents' mentions of refutations was positively associated with their mentions of facts and negatively associated with their mentions of misconceptions in their science explanations. Future research should continue to examine the conditions under which parents spontaneously mention refutations in their explanations, as well as the impact that these refutations have on their children's learning.

**Covariate effects.** The path analysis conducted in the current study also examined the impact of a range of covariates on parents' explanations. A number of noteworthy relationships emerged. For example, parent age was a significant positive predictor of three beneficial outcomes: parents' increased endorsement of facts as accurate, their decreased endorsement of misconceptions as accurate, and their increased mentions of facts in their science explanations. This finding suggests that older (relative to younger) parents possess more science knowledge and generate more accurate science explanations to their children. Additionally, parents' science attitudes were positively associated with their endorsements and mentions of facts. Finally, parent religious beliefs positively predicted parents' ratings of misconceptions as accurate. Future research should continue to examine the effects of such demographic and attitudinal factors.

**Parents' mentions of anthropomorphic statements.** In general, parents rarely mentioned anthropomorphic statements in their science explanations. Despite these near floor effects, exposure to science television reduced this tendency even further. Given that much of the prior research on adults' use of anthropomorphism has been qualitative in nature (Gustavsson & Pramling, 2014; Thulin & Pramling, 2009), it is possible that the low levels of anthropomorphism found in the current study are explained by demand characteristics, such that participants were more cognizant of their performance because it was more obvious in the current study that they were being assessed on the quality of their explanations than it might have been in previous research settings (i.e., during observations of general classroom instruction; Thulin & Pramling, 2009).

The fact that exposure to science television reduced (rather than enhanced) the number of anthropomorphic statements that parents mentioned in their explanations ran contrary to predictions. Despite the unexpected nature of this result, it is somewhat understandable. Indeed, prior research has shown that adults tend to anthropomorphize concepts to children when they lack knowledge about subjects that they are asked to explain (Kallery & Psillos, 2003). Given that each of the three exposure conditions increased parents' science knowledge, it is possible that this new knowledge reduced their need to rely on anthropomorphism as a vehicle through which to deliver their explanations. Consistent with this notion, bivariate correlations suggested that parents' mentions of emotional and social anthropomorphism were negatively associated with their endorsements of scientific facts as accurate; additionally, parents' mentions of all three types of anthropomorphism were negatively associated with their mentions of facts and positively associated with their mentions of misconceptions in their science explanations. It would be useful for future research to build on the current findings by examining how exposure to science media influences parents' explanations regarding even more complicated topics that parents might otherwise struggle to explain to children.

**Effects of gender.** As previously mentioned, mothers (relative to fathers) were more likely to endorse science facts as accurate and to rate those facts as informative to children. Additionally, although prior research has found that parents (especially fathers) are less likely to deliver science explanations to their daughters during informal learning scenarios (Crowley et al., 2001), the current study identified a seemingly contradictory pattern: parents of daughters were *less likely* to mention misconceptions in their explanations than parents of sons, despite the fact that parents of daughters rated misconceptions as more informative to children than parents of sons.

It is unclear how to interpret these results. As previously noted, parents' ratings of misconceptions as informative were unrelated to their mentions of refutations, so it does not appear that parents believed misconceptions were informative *because* they needed to be refuted. However, it is possible that these findings represent distinct subgroups of parents within this one sample. That is, some parents of daughters might perceive misconceptions as informative, which leads them to mention more misconceptions in their explanations; conversely, some parents of daughters night believe that misconceptions need to be refuted, which leads them to mention more refutations in their explanations. Future research should further probe parents' gendered beliefs about science education, and how these beliefs factor into the ways that they discuss science with their children.

**Parents' Perception of Science TV**

Although prior work has found that the amount of educational media children are exposed to is predicted by parents' beliefs that their children would learn from and enjoy that content (Vaala, 2014; Vandewater et al., 2006), this was the first study to examine parents' perceptions of science television in particular. Results of a regression analysis indicated significant associations between parents' intent to show their child the science television show used in this study and their perceptions that their child would learn from and enjoy the show. Importantly, the effect of perceived child enjoyment was over twice as strong as perceived child learning. This finding suggests that parents are more concerned that their child enjoy (rather than learn from) science television, which echoes the findings of previous research demonstrating that preschool teachers care more that their children enjoy (rather than learn from) in-class science activities (Lee, 2006).

**Limitations**

The same limitations relevant to Study 2 also apply to the current study (i.e., the use of relatively short exemplars of only two science topics of only one children's show during a one-shot experiment). Of greater importance, though, is the fact that parents' science explanations were assessed in written form during an online survey that used generic question prompts, likely in total absence of their child. Although this design has the benefit of allowing for generalizations across parents, it lacks external validity. As previously noted, future research should examine face-to-face parent-child interactions around science media in either a lab-based or field study. This type of work would better illuminate the types of questions children spontaneously generate about science content, how parents react to those questions, and how these behaviors vary depending on the types of science depictions used.

# CHAPTER 5

## General Discussion

Because prior research on science television is limited, existing work is imbued with conflicting visions of hope and concern. Some researchers are hopeful (e.g., Stockmayler et al., 2010). After all, beneficial effects of exposure to science television have been documented for school-age children (Mares, Cantor, & Steinback, 1999; Rockman et al., 1996), and research has long demonstrated that educational television can teach preschool children about topics ranging from literacy to mathematics to social behavior (Fisch & Truglio, 2001). Additionally, early longitudinal work demonstrated that exposure to *Sesame Street* in preschool predicts high school students' interest in science and performance in science classes (Fisch & Truglio, 2001). Other researchers remain concerned (e.g., Waxman, Hermann, Woodring, & Medin, 2014). Both experimental and anecdotal evidence suggest that exposure to science storybooks can lead young children to interpret an array of scientific inaccuracies as scientific fact (Ganea et al., 2014; Mayer, 1995), and some researchers believe that television — with its dynamic, attractive, and fantastic visuals — might generate even more potent degradations in knowledge than print media (Marriot, 2002).

It is possible that each of these seemingly conflicting perspectives tells some aspect of the truth. However, the current research literature lacks clarity in how science concepts are depicted in children's science television shows, as well as how exposure to these different types of depictions influences the science knowledge of both children and their parents. Given the cognitive constraints that characterize preschool audiences, it is likely that the pedagogical strategies used to teach science to older children and adults might operate differently for younger viewers. The current project aimed to fill this gap by illuminating the potential for children's science television to promote or degrade the science explanations of both children and parents.

**The characteristics of modern children's science television.** Study 1 sought to describe the characteristics of children's science television shows, with a particular focus on the manner in which educational information is presented in these shows. Results showed that the majority of children's science programs were animated and mainly featured anthropomorphic casts of non-human characters. These shows were replete with educational lessons, most often regarding material about the life sciences or earth/space sciences. These lessons most often occurred during animated segments of the shows, and nearly half of all educational lessons featured at least one type of scientific inaccuracy. Importantly, when misconceptions were introduced during an educational segment, they were only explicitly refuted and corrected about half the time they occurred. Although anthropomorphism occurred less often than misconceptions, visual anthropomorphism was more common than verbal anthropomorphism, and almost all instances of visual anthropomorphism were of the "subtle" variety (i.e., non-human entities featured with human-like faces and socially interacting with other characters).

**The impact of exposure to children's science television.** Conceptual Change Theory suggests that refutation lessons (whereby scientific misconceptions are introduced, refuted, and corrected) are the most effective pedagogical strategy for teaching science concepts to adolescents and adults (Tippett, 2010). However, there are reasons to believe this strategy might be ineffective or even detrimental for teaching science to preschoolers when it is incorporated into children's educational television (i.e., their limited cognitive capacity, their fragmented knowledge networks, and their difficulty differentiating fact from fiction in science narratives; Fisch, 2000; Fisch et al., 1997). To test this possibility, Studies 2 and 3 experimentally manipulated an existing children's science program and examined how exposure to depictions of science with and without embedded scientific inaccuracies influenced the science explanations of both children and parents.

The findings across both studies led to one clear conclusion: exposure to the anthropomorphic clips (i.e., those containing anthropomorphic visuals during the final educational song) led to the most consistent beneficial outcomes. For children, the anthropomorphic clips improved the accuracy of their science explanations (assessed using both their open- and close-ended responses) to a greater extent than factual clips (i.e., those containing no inaccuracies) or refutation clips (i.e., those containing scientific misconceptions). For parents, the anthropomorphic clips improved the accuracy of their science explanations (relative to no-exposure) by increasing their endorsements of scientific facts as accurate and by reducing their belief that scientific misconceptions are informative to children.

Across both studies, the results for the factual and refutation clips were mixed. For children, the factual clips were slightly less effective at improving their science explanations than the anthropomorphic clips, while the refutation clips were completely ineffective at modifying their science explanations, for good or for ill. For adults, the factual clips led to similar overall improvements in their science explanations as the anthropomorphic clips, though this effect operated only via one mechanism (i.e., by imparting new factual knowledge) rather than two. The refutation clips functioned similarly to the anthropomorphic clips.

Taken together, these findings suggest new age-related boundary conditions for the predictions of Conceptual Change Theory. That is, refutation lessons appear ineffective at modifying preschoolers' science knowledge when they are left alone to engage with such material without adult input or feedback. However, these findings also add to existing literature on the benefits and drawbacks of visual anthropomorphism (Geerdts, 2016) by suggesting that these visuals can actually enhance preschoolers' learning from science television, at least under the specific set of circumstances tested in the current project. Future work should continue to examine children's difficulties comprehending refutation narratives, as well as the mechanisms that explain their increases in learning after exposure to anthropomorphic visuals.

**Implications for children's early science learning.** Should these results inspire hope or concern regarding the potential impact of children's science television on young viewers? One conservative takeaway is that few detrimental outcomes of exposure to science television (relative to no-exposure) were documented in the current project, even among parents and children exposed to depictions of science that prior research has deemed problematic (Ganea et al., 2014; Mayer, 1995). The worst result for children was their lack of learning in response to the refutation clips, and there were no detrimental results observed for adults. As such, the perspective that parents, teachers, or researchers should be concerned by children's exposure to science television is unsubstantiated by the current project. Given that prior research has found that well-intentioned educational television can have negative effects in some circumstances (e.g., children rationalizing social exclusion after watching a moral narrative promoting inclusion; Mares & Acosta, 2010; Mares & Acosta, 2008; see also Ostrov, Gentile, & Mullins, 2013), even the worst findings in the current project (e.g., lack of knowledge gain from the refutation clips) seem relatively benign by comparison.

Alternative takeaways are more hopeful. In many ways, exposure to science television benefitted both children and parents in the current project. Notably, one type of depiction presumed by past researchers to degrade learning (i.e., anthropomorphic visuals; Ganea et al., 2014; Waxman et al., 2014) was actually the most effective at modifying both children's and parents' science explanations in beneficial ways. Meanwhile, another type of depiction deemed effective by past researchers for teaching adults (i.e., refutation texts; Braasch et al., 2013; Tippet, 2010), was ineffective at modifying children's science explanations. These findings raise questions about what strategies work (and do not work) when teaching science to preschool audiences. More generally, however, these findings suggest a rather optimistic conclusion: when designed with the cognitive constraints of preschoolers in mind, children's science television could be a powerful tool for enhancing the quality of children's early science learning.

Of relatively equal importance, though, were the beneficial effects demonstrated among parent participants. Regardless of the type of depiction parents viewed, the effects were more or less equivalent: parents provided stronger science explanations to their children after viewing science television. This is the first study to provide evidence for the claim put forth by producers of this content that it can help parents become more effective teachers of science concepts (Bachrach et al., 2012). Because parents often lack science knowledge to answer children's questions (National Science Board, 2012), provide sub-optimal explanations when they do provide causal explanations (Vlach & Noll, 2016), and sometimes ignore their children's questions altogether (Frazier et al., 2009), these findings hint at one possible intervention for improving parents' science talk with their children.

Taken together, these findings have exciting implications for how early science education is approached at schools and in the home. Indeed, state-level curriculum standards expect preschoolers to master both science content- and process-knowledge skills during their early education. However, longitudinal work has found that children enter preschool performing at lower levels in science relative to other school readiness domains (e.g., literacy, creative arts, socio-emotional, etc.), and they show the fewest gains in science knowledge over the course of the academic year (French & Woodring, 2012; Greenfield et al., 2009). Additional longitudinal work has found that achievement gaps in science appear early in kindergarten and persist as late as eighth grade (Morgan et al., 2016). Preschool teachers report feeling underprepared to teach science content (relative to other topics), especially given the variety of other subjects they are pressured to cover during the school day (Greenfield et al., 2009). Because overcoming these obstacles would require investment in teacher education and strategic restructuring of already jam-packed school days, exposure to high-quality science television shows in the home could be considered a cost-effective intervention for improving children's early science knowledge without changes to current educational practices in schools.

Of course, the notion that such exposure would result in meaningful changes to children's early science knowledge rests on at least three suppositions that were not addressed in the current study. First, it supposes that exposure to science television actually produces beneficial shifts in children's science knowledge that last over time and transfer to new contexts. The current study is limited in that it only tested two science topics in a one-shot experiment. There were improvements in children's science explanations in the short-term, but it remains unclear whether this learning would hold over time or transfer to other scenarios outside the lab setting. Additionally, the parent report measure of children's exposure to science programming never emerged as a significant predictor of children's performance on any outcome in Study 2, which suggests that prior exposure to science programming did not enhance children's performance on the narrow set of outcomes measured here. Thus it is still unclear whether exposure to existing science television content actually improves children's science knowledge in meaningful ways.

Second, this notion supposes that most children's science programming is of high quality. The results of Study 1, however, demonstrated that educational lessons manifested in different ways in different science programs. That is, some shows contained more animation than others, some contained misconceptions while some contained none, and some utilized anthropomorphic characters and speech more than others. The quality of knowledge that children extract from exposure to science television is likely connected to the quality of the programs they view and the consistency with which they view them. The impact of these different types of depictions and shows on children's early science knowledge, epistemic curiosity, and ability to reason about evidence remains unclear.

Finally, this notion supposes that parents and children actually discuss this content in the home. Indeed, prior research has shown that children comprehend televised content better when they view with parents who talk to them and ask them questions about what they see (Strouse, O'Dojerty, & Troseth, 2013; Desmond, Singer, Singer, Calam, & Colimore, 1985). Additionally, Study 3 showed that parents understood the content in these programs well and were able to translate it into accurate explanations to their children. Given these results, it is possible that parents could correct confusions that their children have in response to viewing these programs. However, for such interactions to be successful, children must reveal that they believe a misconception, their parents must recognize and sufficiently correct that misconception, and children must understand these corrections and revise their knowledge. As described in the literature review for the current project, there are many ways in which this process might be derailed.

These limitations provide two ripe avenues of future research. First, more research is needed that examines the effects of children's exposure to a wider variety of science content, including other science topics, other shows, and other methods of presenting science concepts within these shows. Importantly, as noted in Study 1, live-action content was relatively less prevalent in modern science programs than animated content. Although prior research suggests that children pay less attention to live-action (rather than fantasy or animated) material (Fisch & Truglio, 2001), separate research also shows that they have more difficulty transferring lessons learned in fantasy (rather than realistic) settings to new contexts (Richert & Smith, 2011). Uncovering content designs that maximize both children's learning and transfer will be an important goal for future research, especially in circumstances where children view this content repeatedly over time.

Second, as noted in both Studies 2 and 3, more research is needed that examines how children and parents interact around this content in realistic settings. It will be important to understand whether or not parents tend to view this content with their children, whether or not they discuss the content with their child while viewing, and whether or not these conversations reflect high- or low-quality educational exchanges. The implications of such interactions for children's learning should also be assessed.

**Conclusion**

This chapter began with a discussion of hope. While the results of the current project provide at least a glimmer of optimism regarding science television's potential to contribute to positive shifts in children's early science learning, far more research is required to understand whether or not this is the case. Such research will continue to inform the design of science television programs in ways that should maximize their benefits for both child and parent viewers.

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Table 1

*Study 1 Examples of Misconceptions in Science Programs*

| Science Concept | Misconception |
|---|---|
| **Peep** | |
| Characteristics of caterpillars | *Caterpillars are walking/talking sticks.* |
| Characteristics of falling stars | *Falling stars are stars that have dropped out of the sky.* |
| States of matter | *Snow disappears when it gets warm because people steal it.* |
| **Dinosaur Train** | |
| Day/night cycle | *The sun moves behind the moon at night.* |
| **Wild Kratts** | |
| Dodo bird extinction | *Pirates caused the extinction of Dodo birds.* |
| **Earth to Luna** | |
| Characteristics of Mars | *Martians exist.* |
| **Cat in the Hat** | |
| How bees make honey | *Bees make honey with marshmallows and chocolate syrup.* |
| **Octonauts** | |
| Characteristics of penguins | *Penguins can fly.* |
| **Go Diego, Go** | |
| Tree growth | *Trees speak Spanish.* |
| Characteristics of manatees | *Manatees turn into mermaids.* |
| **Ready Jet Go** | |
| Characteristics of Goldilocks planets | *Goldilocks planets are made of solid gold.* |

Table 2
*Study 1 Examples of Verbal Anthropomorphism in Science Programs*

| Science Concept | Misconception |
|---|---|
| **Doki** | |
| Characteristics of telescopes | *Telescopes listen with radio waves.* |
| **Dinosaur Train** | |
| Characteristics of nocturnal animals | *Some animals enjoy being awake at night.* |
| **Octonauts** | |
| Characteristics of turtle eggs | *Turtle eggs feel fussy.* |
| Sea turtle predators | *Birds want to eat sea turtles.* |
| Characteristics of the Pacific octopus | *The Pacific octopus is curious.* |
| **Go Diego, Go** | |
| Characteristics of iguanas | *Iguanas feel afraid.* |

Table 3
*Study 2 Questions Assessing Children's Endorsements of Anthropomorphism*

| **Anthropomorphic Trait** | **Question** *(Do you think…?)* |
|---|---|
| ***Nighty Night, Sun*** | |
| *Physical* | …the sun sings and dances? |
| | …the sun talks? |
| *Emotional* | …the sun loves daytime? |
| | …the sun feels happy? |
| *Social* | …the sun plays games with the earth? |
| | …the sun is friends with the earth? |
| ***Butterfly Feet*** | |
| *Physical* | …butterflies sing and dance? |
| | …butterflies talk? |
| *Emotional* | …butterflies love flowers? |
| | …butterflies feel happy? |
| *Social* | …butterflies play games with other butterflies? |
| | …butterflies are friends with other butterflies? |

***Note.*** Children could respond "yes" (coded as 1) or "no" (coded as 0) for each question. Scores for each trait across topics could range from 0 to 2.

Table 4

*Study 3 Indirect Effects of Condition on Parents' Science Explanations*

| | **Mentions of Facts** | **Mentions of Misconceptions** |
|---|---|---|
| **Indirect Effect of Condition** | | |
| *(via endorsements of facts)* | | |
| Factual | .11** | — |
| Refutation | .11** | — |
| Anthropomorphic | .11** | — |
| **Indirect Effect of Condition** | | |
| *(via ratings of facts)* | | |
| Factual | .03 | — |
| Refutation | .02 | — |
| Anthropomorphic | .03 | — |
| **Indirect Effect of Condition** | | |
| *(via endorsements of misc.)* | | |
| Factual | — | .00 |
| Refutation | — | -.01 |
| Anthropomorphic | — | .00 |
| **Indirect Effect of Condition** | | |
| *(via ratings of misc)* | | |
| Factual | .04 | -.06 |
| Refutation | .07* | -.09* |
| Anthropomorphic | .09* | -.12** |

***Note.*** The indirect effects of condition on parents' mentions of facts and misconceptions via all four mediators are reported. Empty cells reflect indirect paths that were not tested in the final model. Coefficients are standardized, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5

*Study 3 Regressions Results for Covariates Included in the Revised Path Analysis Model*

| | **Mediators** | | | | **Science Explanation** | |
|---|---|---|---|---|---|---|
| | ***Endorsements of Facts*** | ***Ratings of Facts*** | ***Endorsements of Misc.*** | ***Ratings of Misc.*** | ***Mentions of Facts*** | ***Mentions of Misc.*** |
| | ***β*** | ***β*** | ***β*** | ***β*** | ***β*** | ***β*** |
| **Covariate** | | | | | | |
| *Parent race* | .14* | .08 | -.15 | .00 | -.04 | -.11 |
| *Parent age* | .16* | .09 | -.25*** | -.04 | .16** | -.13 |
| *Parent gender* | .22*** | .17* | -.10 | -.10 | -.03 | .02 |
| *Child gender* | .02 | -.02 | .02 | .21** | .04 | -.16* |
| *Parent religious beliefs* | .10 | -.01 | .03 | .21* | .05 | .00 |
| *Parent magic beliefs* | -.20* | .02 | .12 | -.04 | -.12 | -.04 |
| *Parent science attitudes* | .15 | .23* | -.18 | -.14 | .13* | .03 |
| *Mentions of Refute.* | — | — | — | — | .15* | -.14* |

***Note.*** The effects of each covariate included in the revised path analysis are reported. Empty cells indicate that a covariate was not included in that analysis. Coefficients are standardized, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 6
*Study 3 Regression Results Predicting Parents' Intent to Show Child the Science TV Program*

| | ***Intent to Show Child*** |
|---|---|
| | ***β*** |
| **Block 1: Demographics** | |
| *Parent race* (1 = *White*, 0 = *Other*) | .03 |
| *Parent age* | .21* |
| *Parent gender* (1 = *Female*, 0 = *Male*) | .33*** |
| *Child age* | .05 |
| *Child gender (1 = Female, 0 = Male)* | .13 |
| **$R^2$-change** | **.17**** |
| **Block 2: Background Variables** | |
| *Parent religious beliefs* | .15 |
| *Parent magic beliefs* | -.04 |
| *Parent science attitudes* | .28** |
| **$R^2$-change** | **.10**** |
| **Block 3: Clip Ratings** | |
| *Perceived child enjoyment* | .70*** |
| *Perceived child learning* | .26** |
| **$R^2$-change** | **.52***** |
| **Block 4: Interaction** | |
| *Perceived enjoyment*learning* | .08 |
| **$R^2$-change** | **.00** |

***Note.*** Regression results predicting parents' intent to show their child the science TV program used in the study are reported. Coefficients are standardized, * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 1
*Study 1 Examples of Visual Anthropomorphism*

Figure 1a
*Examples of Subtle Visual Anthropomorphism*

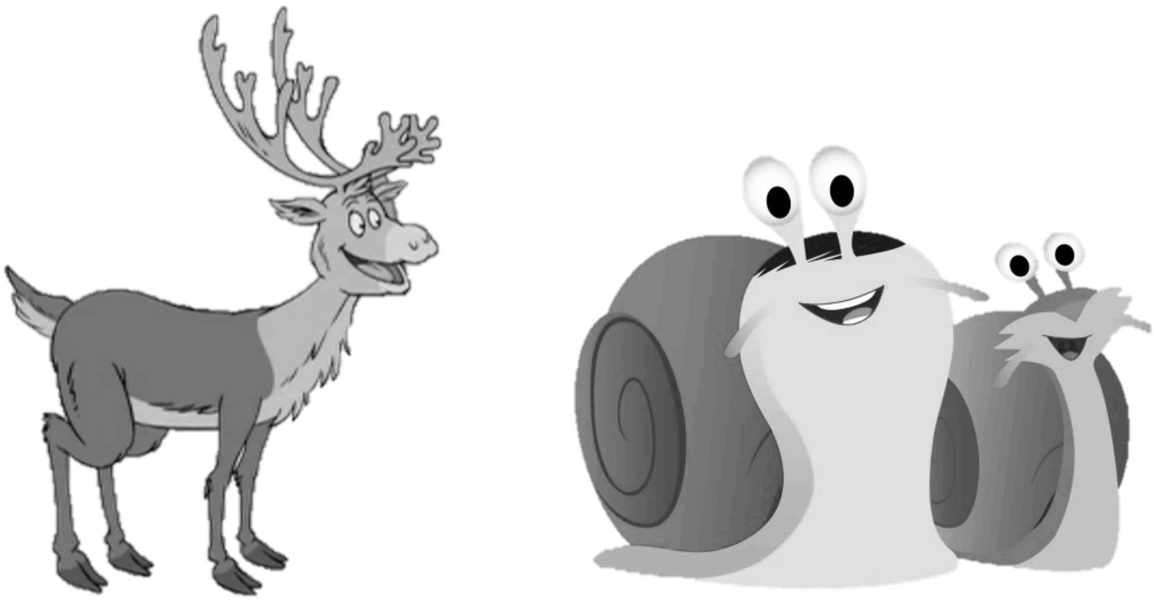


Figure 1b
*Examples of Extreme Visual Anthropomorphism*

Figure 2
*Study 1 Breakdown of Type of Science Lessons Taught*

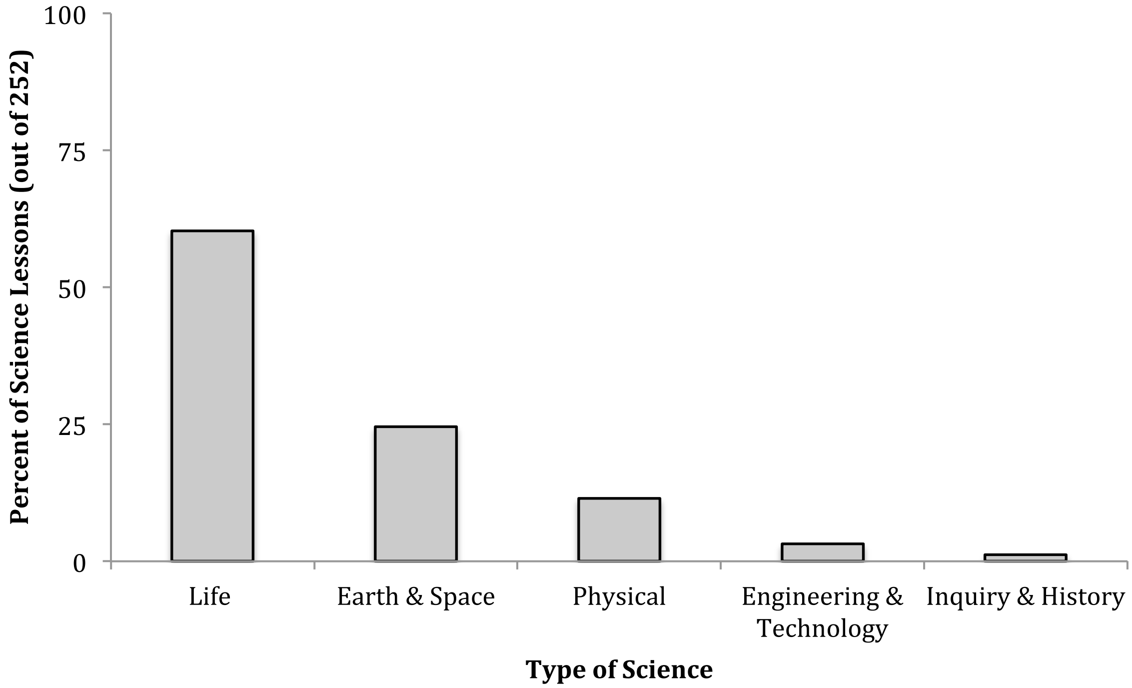


Figure 3
*Study 1 Presence of Scientific Inaccuracies During Educational Segments*

Figure 3a
*Prevalence of Misconceptions During Educational Segments*

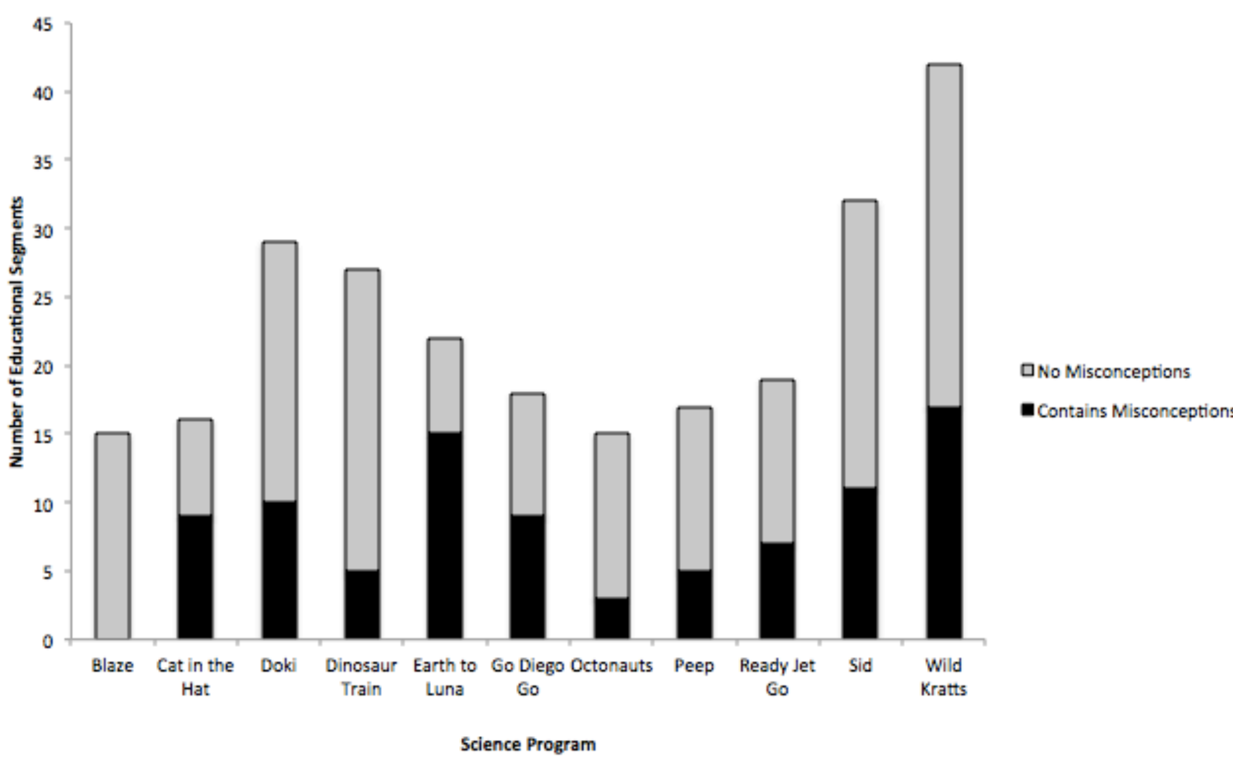



Figure 3b
*Prevalence of Anthropomorphism During Educational Segments*

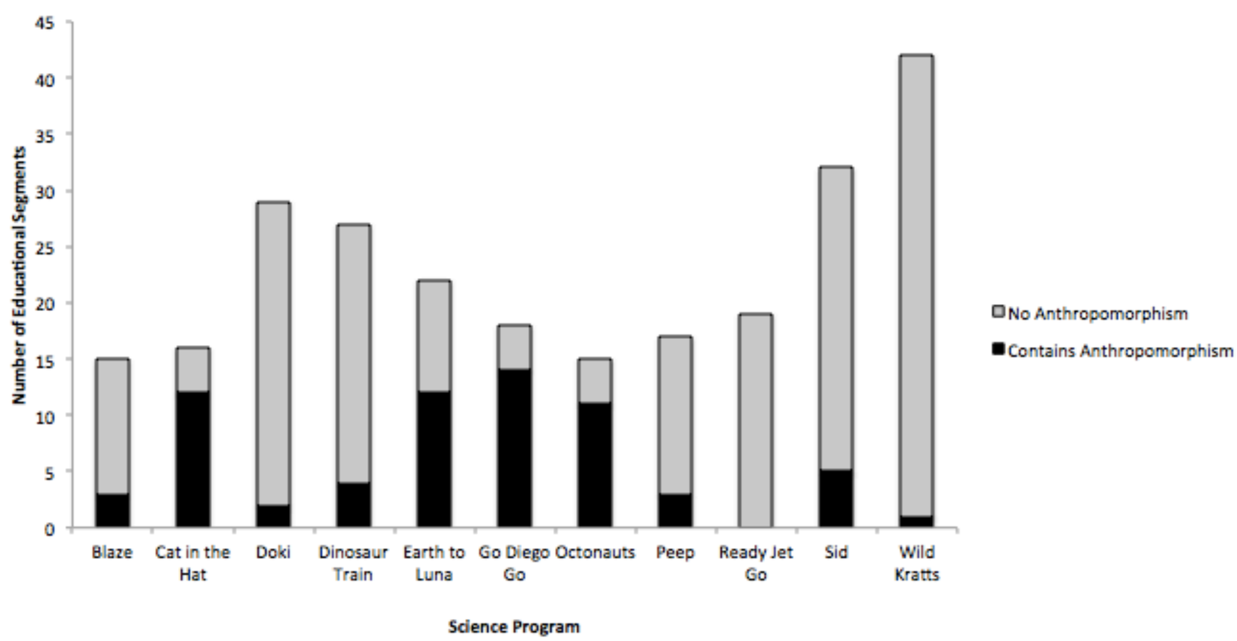


Figure 4
*Examples of Anthropomorphic Visuals in Experimental Clips*

Figure 4a
*Examples of Anthropomorphic Visuals in "Nighty Night, Sun"*

Figure 4b
*Examples of Anthropomorphic Visuals in "Butterfly Feet"*

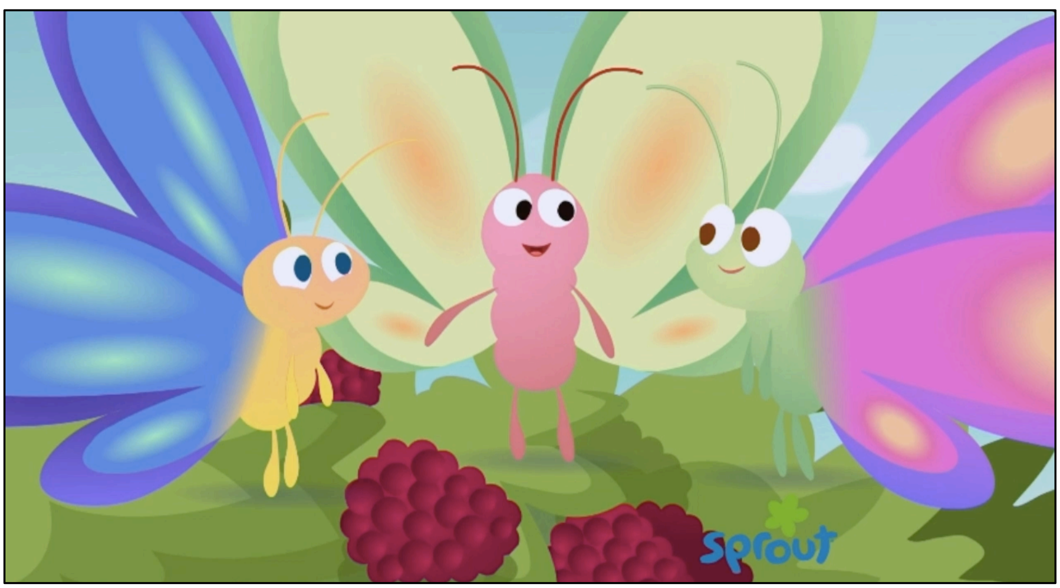


Figure 5
*Children's Mentions of Facts in Open-Ended Science Explanations*

Figure 5a
*Children's Mentions of Facts by Condition (Day/Night Cycle)*

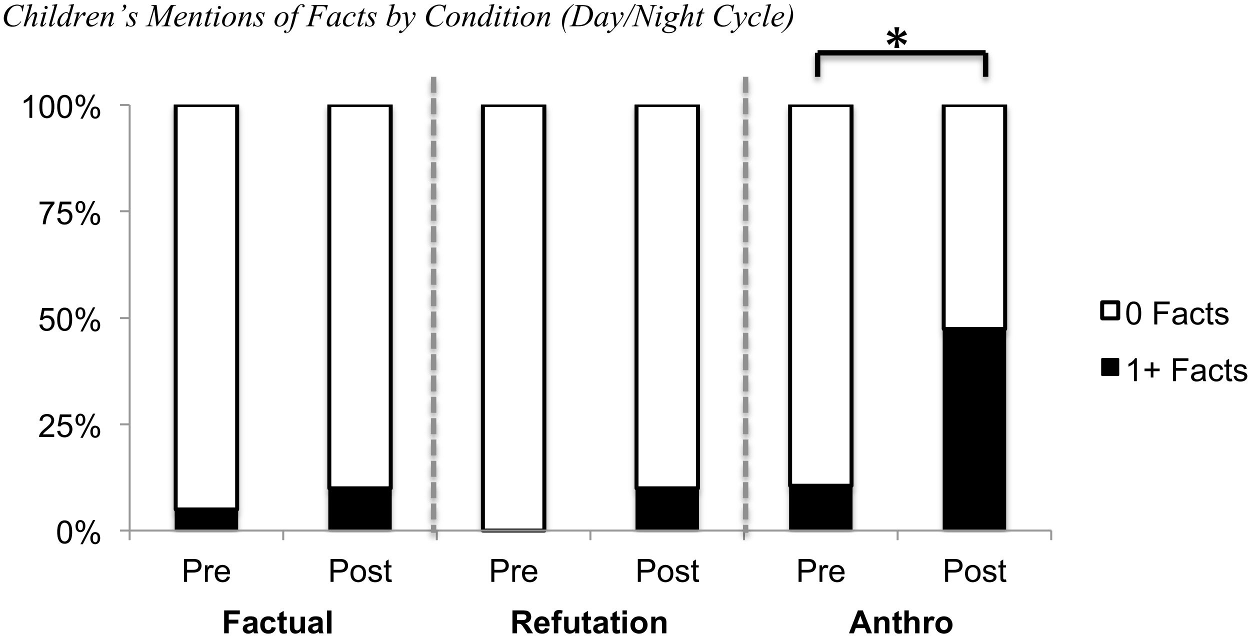
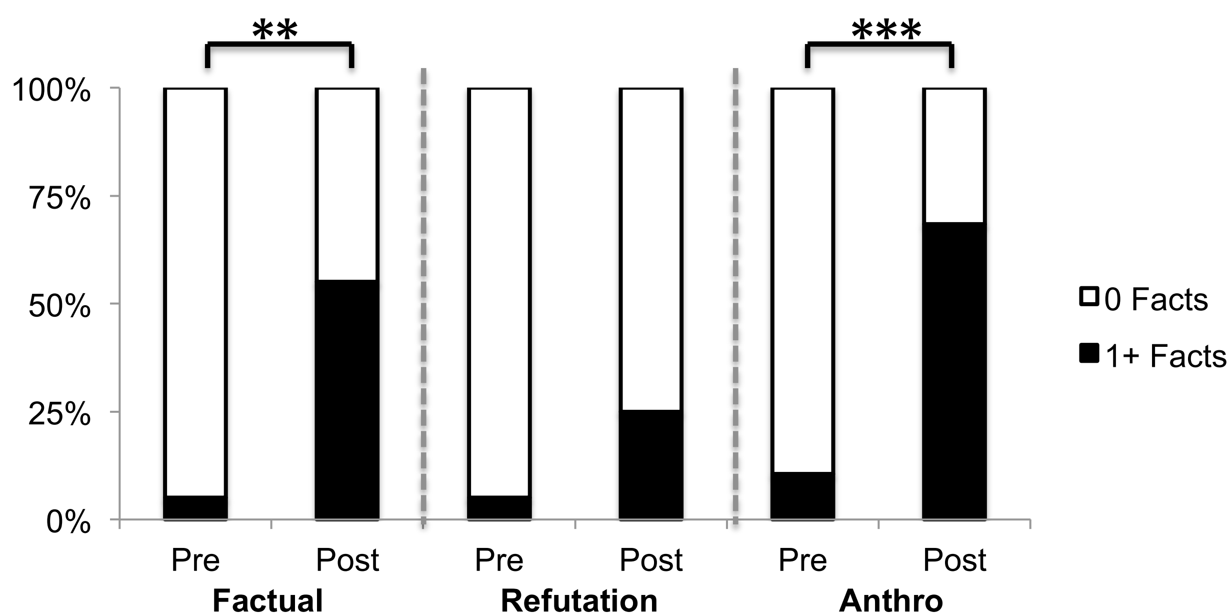



Figure 5b
*Children's Mentions of Facts by Condition (Butterfly Feet)*




*Note.* Black bars represent the percentage of children within each condition who mentioned at least one fact at pre- or post-test in their open-ended science explanations. McNemar's test was used within in each condition to test whether the proportion of children who mentioned at least one fact at post-test was significantly different than the proportion of children who mentioned at least one fact at pre-test. * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 6
*Children's Mentions of Misconceptions in Open-Ended Science Explanations*

Figure 6a
*Children's Mentions of Misconceptions (Day/Night Cycle)*

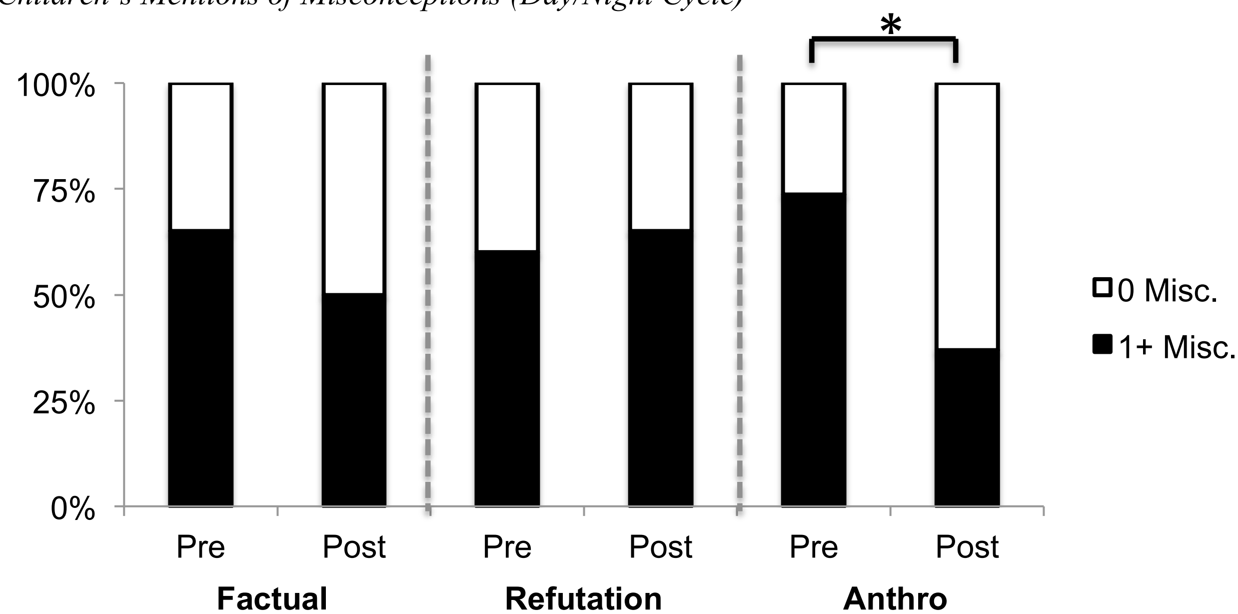
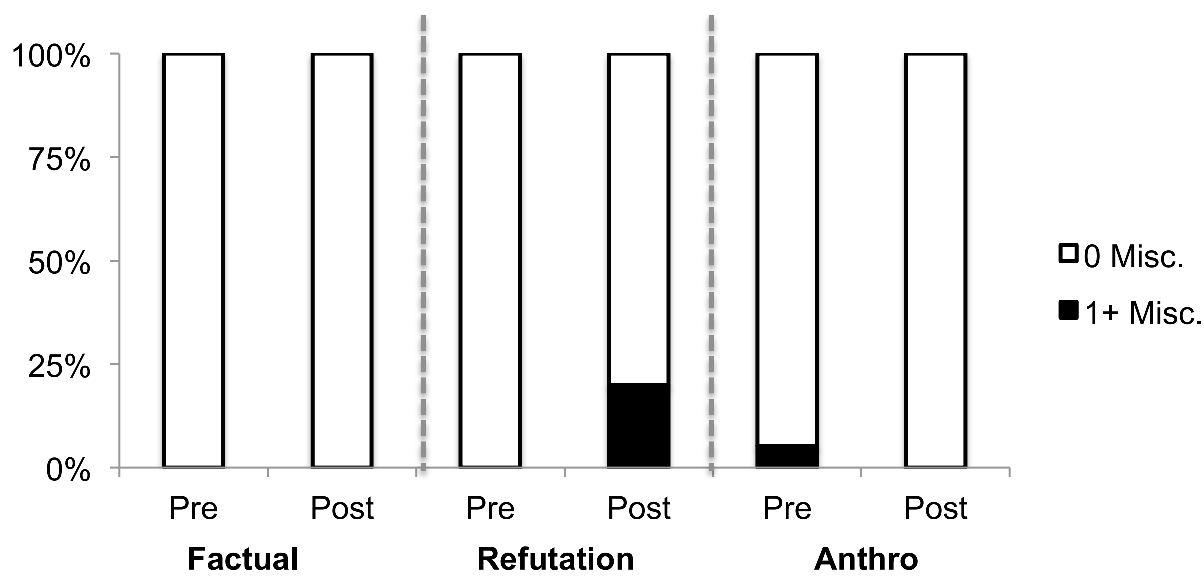


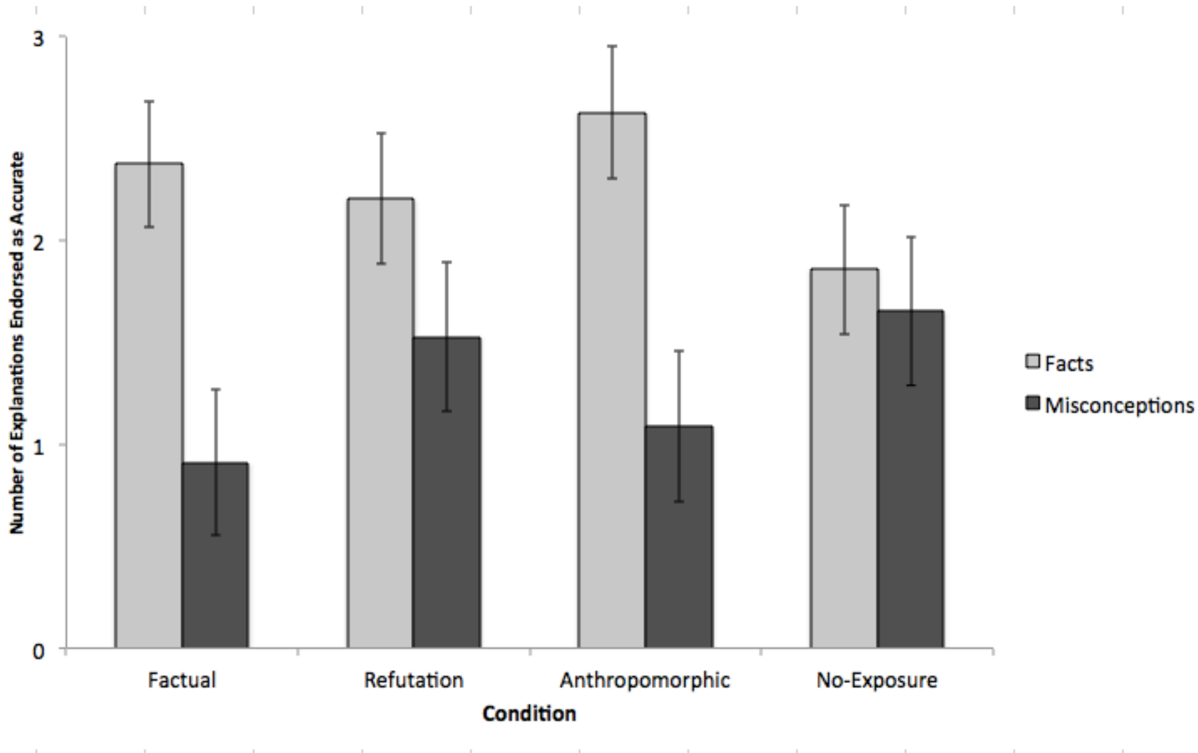

Figure 6b
*Children's Mentions of Misconceptions (Butterfly Feet)*




*Note.* Black bars represent the percentage of children within each condition who mentioned at least one misconception at pre- or post-test in their open-ended science explanations. McNemar's test was used within each condition to test whether the proportion of children who mentioned at least one misconception at post-test was significantly different than the proportion of children who mentioned at least one misconception at pre-test. * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 7

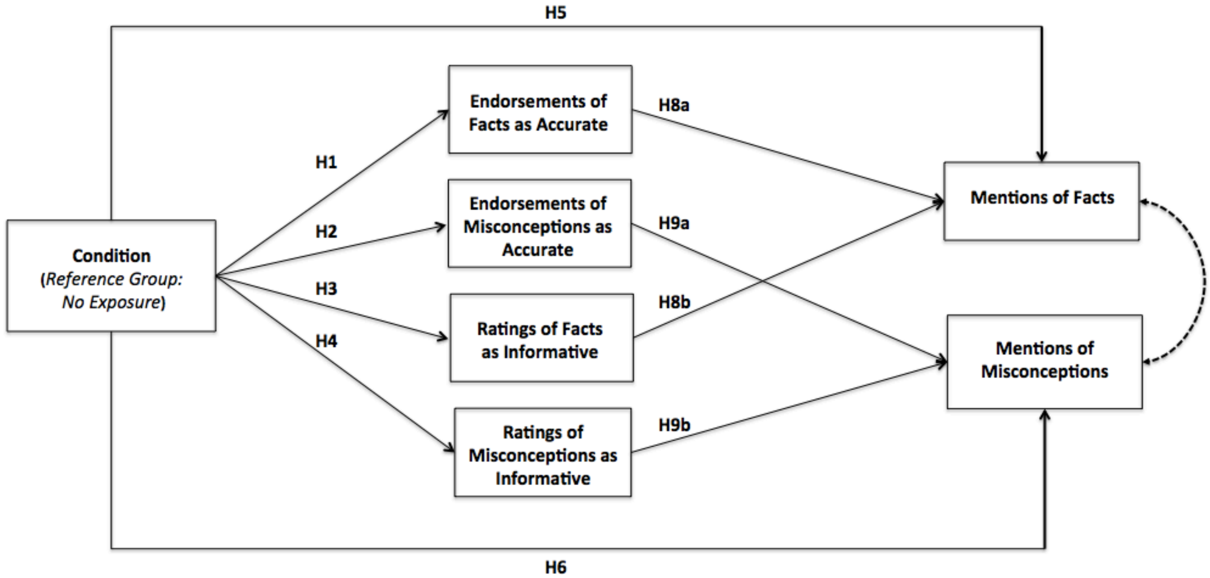
*Study 2 Children's Close-ended Endorsements of Scientific Facts and Misconceptions*




***Note.*** Scores could range from 0 to 3. Error bars represent 95% confidence intervals around the mean.

Figure 8

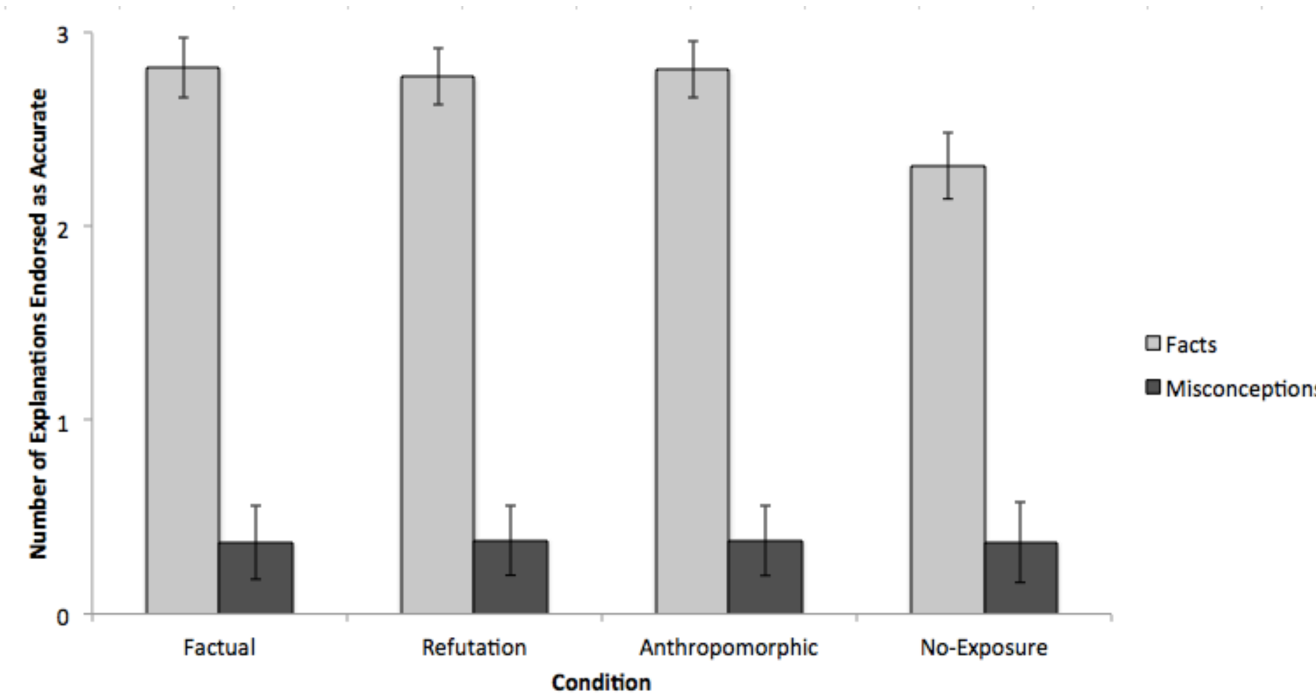
*Study 3 Conceptual Model of Mediation Hypotheses*




***Note.*** This conceptual model depicts the hypothesized impact of each of the three exposure conditions on four mediators, which were expected to explain the effect of condition on parents' mentions of facts and misconceptions in their science explanations. Hypotheses are labeled. H2 and H3 refer only to the effect of exposure to the refutation condition (not to the factual or anthropomorphic conditions).

Figure 9

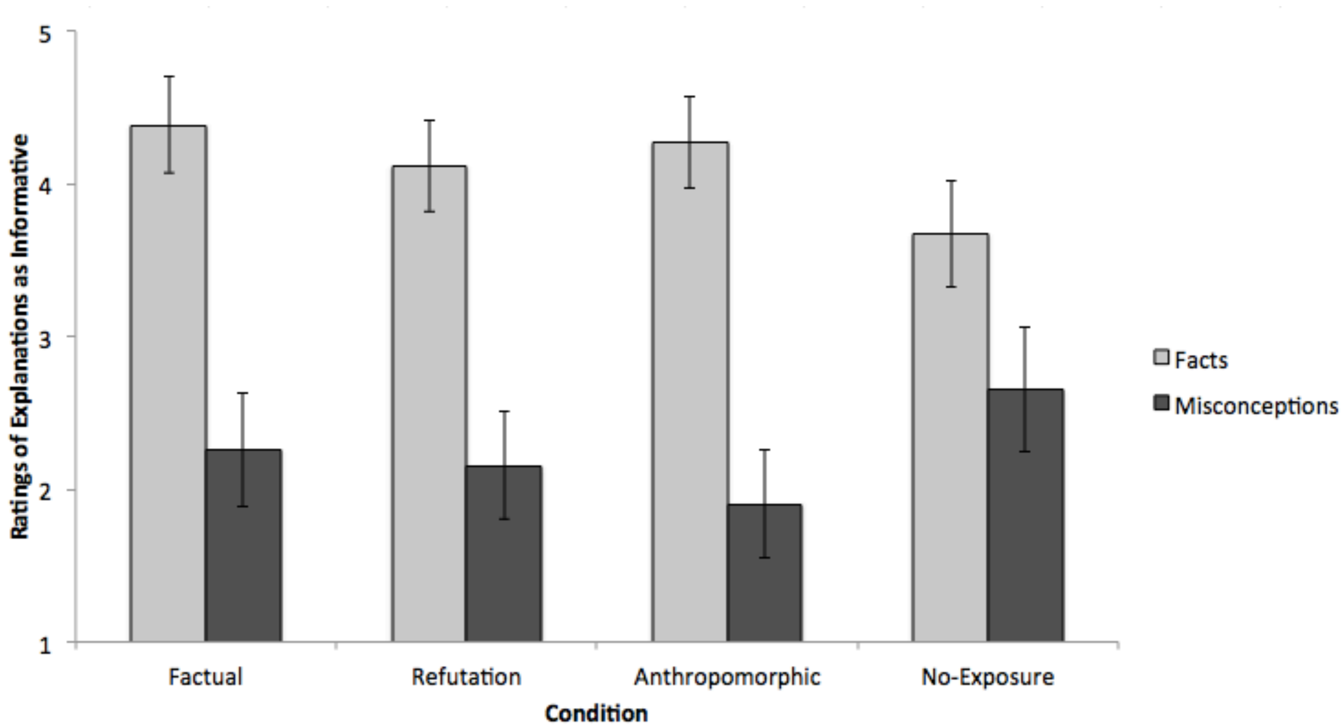
*Study 3 Parents' Close-ended Endorsements of Scientific Facts and Misconceptions*




***Note.*** Scores could range from 0 to 3. Error bars represent 95% confidence intervals around the mean.

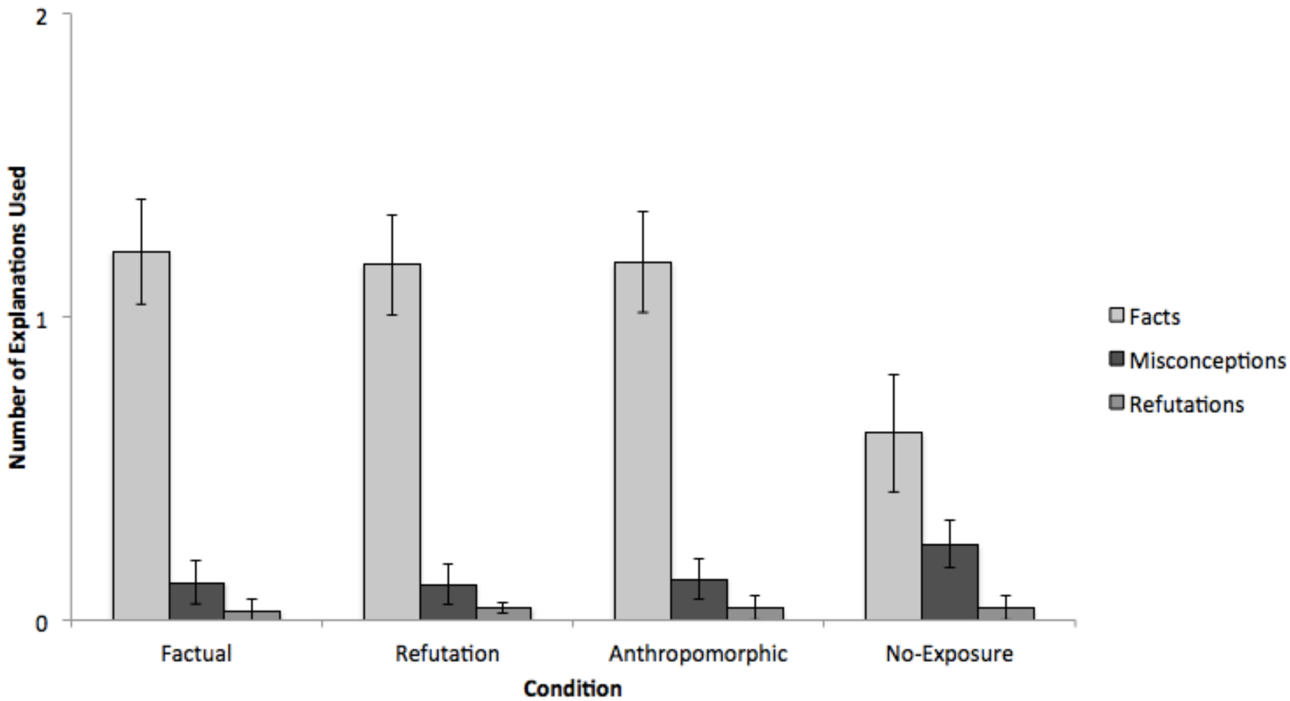
Figure 10

*Study 3 Parents' Ratings of Scientific Facts and Misconceptions as Informative to Children*




***Note.*** Parents responding using a 5-point rating scale (1 = *not at all informative*, 5 = *very informative*). Error bars represent 95% confidence intervals around the mean.

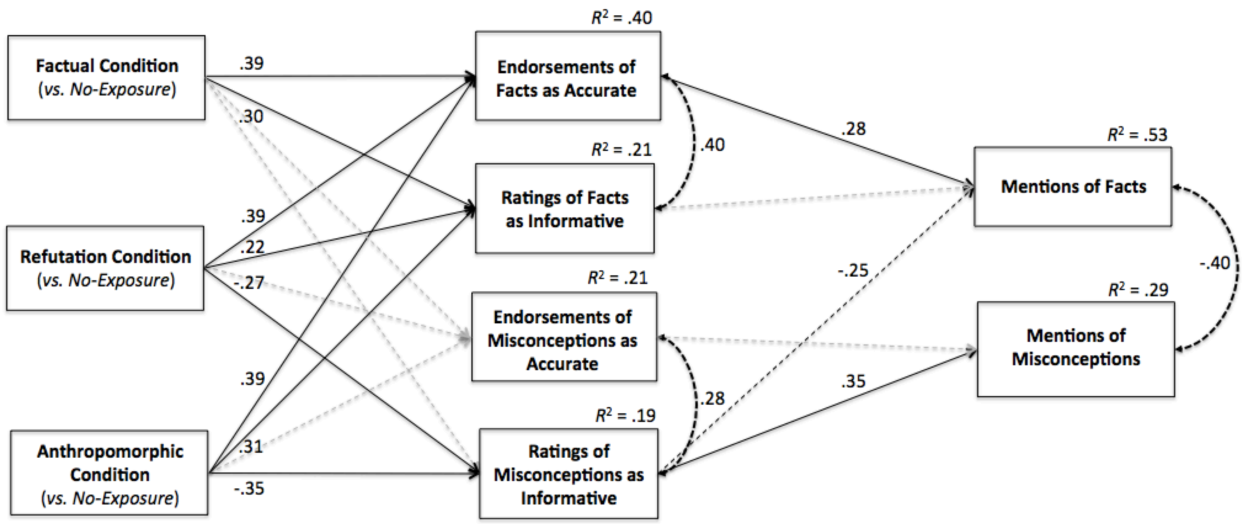
Figure 11
*Study 3 Parents' Mentions of Facts, Misconceptions, and Refutations*




***Note.*** Scores could range from 0 to 3. Error bars represent 95% confidence intervals around the mean.

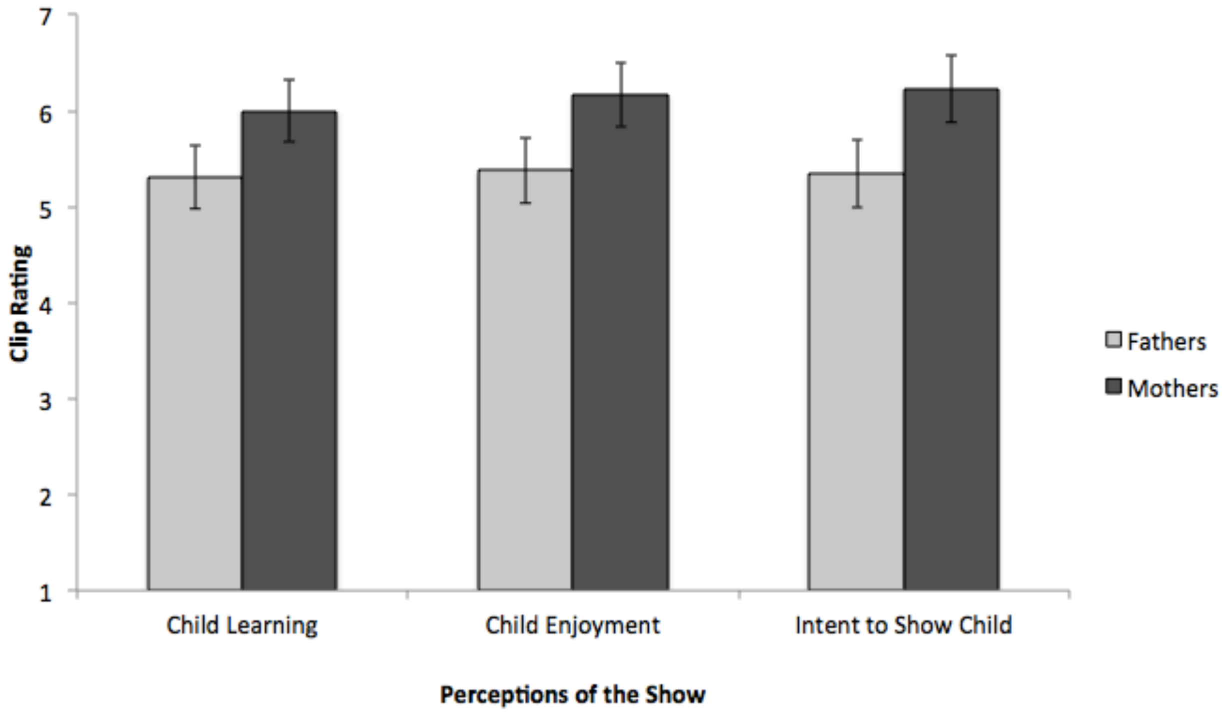
Figure 12

*Study 3 Path Analysis Predicting Parents' Science Explanations*




***Note.*** This revised statistical model depicts the effects of each exposure condition on parent's science explanations via four mediators. Fit statistics indicated that this model fit the data, $\chi^2(11) = 18.18$, $p = .08$, $\chi^2$/df ratio = 1.65, CFI = .98, RMSEA = .07, 95% CI [.00, .12], $p = .26$, SRMR = .03. Residuals were correlated between parents' endorsements and ratings of facts, as well as between their endorsements and ratings of misconceptions. Paths depicted in black (and their associated beta weights) are significant at $p < .05$. Paths depicted in grey were included in the model but were not significant. The dotted black path connecting parents' ratings of misconceptions with their use of facts was not hypothesized, but modification indices suggested that adding it would improve model fit. Seven covariates were included in the portion of the model predicting each mediator, and eight covariates were included in the portion of the model predicting parents' mentions of facts and misconceptions (see Table 13). Coefficients are standardized.

Figure 13
*Stud 3 Parents' Perceptions of the Show*




***Note.*** The effect of condition on parents' perceptions of the show (i.e., that their child would learn from and enjoy the show, and that they would expose their child to the show) was tested using a MANOVA. Parents responded to two questions for each outcome on a 7-point scale (1 = *completely disagree*, 7 = *completely agree*). Error bars represent 95% confidence intervals around the mean.