Explanatory Parent–Child Conversation Predominates at an Evolution Exhibit

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ABSTRACT: To investigate how parents support children's learning at an exhibit on evolution, the conversations of 12 families were recorded, transcribed, and coded (6,263 utterances). Children (mean age 9.6 years) and parents visited Explore Evolution, which conveyed current research about the evolution of seven organisms. Families were engaged

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with the exhibit, staying an average of 44 minutes. Parents' and children's explanatory, nonexplanatory, and evolutionary conversation was coded. Overall, substantive explanatory conversation occurred in 65% of parent utterances, whereas nonexplanatory conversation occurred in 21% of the utterances. We found substantial use of exhibit text by parents (12.9% of utterances) who read it aloud and reframed the text for their children. Parents also used evolutionary terms and evolutionary concepts (10.2%), showing that such an exhibit is a valuable way to introduce this difficult topic to elementary-school–aged children. Parents' use of explanatory conversation positively related to their children's use of explanatory and evolutionary conversation, indicating that a dialogic interchange was occurring. Parents' attitudes toward the exhibit content, particularly the issue of human evolution, related to the museum experience. Overall, this analysis shows that parents and children are having nuanced discussions and illustrates the potential of informal experiences in supporting children's learning of a complex topic. *Sci Ed* **95:**720–744, 2011

INTRODUCTION

Museums provide an opportunity for visitors to learn about science through self-directed, informal experiences that are often shared with family or friends. In contrast to the more formal settings of schools, learning in natural history museums and science centers is more likely to be free-choice, voluntary, and play-based (Falk & Dierking, 2000, 2010) with families often engaging in a dialogic interchange (Ash, 2003) in which parents relinquish some of the control of the conversation to the child (Leinhardt & Knutson, 2004). Such museums may provide interactive hands-on exhibits that encourage children to learn about complex topics by using the exhibit content as an educational resource while participating in fun, multisensory activities. However, it is not the case that family visits to such centers are unstructured; in their role as conversational partners, parents can focus attention, provide interpretation, and organize exhibit material to support children's learning (Leinhardt, Crowley, & Knutson, 2002).

Here we examine the nature of parent–child conversations at an evolution exhibit, called Explore Evolution. In this case, the exhibit development team presented a challenging and potentially controversial topic to families and other public audiences through iteratively developed graphics and interactive inquiry-based activities (Diamond & Evans, 2007; Diamond, Evans, & Spiegel, in press). On the basis of prior museum studies as well as developmental studies of parent–child conversation, we predicted that we would witness a complex interaction, including discussion of the scientific processes, using the types of supportive conversational strategies found in the prior work. We also predicted that family characteristics such as parents' knowledge and background would relate to the exchanges during the visit. However, given the nature of the topic, which was difficult for the parents as well as for the children, one key research question was whether the nature of the interaction might be more dialogic than didactic in this particular context. A dialogic interchange, with its focus on both parents' and children's explanations, discussion, and questioning, would be more likely to form the basis of a successful learning experience and model the kind of argument skills encouraged in formal as well as informal settings (Kuhn, 2010; Kuhn, Iordanou, Pease, & Wirkala, 2008; Lehrer, Schauble, & Lucas, 2008).

Parent–Child Conversations About Science

Through encouragement and coactivity, parents play an important role in socializing and influencing children's participation in mathematics and science activities outside of school (Simpkins, Davis-Kean, & Eccles, 2005). These activities, such as visiting museums together, include opportunities for learning and play and may provide a foundation for future science learning (Falk & Dierking, 2010). Research on different types of interactions at museums shows that children spend more time at exhibits when they are with their parents than when they are alone or with peers (Crowley et al., 2001a). Examinations of parent–child conversation in museums have also shown that parents use this time to guide learning in different ways, including directing children's attention, engaging children in discussion, and using specific teaching strategies such as asking *wh*-questions and making comparisons between the exhibit and real-world knowledge (Allen, 2002; Ash, 2003; Benjamin, Haden, & Wilkerson, 2010; Callanan & Jipson, 2001; Crowley et al., 2001a; Crowley, Callanan, Tenenbaum, & Allen, 2001b; Haden, 2010; Palmquist & Crowley, 2007; Valle & Callanan, 2006).

In the current study, one of our main foci is the nature of parent and child explanations as a means of navigating the complex topic of evolution. Research in developmental psychology has demonstrated that participation in parent–child conversation can be a rich source of explanatory information for children (Harris & Koenig, 2006; Hickling & Wellman, 2001) and that children, starting as early as 2.5 years old, actively seek explanatory information from adults by asking causal questions (Callanan & Oakes, 1992; Chouinard, 2007; Frazier, Gelman, & Wellman, 2009). Naturalistic diary studies of children's conversation reveal that by 3–4 years of age, though, children are more likely to give explanations than ask questions (Hickling & Wellman, 2001). Moreover, compared to judgments or predictions, explanatory interchanges are more likely to stimulate the development of children's cognitive competency (for a summary, see Wellman, in press). Such interchanges also form the basis for the kinds of competencies needed for successful learning experiences in formal settings, especially where inquiry-based activities are incorporated into the curriculum (Forbes & Davis, 2010).

Studies of parent and child conversation at museums have shown that parents aid children's learning by providing explanations, often in the form of "explanatoids," or brief, informal explanations that may help children process exhibit material (Crowley et al., 2001a). Consistent with findings from developmental psychology, research in museums has shown that children who hear adult explanations develop a better conceptual understanding of the exhibited phenomena than do children who explore on their own (Fender & Crowley, 2007). In Fender and Crowley's study, which focused on children's understanding of simple animation devices, such as a zoetrope, they found that children can learn procedural information by manipulating the exhibit on their own. However, for abstract information, parental explanations were necessary. Complex conceptual topics, such as evolution, are difficult to demonstrate with interactive experiences, and in this case, parents' support through verbal explanations may be even more critical if children are to grasp the topic.

We build upon both the developmental and museum research by analyzing the conversational exchanges between parents and their elementary-school-age children as they tackle a subject that parents themselves find challenging. Moreover, given the difficulty of the topic of evolution, in this study we examine to what extent children contribute to this interchange. If children are providing explanations and questions as well as eliciting explanations from their parents, this is powerful evidence that the dialogue is likely to provide a rich learning experience for the child. On the other hand, it is entirely possible that children would not engage with the topic. If this were the case then the learning experience might be a more didactic one with the parent acting as an authority, or the majority of the interchange might be nonexplanatory conversation focused on activities unrelated to the topic of the exhibit.

Factors such as parent characteristics may also affect the outcome of a family's museum visit, in particular their level of education and experience visiting museums, which have been associated with how much scientific explanation occurs during a visit (Tenenbaum, Callanan, Alba-Speyer, & Sandoval, 2002; Tenenbaum & Callanan, 2008). Szechter and

Carey (2009), for example, found that parental attitudes toward science were positively correlated with the proportion of exhibits visited. Differences among families' cultures seem to affect how parents view the process of learning in museums (Gaskins, 2008). Particularly in the case of evolution, factors such as the compatibility of a family's religion with the basic tenets of evolutionary theory may also play a role in how parents interpret and respond to the exhibit content.

Furthermore, when parents enter an exhibit, they tend to make decisions about whether their children's level of interest and ability matches the focus of the exhibit (Gaskins, 2008). They adjust their level of interaction at the exhibit depending on their individual children's characteristics, including their gender and knowledge of the content (Crowley et al., 2001b; Palmquist & Crowley, 2007). Given the nature of the topic of evolution, it is likely that parents' own level of knowledge may limit their ability to guide their children. We also evaluate the contributions of such characteristics to the learning experience.

Museum Visitors' Understanding of Evolution

Our assumption that adults would not be very familiar with the exhibit material was based on extensive research centered on adults' and children's understanding of evolution, which has shown that evolutionary concepts are difficult to grasp for all age groups (e.g., Banet & Ayuso, 2003; Bishop & Anderson, 1990; Brumby, 1984; Clough &Wood-Robinson, 1985a, 1985b; Dagher & BouJaoude, 1997; Evans, 2000a, 2008; Good, 1992; Lawson & Worsnop, 1992; Nehm & Reilly, 2007). In addition to religious beliefs and a lack of exposure to evolutionary theory in school curricula (e.g., Beardsley, 2004; Lerner, 2000), several conceptual factors appear to hinder understanding. These include intuitive beliefs in the stability of species (Evans, 2000a; Gelman, 2003; Medin & Ortony, 1989) and the inherent purpose of nature (Evans, 2001; Kelemen, 2004; Keil, 1994) as well as anthropomorphic beliefs. An example of the latter is the explanation, given by a museum visitor, that changes in the beak size of the Galapagos finches could be brought about through an intentional process: ". . . [they] had to try and work harder, probably, to develop their beaks" (Evans, Spiegel, et al., 2010, p. 336). From an evolutionary perspective the living world is neither stable nor purposeful; thus, for many, evolutionary theory is highly counterintuitive and difficult to grasp. As well, many urban adults and children have a relatively impoverished knowledge of nature (Atran, Medin, & Ross, 2004). Research done with adult museum visitors, who might be expected to have a reasonable grasp of evolutionary principles, has shown that only about one third of them do so (Evans, Spiegel, et al., 2010; Macfadden et al., 2007).

In a research study conducted prior to the development of the Explore Evolution exhibit, Evans, Spiegel, et al. (2010) investigated whether visitors to a natural history museum would explain several questions about biological change using one or more of the following explanatory frameworks: evolutionary reasoning, intuitive reasoning (described above), or creationist reasoning. As the term *evolution* was not mentioned in the instructions or participant recruitment materials, the researchers were interested in whether adult visitors would spontaneously produce evolutionary explanations. The questions focused on change in the seven organisms that were to be featured in the exhibit, which ranged in size from HIV to whales (e.g., "There were once no fruit flies on Hawaii. Then, about 8 million years ago, a few fruit flies landed on the islands. Now there are about 800 different kinds of fruit flies in Hawaii. How would you explain this?"). All of the visitors were found to be "mixed" reasoners, using concepts from more than one reasoning pattern, with 72% using intuitive and evolutionary concepts and a further 28% including creationist reasoning, as well, particularly for questions about human evolution. Notably, even though these visitors were interested in natural history and were more highly educated than the population at large

(60% had a college degree or more), none of them used evolutionary reasoning exclusively for all seven organisms. However, in contrast to the public at large, they were less likely to embrace creationist views of the origins of humans (28% vs. 47%; Gallup Poll, 2007).

Whereas the above research was conducted before the exhibit was installed, a follow-up study showed that it is possible to gain an understanding of evolution from a single visit to an exhibit on the topic (Evans, Spiegel, Gram, & Diamond, 2009; Spiegel et al., in press). Spiegel et al. (in press) studied visitors' learning over one museum visit to Explore Evolution using pre- and poststructured interviews and surveys. Following their visit to the exhibit, adults and adolescents not only increased their endorsement of evolutionary explanations and exhibited more evolutionary reasoning in their open-ended explanations of biological change, but they also decreased their use of some intuitive explanations. These changes were incremental, but nonetheless there were significant shifts in reasoning and causal explanation. Such explanations provide the causal links and knowledge structures that unite diverse concepts, and, as such, they play a critical role in developing an understanding of a topic. Youth aged 11–14 years changed their reasoning the least; these young visitors saw the exhibit alone, without parents to provide guidance, suggesting that they might have benefited from visiting the exhibit with others and engaging in conversation about it. Overall, these results demonstrate that gaining an understanding of evolution presents a formidable challenge even to those who are prepared to engage the topic, but learning can be supported by exposure to evolutionary concepts in informal educational settings.

The Present Study

In the current study, we examined parent–child conversation at the Explore Evolution exhibit (http://explore-evolution.unl.edu). This was a National Science Foundation–funded exhibit, copies of which were installed in five university museums in the Midwest. The goals of the exhibit were (1) to showcase current evolutionary researchers and their findings, (2) to encourage visitors to think about evolution as scientists by showing how the researchers ask evolutionary questions, collect data, and integrate the evidence, and (3) to present a range of contemporary research projects on the evolution of different organisms (Diamond & Evans, 2007). The exhibit comprised an introductory DNA double-helix model with a timeline of scientific discoveries related to evolution and seven exhibits that explained the evolution of particular organisms or organism relationships. These were arranged around the gallery, from the smallest to the largest organisms: HIV, diatom, ants, fruit flies, finch, whale/hippo, and chimp/human. The basic evolutionary processes of variation, inheritance, selection, and time were explained in the text at each exhibit, demonstrating that evolution occurs in all living organisms, regardless of size.

The exhibit presented the material through a variety of media, with the primary medium being visually compelling exhibit displays and text describing various scientists' current evolutionary research in the settings in which they gathered the data; these ranged from the mountains of Pakistan to a traditional laboratory. The text, which presented evolutionary explanations for the questions that drove the research, was a potentially valuable tool for parents who might not have been able to explain these concepts on their own. In addition, the exhibits included representations of phylogenetic trees, microscopic evidence, video displays, and several interactive features such as calipers to measure the sizes of Galapagos finches' beaks and a device to listen to the mating songs of the fruit flies and record a matching song. These elements were intended to encourage inquiry-based learning in which visitors would ask questions, make observations about the scientific evidence presented, and construct explanations. The exhibit text, written by the science writer, Carl Zimmer, was formulated with the goal of being accessible to middle-school–aged children.

In the current study, we targeted elementary-school–aged children to observe situations in which they might interact with their parents in the course of exploring the exhibit. Our research focused on how the discussions between children and their parents might influence their understanding of the exhibit content. To address this issue, we examined the *entire* content of parents' and children's conversation during their visit to the museum gallery. We considered three primary questions in this analysis.

First, because of the importance of explanation as a contributor to children's conceptual development (e.g., Frazier et al., 2009; Wellman, in press), we expected that families would engage in the kinds of talk that lead to scientific understanding, namely discussing the exhibit content, asking questions, and providing explanations. More specifically, we asked the question: How was the exhibit content discussed (i.e., evolutionary vs. intuitive reasoning) and to what extent did explanatory conversation predominate over nonexplanatory conversation for parents as well as for their children, indicating that a dialogue was occurring in which the conversational partners played complementary roles?

Second, in addition to coding all of the families' spontaneous unscripted talk, we coded their use of exhibit text, as previous work has shown that use of text cannot be determined through observation alone (McManus, 1989). Some earlier research has suggested that visitors read aloud at only a small proportion of exhibits, but that when they do, it can be to supplement their knowledge or to answer questions for children (Diamond, 1986). Other work has shown that exhibit text often provides the topic of the conversation (McManus, 1989). In our study, it was impossible to capture all of the silent reading that occurred at the exhibit, but because many parents read aloud to their children, we were able to analyze how much reading aloud occurred as well as reactions to and reformulations of that text. Therefore, we asked: To what extent did exhibit text play an important role in this context where parents may not have been familiar or comfortable with the scientific content?

Third, we addressed the relationship between the type of conversation which occurred and characteristics of the exhibits and of the family. Previously, researchers have found a relationship between the type of organism discussed in the exhibit and the number of evolutionary explanations produced by visitors, with invertebrate and microscopic organisms eliciting fewer evolutionary explanations than vertebrates such as birds and mammals, and humans eliciting the greatest number of creationist explanations (Evans, Spiegel, et al., 2010). In addition, research has shown that the compatibility of visitors' religion with evolution is related to their interest in learning about evolution and their endorsement of evolutionary themes (Spiegel et al., in press). Therefore, we asked: To what extent did these characteristics play a role in family visits and potentially influence how parents structure the visit and react to the exhibit content?

METHOD

Participants

The study took place at a university natural history museum in the Midwest. Participants were 12 families who were recruited for a naturalistic visit either at the door or through the museum e-mail list-serve and had not previously been to the exhibit. We obtained consent from parents and children and provided them with tickets to the museum's planetarium as a thank you for participation. Across the family groups, there were 16 children (mean age = 9.6 years; range = 6.9–12.0 years) with 9 boys and 7 girls. Families were primarily Caucasian (two were African American). Most of the parents (mean age = 44 years; range: 36–54 years) had completed a college education (92%; range: 14–17+ years of education). The parents' occupations consisted of the following: science and engineering related (4), humanities (1), teaching related (3), esthetician (1), and stay-at-home (2). The sample was made up of typical museum visitors (mean number of visits to a museum in a year = 6.17, range: 2–14; see Korn, 1995). Two additional families participated but could not be included due to audio equipment difficulties.

Procedure

Families were asked to visit the Explore Evolution gallery for as long as they wanted and to behave as they would in any other visit to the museum. The length of the visits ranged from 14 to 97 minutes ($M = 44$, $SD = 23$). Parents were asked to wear a wireless microphone and were followed as unobtrusively as possible (at a distance of about 10 feet) by a research assistant carrying a small handheld video camera; visits were videotaped and then transcribed for analysis.

Measures

After the visit, parents completed a brief demographic survey, which asked them to provide their level of education, their rating of the importance of understanding evolution, from 1 (not important) to 4 (very important), and their rating of the compatibility of their religious beliefs with the theory of evolution, from 1 (incompatible) to 5 (compatible).

Coding

Each family's entire visit to the gallery was transcribed into conversational utterances. We operationalized utterances as continuous units of speech or thought without long pauses or interruptions; utterances could consist of words, phrases, sentences, or multiple sentences. Each video was transcribed, and transcripts were double-checked for accuracy.

Several schemes were used to code the conversational data. One set was content based in that they were used to code what participants were saying about the biological problems presented (see Table 1 for examples). The primary scheme was *evolutionary reasoning*, which included the use of evolutionary terms as well as elaborations on evolutionary concepts such as variation, selection, inheritance, and time. We also coded two kinds of *intuitive reasoning* about biological phenomenon: anthropomorphizing and personifying the animals. These codes were developed from the earlier studies (Evans, Spiegel, et al., 2010; Spiegel et al., in press).

The second set of schemes consisted of functional codes of the types of conversational acts that occurred: explanatory, nonexplanatory, and use of exhibit text (see Table 2 for examples). *Explanatory* codes consisted of those conversational elements which conveyed or elicited scientific content, including: describing scientific evidence at the exhibit, providing causal explanations, using analogies, asking causal questions, and asking factual questions. *Nonexplanatory* codes consisted of conversational elements that were related to more logistical aspects of the visit, including giving directions, discussing personal experiences, discussing what to do next, and expressing affect. Many of these codes were adapted from previous research (e.g., Crowley et al., 2001a) with emergent codes added as needed. Finally, we coded visitors' use of the *exhibit text*, including when they read aloud and when parents reformulated the content to make it more understandable by rephrasing difficult terminology.

An utterance could have multiple conceptual elements, each of which could be assigned a code, though not every utterance had to receive a code. A given conceptual element could be coded once only under each coding scheme (e.g., as "providing causal explanation" from the explanatory conversation scheme and "reading text aloud" from the exhibit text scheme). Interrater reliability was calculated for each code using a randomly selected sample of 20% of the data independently coded by two individuals.

TABLE 1
Content-Based Coding: Evolutionary and Intuitive Reasoning

Coding Scheme	Coding Category	Operational Definition	Examples	Reliability Percent Agreement (Kappa)	Percentage of Adult utterances with code	Percentage of Child utterances with code
Evolutionary terms and concepts				86–100	10.22	3.74
	Term	Mention of evolution term	"Evolution," "Darwin(ian)," "Survival of the fittest"			
	Variation	Differences among individuals in a population	Parent: See the variation in the leg bones that they found in the fossils. So within any population some are going to be bigger and some are going to be smaller.			
	Inheritance	Traits (genes) are inherited and passed on to the next generation	Parent: Parents with big beaks will have kids with big beaks.			
	Common descent	Reference to a common ancestor or a descendent	Parent: So it says there's GENETIC SIMILARITIES BETWEEN SIV AND HIV and that suggests to the scientists that the human form of the virus came from the monkey form. So they want you to follow the line up from this guy and see what happened.			

(Continued)

TABLE 1
Continued

Coding Scheme	Coding Category	Operational Definition	Examples	Reliability Percent Agreement (Kappa)	Percentage of Adult utterances with code	Percentage of Child utterances with code
	Natural selection	Organisms with adaptive traits are more likely to survive	Parent: Random mutation, the ones who had this, survived better in their environment than the ones who had this. Right? So this was selected for.			
	Time	Implication that there had to be enough time for natural selection to occur	Parent: One simple change might take millions of years to happen. And this is a guy who was really famous for his ideas about natural selection. He went to a place called the Galapagos Islands. His name is Charles Darwin.			
Intuitive reasoning	Anthropomorphizing organisms	Use of mental state terms (e.g., thoughts, effort, desires, language) to refer to organism's actions	Parent: Then a couple of those viruses say "Aha! I don't want to get killed off by your medicine! I'd better change!"	99.56 (0.74)	1.35	0.58
	Personifying organisms	Reference to organisms as he, she, I, or me, rather than it	Parent: And this is RNA which is related to DNA. Okay? And he's going to try and hook into the DNA.	99.65 (0.75)	1.41	0.66

TABLE 2
Conversational Functions Coding Schemes: Explanatory, Nonexplanatory, and Use of Exhibit Text

Coding Scheme	Coding Category	Operational Definition	Examples	Reliability Percent Agreement (Kappa)	Percentage of Adult Utterances With code	Percentage of Child Utterances With code
Explanatory conversation	Describing scientific evidence	Talk about evidence observed at the exhibit or scientific principles generally	Parent: This is what we call an evolutionary tree.	86.92 (0.74)	37.38	40.14
	Providing causal explanations	Explanations of scientific information using causal statements	Parent: So you get, you have 23 of these I think, in every cell. . . . there must be forty-six because you get half from your parents.	94.04 (0.67)	13.96	7.71
	Using analogies	Use of analogies to explain concepts	Parent: These guys, you see, they look like zippers that are mis-matched, the different ways that they mis-match make the DNA helixes different sizes.	97.21 (0.60)	3.06	2.92
	Asking causal questions	Question about causal connections in the exhibit	Parent: Why would they have to have stronger shoulder muscles?	99.23 (0.81)	3.00	2.38
	Asking factual questions	Factual questions about exhibit content	Parent: What's this continent?	96.75 (0.84)	14.26	9.43

(Continued)

TABLE 2
Continued

Coding Scheme	Coding Category	Operational Definition	Examples	Reliability Percent Agreement (Kappa)	Percentage of Adult Utterances With code	Percentage of Child Utterances With code
Nonexplanatory conversation	Giving directions	Directions given on exhibit use	Parent: Let's follow his voyage.	97.06 (0.79)	9.00	4.33
	Discussing personal experiences	Mention of personal experiences or prior knowledge related to the exhibit	Parent: Remember that one show we watched where that lady was swimming with that whale?	98.37 (0.69)	3.38	2.30
	Discussing what to do next	Talk or questions about what participants want to do next	Parent: Where would you like to go next? Did you want to look here?	98.84 (0.78)	3.71	2.07
	Expressing affect	Expression of emotion toward exhibit content (e.g., wonder, enjoyment, disgust)	Parent: Oh, this is so cool!	99.15 (0.84)	3.44	4.64
Using exhibit text	Reading exhibit text aloud	Exhibit text read aloud	Parent: So it says, A VIRUS FUSES WITH THE CELL AND RELEASES ITS GENES INTO THE CELL.	99.54 (0.99)	12.88	6.51
	Reformulating exhibit text	Restatement of information from the exhibit text that was previously read aloud into a more easily understood format	*Reformulation of above utterance* Parent: So here's the virus. He's bouncing around. And then here's the cell and he hooks onto the cell. . . . So he's gonna hook on there and then he's going to put his gooby insides inside there.	99.23 (0.73)	2.57	0.17

RESULTS

Overview of Conversation

The families' conversations resulted in 6,263 utterances, which were coded according to the several schemes described above; adults produced 59% of the talk, and children produced 41% of the talk. The percentages of adult and child conversational utterances that included the various codes are presented in Tables 1 and 2. Throughout the Results section, we present excerpts of conversational exchanges from the transcripts, annotated with their codes, to provide evidence of how parents and children engaged in sophisticated conversations about evolution in this informal setting.[1]

***Research Question One:* How was the exhibit content discussed (i.e., evolutionary vs. intuitive reasoning) and to what extent did explanatory conversation predominate over nonexplanatory conversation for parents as well as their children, indicating that a meaningful dialogue was occurring?**

Content-based schemes. The results of the evolutionary reasoning coding revealed that 10.22% of adults' and 3.74% of children's utterances contained an evolutionary code. Adults used more evolutionary reasoning than children ($t = 2.80$, $p < .05$). Parents' evolution talk consisted of mentioning evolutionary terms (4.33% of parent utterances) as well as elaborating on the concepts. Notably, across our families, every evolutionary concept was discussed at least once, including common descent and the key concepts of variation, inheritance, selection, and time, which were incorporated by the exhibit designers into the text at each individual organism exhibit. The most common concept that was discussed was variation (1.55% of all utterances), as in the following example. Prior research has suggested that variation is one of the earliest sophisticated evolutionary concepts to be understood (Evans, Spiegel, et al., 2010).

Exhibit on Sexual Selection in the Fruit Fly:

Parent: Okay, alright, so we get variation between the individuals of the same species. Well that makes sense doesn't it? I mean there's variation between people, right? [*variation*]

In addition to discussing the exhibit content using evolutionary terms and concepts, parents also used intuitive reasoning when trying to convey some of the more complicated principles. We found that parents used *personifying language* (1.41%) and *anthropomorphizing language* (1.35%) when referring to the organisms.

Functional conversation schemes. In this section, we examine the explanatory and nonexplanatory strategies that parents were using to convey scientific content and engage children during the museum visit. Eighty percent of parents' utterances contained at least one of these types of codes, with 65% containing at least one explanatory code and 21% containing at least one nonexplanatory code. The most frequent explanatory codes were *describing scientific evidence* (37.38%), *asking factual questions* (14.26%), and *providing causal explanations* (13.96%). Of the explanatory conversation codes, adults provided more causal explanations ($t = 2.69$, $p < .05$), and asked more factual questions ($t = 4.08$, $p < .01$) than children did. There were no significant differences between adults and children in the number of codes for describing scientific evidence, asking causal questions, or using

[1] Exhibit text that was read aloud by participants has been transcribed in CAPS.

analogies. The most frequent nonexplanatory code was *giving directions* (9.00%). Of the nonexplanatory conversation codes, adults gave more directions ($t = 3.15$, $p < .01$), talked about personal experiences more ($t = 3.37$, $p < .01$), and discussed what to do next ($t = 2.58$, $p < .05$) more than children did. There were no significant differences in the number of codes for expressing affect. As an illustration, the following example shows a boy asking questions and his parent providing explanations of how a virus survives and spreads.

Exhibit on the Rapid Evolution of HIV:

Child: Yeah, it's not very practical because if the virus were very smart [*anthropomorphizing*], it would go out of the body.
Parent: Oh, but the virus needs the body to reproduce!
Child: Yes, but when the body is dead and it can't infect anything else, where is it supposed to go? [*causal question*]
Parent: It's a short term strategy, isn't it? [*factual question*]
Parent: So what it depends on then is that people will interact with each other to pass the virus along from person to person. [*causal explanation*]
Child: What if they don't? [*causal question*]
Parent: Oh, well then the virus has chosen [*anthropomorphizing*] a bad person to infect.
Child: Yeah.

In the above example, the parent is clearly conveying important and relevant biological information about viral reproduction. Her cause and effect description of the virus' spread depending on human interaction fulfilled our criteria for a causal explanation; however, it did not count as evolutionary reasoning because it did not invoke one of the specific evolutionary concepts (see Table 1). This explanation also illustrates one of the intuitive reasoning patterns, anthropomorphizing, seen when the parent refers to the virus as having "chosen" a bad person to infect and when the child describes the virus as "smart." The misrepresentation of the virus' behavior was surprising because this mother was highly educated and trained as a biologist; nonetheless, parents did use this type of reasoning, seen in the following example as well, seemingly to help children understand the concepts.

Timeline of Whale Evolution at DNA Exhibit:

Parent: How does it take that huge change? [*causal question*] See that's what they're, the scientists, are trying to figure out. [*describing scientific evidence*]
Parent: They think maybe it was something in their environment like those birds with the seeds.
Child: They just, like, poof changed? [*factual question*]
Parent: Maybe their environment—they then didn't poof change. Their environment got with water and something happened and one of them was born with a fin and another one was born with a fin [*variation*] and the two fin guys said "Hey! Let's make a family!" [*anthropomorphizing*] And they made a family of little fin guys [*inheritance*] while everybody else still had legs. [*causal explanation*]
Parent: But the fin guys could swim! And now their land was turning into a lake so all the fin guys lived and all the land guys died [*selection*]. [*causal explanation*]

The preceding and following examples show the rich nature of the dialogue between parents and children, with many important evolutionary processes being discussed in an informal, relatable, and often humorous, manner.

Exhibit on Environmental Pressures Impacting the Galapagos Finches:

Parent: How about DNA, have you ever heard of that? [*factual question*]
Child: Yes.
Parent: You have?
Child: Like. . . if you have a twin, like, you might have the same DNA. [*causal explanation*]
Parent: You could, yeah. And even you and me share a lot. [*describing scientific evidence*]
Child: Yeah.
Parent: You know, things like blue eyes, and blondish hair [*personal experience*], huh [*factual question*]? [*describing scientific evidence*]
Child: We're both kinda skinny [*personal experience*]. [*describing scientific evidence*]

This excerpt and the following one show how parents used real-world examples in addition to information from the exhibit to explain scientific concepts such as DNA and inheritance of features, which are the basis for understanding evolutionary processes.

Exhibit on DNA Double Helix and Timeline of Evolutionary Research:

Parent: So if you can imagine this is the instructions to make your whole body. [*using analogies*]
Parent: So then it only needs to use parts of it at different times, I think. [*describing scientific evidence*]
Child: I think that doesn't look that really like my body. [*describing scientific evidence*]
Parent: It doesn't look like your body but it's just like a recipe doesn't look like a cookie. [*using analogies*]
Parent: The recipe just tells you what ingredients. [*using analogies*]

The explanatory strategy of using analogies also shows parents' creativity in trying to effectively explain concepts.

Even when parents were not providing explanations about scientific concepts, they helped children to interact with the exhibit, as in the following example where the family is using the karaoke interactive to recreate the fruit fly mating song.

Exhibit on Sexual Selection in the Fruit Fly:

Parent: Just . . . Click on it [*giving directions*]
Parent: Now look at how similar that was. [*giving directions*]
Parent: Play that one and then play yours. [*giving directions*]
Child: Yeah
Parent: That's so awesome. [*expressing affect*]
Parent: Look at how close though! [*giving directions*]
Child: No Mom, now it's your turn.
Parent: You could get yourself a fly girlfriend.

From this excerpt, we see how parents engaged children with the exhibit interactives playfully and were also enjoying themselves.

To examine the question of how much of a conversational exchange occurred within individual families (i.e., how was adult and child conversation related), we ran zero-order correlations between the parents' and children's total codes for each of the following variables: evolutionary codes, explanatory codes, nonexplanatory codes, and reading exhibit text codes. For the three families with more than one child participating, the children's data were collapsed. The significant findings were that parents' use of explanatory conversation positively correlated with their children's use of explanatory conversation ($r = .69$, $p < .05$) and evolutionary reasoning ($r = .68$, $p < .05$).

Research Question Two: **To what extent did exhibit text play a role in this context where parents may not have been familiar or comfortable with the scientific content?**

In contrast to some previous research, we found that museum visitors at Explore Evolution frequently used exhibit text by reading it aloud to their family members; 12.88% of all parent utterances and 6.51% of children's utterances contained exhibit text read aloud. For 20% of the utterances where parents read aloud, they reformulated the exhibit text for children to understand. Furthermore, this value represents the minimum occurrence of reformulating text because many parents read the text silently before apparently reframing it, thus we could not code it as reformulated text with certainty. There were no differences in the number of utterances in which parents and children read exhibit text aloud; however, parents reformulated exhibit text more ($t = 2.21$, $p < .05$) often than children. The excerpts below show how parents used the exhibit text in conversation.

<u>Exhibit on the Common Ancestry of Human and Chimp</u>:

Parent: CHIMPANZEES' EYES DON'T HAVE THE WHITE SURROUNDING THE IRIS. BUT CHIMPS' VISION IS VERY SIMILAR TO OURS. [*reading exhibit text*]
Parent: You know how we have the whites around our eyes? Chimps don't have that. [*reformulating exhibit text*]

<u>Exhibit on DNA Double Helix and Timeline of Evolutionary Research</u>:

Parent: Oh, come here, this is important. You're going to be asked this question – you're going to be asked this question probably in the fifth grade by Mrs. [XXX]. [*personal experiences*]
Parent: IN EVOLUTION, THE PROCESS BY WHICH THE GENETIC MAKEUP OF ALL LIVING BEINGS CHANGES OVER TIME [*evolution terms*], THERE'S FOUR BASIC FORCES AT WORK. [*reading exhibit text*]
Parent: IN THIS EXHIBIT, YOU'LL SEE HOW THESE FORCES OPERATE TOGETHER IN ORGANISMS RANGING FROM VIRUSES TO WHALES. THE FIRST THING IS VARIATION. [*reading exhibit text*]
Parent: So, let's remember it this way: it's V, VARIATION; I, INHERITANCE; S, SELECTION; T, TIME. [*evolution terms*] VIST. [*reading exhibit text*]
Child: VIST.

This excerpt shows that parents used text that was specifically designed to help frame the major concepts of the exhibit (VIST: variation, inheritance, selection, and time). To analyze the relationship between the use of exhibit text in an utterance and the presence of other substantive conversation, we conducted zero-order correlations on the 6,263 utterances for the following codes: reading exhibit text, explanatory conversation codes, nonexplanatory conversation codes, and the evolutionary reasoning. The use of text in an utterance was positively related to the presence of explanatory conversation ($r = .28$, $p < .01$) and

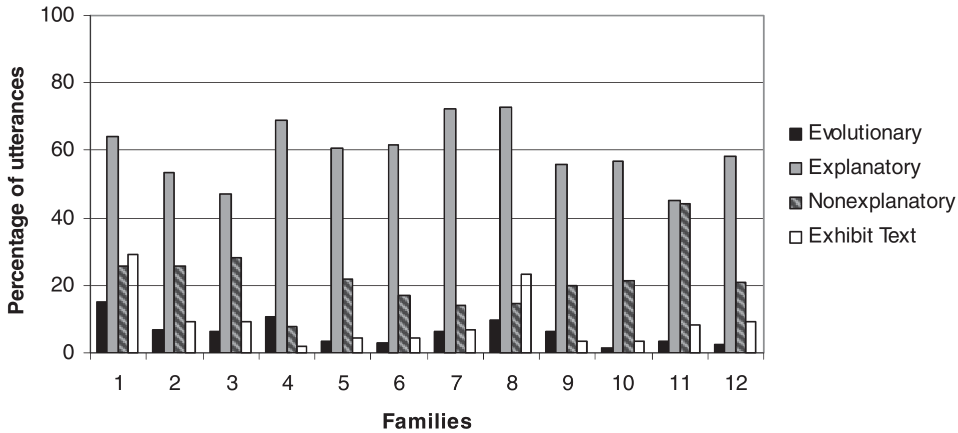

Figure 1. Percentage of utterances containing different types of codes by family group.

evolutionary reasoning ($r = .28$, $p < .01$). The significant correlation between the exhibit text and both explanatory talk and evolutionary talk indicates that parents were frequently drawing useful information from the text. The use of exhibit text was negatively related to the presence of nonexplanatory codes in the utterances ($r = -.072$, $p < .01$).

***Research Question Three:* To what extent did exhibit and demographic characteristics play a role in family visits and relate to how parents structured their visit and reacted to the exhibit content?**

Individual differences in family groups. Families did vary in how much of their talk included explanatory conversation, nonexplanatory conversation, evolutionary reasoning, and exhibit text (Figure 1). To assess whether these differences were related to attitudes toward learning about evolution or other personal characteristics, we correlated these variables with individual family characteristics including the length of their museum visit ($M = 44$ minutes, $SD = 23$), the primary parent's level of education ($M = 16.42$ years, $SD = 0.90$), the parent's report of the compatibility of their religious beliefs with the theory of evolution ($M = 4.00$, $SD = 1.63$), and their rating of the importance of understanding evolution ($M = 3.18$, $SD = 0.96$). These analyses revealed that individual differences among these measures related to some aspects of the museum visit (Table 3).

We found, in this relatively small sample, that parents' education level was positively related to the compatibility of their religious beliefs with the theory of evolution and their rating of the importance of understanding evolution. However, of these variables, only parents' rating of the importance of understanding evolution tended to be positively related to the kinds of talk that were produced during their family's visit, including the number of evolutionary reasoning, explanatory and nonexplanatory conversational codes. We also found that the length of the family's museum visit positively related to their rating of the importance of understanding evolution, the number of explanatory conversational codes they produced, and the number of evolutionary reasoning codes they produced, but not the number of nonexplanatory codes they produced (see Table 3).

Responses to different exhibit organisms. Finally, there were differences in how much evolutionary talk was elicited by the different organisms exhibited (Figure 2). The chimp/human common ancestry exhibit elicited the least amount. Families spent the least amount of time at the chimp/human exhibit and the most time at the HIV exhibit (see Table 4). Overall, families spent an average of $5^1/_2$ minutes at each organism exhibit.

TABLE 3
Correlations Between Conversational Content and Family Characteristics (N = 12)

	Explanatory Conversation	Nonexplanatory Conversation	Evolutionary Reasoning	Use of Exhibit Text	Length of Museum Visit (minutes)	Parent's Education Level	Compatibility of Religious Beliefs with Evolution	Importance of Understanding Evolution
Explanatory Conversation	–							
Nonexplanatory Conversation	.48	–						
Evolutionary Reasoning	.90**	.67*	–					
Use of Exhibit Text	.49	.78**	.65*	–				
Length of Museum Visit (minutes)	.95**	.48	.91**	.48	–			
Parent's Education Level	.40	.49	.30	.13	.39	–		
Compatibility of Religious Beliefs with Evolution	.20	.37	.23	−.08	.20	.63*	–	
Importance of Understanding Evolution	.56†	.55†	.60*	.47	.68*	.65*	.58†	–

Note. † $p < .10$; * $p \leq .05$; ** $p \leq .01$.

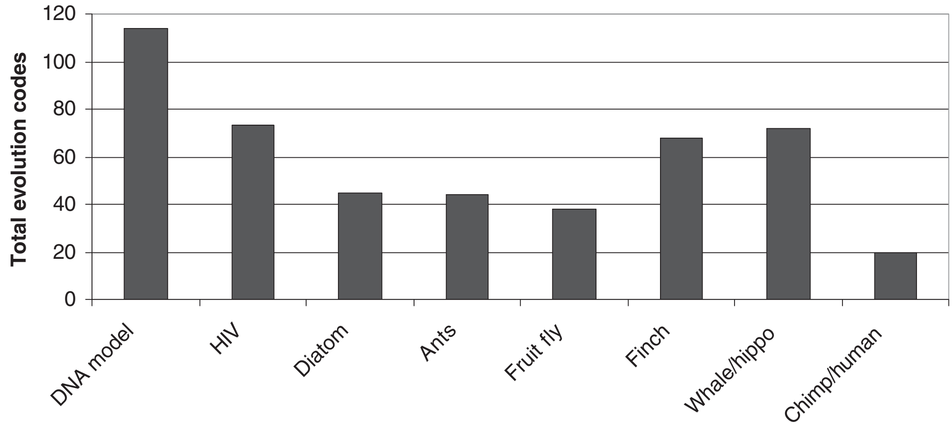

Figure 2. Total evolutionary reasoning codes produced across families for each organism exhibit.

DISCUSSION

This study of parent–child conversations at an evolution exhibit revealed that, in support of our hypothesis, substantive, explanatory content (63% of utterances) predominated in families' talk, suggesting that they engaged in sophisticated talk in an informal educational setting. Parents provided a great deal of support for their children's learning of the process of science and scientific content, including focused discussion of the challenging topic of evolution (10.22% of parents' utterances). Much of this evolutionary talk came from the exhibit text, suggesting that this was an important source of information, even for adults, during the visit. In addition to reading text, parents asked questions and provided explanations to guide children's understanding. Individual family characteristics, such as parents' education level, related to the parent's attitudes toward the exhibit content. Notably, parents' rating of the importance of understanding evolution, but not their education level, was related to how long their family spent at the museum exhibit and how much evolutionary talk they produced.

Discussion of Evolutionary Processes

Importantly, every family produced at least some evolutionary talk demonstrating that the exhibit was effective in eliciting talk about evolutionary principles with children who

TABLE 4
Mean (SD) Time Spent at Each Organism's Exhibit

	Time at Exhibit (minutes)
DNA	5.61 (7.93)
HIV	6.73 (8.41)
Diatom	5.93 (3.99)
Ants	6.22 (1.63)
Fruit fly	5.04 (3.24)
Finch	4.34 (3.35)
Whale/hippo	6.08 (5.19)
Chimp/human	3.77 (3.39)

may not yet have learned them in school. Parents' greater use of evolutionary terms and concepts compared to children supports our expectation that children of this age needed help in interpreting and understanding the exhibit content. In addition to evolutionary reasoning, we found that parents and children used intuitive reasoning such as anthropomorphizing and personifying language to talk about the animals and their behavior (see also Jungwirth, 1975). Although it only occurred in a small percentage of utterances, it was about the same as the percentage of utterances that included discussion of the major evolutionary concept of variation. Parents might have used this language unconsciously; they might also have thought that attributing anthropomorphic tendencies to animals would make the material easier for children to understand. However, this type of language may have implications for how children understand evolutionary processes. In a study that compared the effects of anthropomorphic and nonanthropomorphic language, Legare, Evans, and Lane (2010) found that elementary school children who heard a story that incorporated anthropomorphic language were more likely to both endorse and use such language to explain evolutionary change.

Parents' use of both evolutionary reasoning and intuitive reasoning, such as anthropomorphizing, also demonstrates the common tendency toward mixed reasoning found in prior work (Evans, Spiegel, et al., 2010). This pattern probably reflects the fact that parents and children have access to multiple explanatory frameworks, which allows them to shift between explanations depending on the context (Evans, Legare, & Rosengren, 2010). This kind of explanatory flexibility may be beneficial as it would allow parents, for example, to read text that is presented in an evolutionary framework and then translate the same information into an intuitive explanation that seems more appropriate for the child, or the parent could reformulate a child's intuitive explanation. In the following illustrative interchange, the parent gently reformulates the child's intuitive explanation of evolutionary change, providing, instead, a more accurate description of the mechanism of natural selection:

<u>Exhibit on the Diversity of Microscopic Diatoms:</u>

Child: Oh, look at this.
Parent: Oh look, this is how they're getting the cores to do the testing to look for the diatoms and the pollen.
Child: So these [diatoms] must have been everywhere and they mutated to fit the environment that they are now in. [*Child's intuitive explanation*]
Parent: That's right.
Parent: Or they mutated and those that were best suited for that environment were the ones who survived. [*Parent's more scientifically accurate explanation*]
Child: Yeah.
Parent: Because you can't mutate to be something because an organism will never know what's coming around the pike or coming around the bend. So basically it's just the ones who happen to be really well adapted, are the ones who survive. [*Parent clarifies the difference between the intuitive and scientifically accurate explanations*]

Parents' Strategies for Supporting Learning

Parents guided learning throughout the informal conversations. They asked more factual questions, suggesting that they were trying to keep children engaged and assess what their children knew about the topics. Parents also provided more causal explanations, compared to children, which supports our prediction that parents would provide the kinds of scientific connections needed by children of this age to understand the exhibit. It is important to note, however, that children were also clearly engaged in the learning experience. Explanatory conversation far exceeded nonexplanatory conversation for both parents and children. Unlike previous research (Crowley et al., 2001a), we found no significant differences in the number of *describing scientific evidence* codes for children and adults. This may be because children in our study were older than those in previous work and were more capable of interacting with exhibit materials. In addition, there was no significant difference in how much parents or children asked causal questions, suggesting that the exhibit succeeded in spurring thoughtful questions in both groups about the evolutionary processes shown. The process of generating causal questions and explanations has also been noted as key to successful classroom science learning when learning about natural selection (Sandoval & Reiser, 2004) or other scientific content (Berland & Reiser, 2008; Kuhn, 2010); thus, parents' strategies during informal activities may be similar to teachers' efforts in school.

Parents appeared to shape their children's experience at the exhibit through this use of explanatory talk, providing evidence of a dialogic interchange. Their use of explanatory conversation was positively related to their children's use of explanatory and evolutionary conversation, suggesting that children are responsive to the kinds of talk their parents' produce in this context. It is unclear whether these patterns had been established long before the parents and children came to the museum; in general, parents who explain a lot may raise children who also explain a lot (Wellman, in press). Thus these children may also be better prepared to benefit from informal learning contexts than families with different conversational patterns. Future research should focus on families that are less experienced museum-goers (see Zimmerman, Reeve, & Bell, 2009) and/or have different conversational patterns to determine how these characteristics affect interaction.

Parents and children unconsciously and without prompting used this exhibit to engage in a sustained dialogue on a complex scientific topic (Allen, 2002), shown in our excerpts to be nuanced discussions. Families stayed at each of the individual organism exhibits for an average of $5^1/_2$ minutes, much more than the 1–2 minutes per exhibit that has been reported by other researchers (Crowley et al., 2001a; Sandifer, 1997). Several factors might explain these differences, including the fact that the exhibit itself was housed in an enclosed space in the museum, thus there were few competing interactive displays nearby and our families could focus their attention. Moreover, the complexity of the material, which included manipulative features that invited visitor exploration, may have increased the hold time by improving active prolonged engagement (Gutwill & Allen, 2010; Perry & Tisdal, 2004; Szechter & Carey, 2009).

Parents in our study also guided the museum visit through nonexplanatory conversation, by giving directions and asking about what to do next; children were less likely to do this. There were no significant differences in the amount of time that parents and children read exhibit text; however, parents did reformulate exhibit text more than children. We were encouraged by this finding that parents read the exhibit text aloud and then reformulated it, as it suggested that parents might be using the exhibit to support their own learning while conveying complex biological information to their children. Having the text as a tool from which to extract key information could have given parents more confidence in providing explanations for this challenging scientific topic. The complexity of the topic might explain why parents in this study used text (12.9%) more often than has been reported in other studies at biological exhibits. For example, parents in the study of Zimmerman et al. (2009) used text 4.7% of the time.

We have no direct evidence that there was an improvement in children's understanding of evolution as a result of this visit. Other research on this particular exhibit, however, shows that learning does occur after one visit, for both adults and older children (Evans et al., 2009; Spiegel et al., in press). The current study suggests that the nature of the conversations between parents and children is a significant factor in enabling learning about evolution in museums.

The Interaction of Exhibit and Parent Characteristics

Explore Evolution was a controversial as well as a complex exhibit. We found that parents' attitudes toward the exhibit content were associated with the educational quality of the museum visit, in that their rating of the importance of understanding evolution correlated positively with the length of the museum visit and the number of evolutionary reasoning codes produced. Thus, not only do overall attitudes toward science influence the learning experience (Szechter & Carey, 2009), but it is also crucial to ensure that parents view the particular exhibit topic as important for their children to understand.

These attitudes toward exhibit content may include religious or cultural beliefs. Although museum-going adults endorse creationism less than the population at large, research conducted prior to the completion of this exhibit demonstrated that the chimp/human exhibit was more likely to elicit creationist themes than any of the other organisms (28% vs. 6%; Evans, Spiegel, et al., 2010) and in several other studies it has been found that the issue of human origins is more likely to arouse existential anxieties than questions about the origins of nonhuman species (Evans, 2008). Parents in earlier studies often revealed their uncertainty about the moral ramifications of accepting the idea of human evolution, with statements such as "if children are nothing more than apes evolved, then we cannot expect them to act more than that to each other. . . .We must instill the belief of their divine worth" (Evans, 2000b). In the current study, we found that families spent the least amount of time at the chimp/human exhibit and it elicited the least amount of evolutionary reasoning. Families may have spent less time at the chimp/human exhibit because it was positioned toward the end of the exhibit trajectory, but as they spent more time on average at the whale/hippo exhibit, which was next to it, it seems more likely that other factors, such as religious beliefs, may be involved.

As an example, we provide a poignant interchange between a mother and her son (Family #11 in Figure 1); this family was the only group for whom the percentage of explanatory utterances was about the same as that for the nonexplanatory utterances. During this exchange, they are standing in front of a full-size chimp portrayed on a mirror where the visitor is invited to compare him/her self with the chimp.

<u>Exhibit on Common Ancestry of Human and Chimp</u>:

Parent: You guys talk about evolution in school, don't you?
Child: Not really.
Parent: Well that's good.
Parent: Because we really don't believe that you evolved from the monkey.
Parent: Do you want to look at these things?
Child: Uhh. . .
Child: It looks pretty darn close, huh?

While this mother's negative reaction to the chimp/human exhibit is not surprising, given her apparently creationist beliefs, other family groups might also have shied away from discussing the chimp/human common ancestor because of its controversial nature (see Evans, Spiegel, et al., 2010); thus more research is needed to tease apart the effects of cultural and religious beliefs on how families engage with evolutionary topics. In contrast to the above excerpt, the parent in the following example seems to be trying to have a more open dialogue in which he juxtaposes the scientific explanation of evolution with creationism.

Explanatory Panels Around a Model of DNA Double Helix:

Parent: Alright so, do you remember when you were in the pool and you were talking to that boy about how the earth was created?
Child: Uhhuh.
Parent: Do you remember what happened, what did he say?
Child: He said God created it.
Parent: Right, right, so do you see what's happening here? And what people are talking about here is, the scientists are saying that the monkeys and the humans were similar.
Child: So this turned to this. . . .
Parent: That's what the scientists are saying.
Parent: So what was that boy's belief?
Child: That God created it all.
Parent: Right.
Child: But then—He created all of this, without this, any of this happening.
Parent: Right, right, but then there's a problem with the timing because the Bible, you would look at the Bible, and if you read the Bible it would say that it was only so long, uh you know, maybe a couple thousand years but what are the scientists saying?
Child: 4.5 billion!
Parent: Yeah, so that's, that's why that little boy told you that and that was the problem.

Based on these excerpts, it is clear that parents can set the tone for how children react to and engage with the exhibit material. They can provide more or less opportunity for discussion and questions and show differing degrees of tolerance for diverse perspectives. The above example also shows how productive parent–child conversation can be in an informal setting, allowing a careful and personal examination of evolutionary theory that may not be possible in the classroom. While it is evident that parents and children can engage in sophisticated conversations, the productivity of these conversations may be dependent on parents' beliefs about the importance of understanding such topics.

CONCLUSION

In sum, our study shows that parents and children were highly engaged with the complex topic of evolution when presented in a public informal setting. We found that 10% of what adults said was explicitly about evolution, likely much more evolutionary content than children would be exposed to in everyday parent–child conversation or that they would have encountered at school at this age. In addition, the exhibit provided parents with many opportunities to talk about scientific processes in general, which would provide the building blocks for understanding evolution. Consistent with previous research, we found that individual family characteristics related to aspects of the museum visit, adding the important finding that the parents' attitudes toward the specific exhibit content was a key factor in the family's museum experience. This was clear in the above example of the parent who shared her negative opinion of the chimp/human exhibit. Many parents, however, made an effort to broach elements of this difficult topic and explain this most fundamental theory in biology.

Parents were not overly didactic; they responded to their children's level of interest, their children's questions, and their children's interpretation of the exhibits. Research in developmental psychology and museum studies has demonstrated that a rich dialogue that incorporates explanation, questioning, and evidence, will promote an understanding of scientific topics. Although more research is needed to determine how long-term learning about complex topics such as biological evolution is supported by such informal learning experiences, we have provided evidence that the sort of sophisticated conversation that would be needed to understand evolutionary concepts occurs in such settings. This study also reveals interesting similarities between that the kinds of learning experiences provided by parents in their everyday conversational interactions and the kinds of inquiry activities encouraged in school settings. In both cases, explanation plays a central role. Naturalistic studies of parent–child conversations in informal settings provide illustrative examples that could be modeled in more formal inquiry-based methods in school settings.

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