COGNITIVE DEVELOPMENT IN INFORMAL LEARNING INSTITUTIONS: COLLABORATIONS ADVANCING RESEARCH AND PRACTICE

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COGNITIVE DEVELOPMENT IN INFORMAL LEARNING INSTITUTIONS: COLLABORATIONS ADVANCING RESEARCH AND PRACTICE

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EDITORIAL
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Editorial: Cognitive Development in Informal Learning Institutions: Collaborations Advancing Research and Practice

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Editorial on the Research Topic

Cognitive Development in Informal Learning Institutions: Collaborations Advancing Research and Practice

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OVERVIEW

Researchers in cognitive development and developmental science more broadly are encouraged to bring our science into the "messiness of the real world" (Golinkoff et al., 2017, p. 1407). Many have heeded this call by establishing partnerships with community and educational institutions (e.g., museums, science centers, libraries), and in some cases, engaging in research that can serve real-world applications (Callanan, 2012; Sobel and Jipson, 2016; Haden, 2020). The goal of this Research Topic was to spotlight the growing number of collaborations with informal learning institutions and illustrate the cutting-edge cognitive and social-cognitive research occurring through these partnerships across a range of topics.

We thank all authors who submitted manuscripts and reviewers that provided thoughtful critiques. Their work resulted in nine empirical articles and one perspective article that successfully met our Research Topic criteria.

CONTRIBUTIONS

Several articles in this collection point to how the deliberate design of museum exhibits and facilitation strategies used by practitioners can support parent-child conversations and children's learning. Letourneau et al. considered how staff facilitation vs. labels printed on exhibits affected whether and how children and caregivers explored a science exhibit. They found little difference in families' goal setting across the facilitation and exhibit label conditions, but prompts by staff led caregivers to be more hands-off, whereas exhibit labels seemed to encourage more actions between caregivers and children during the science activity. Marcus et al. used design-based research methods to understand how iterations of a program at a children's museum promoted engineering engagement and talk. Design features that promoted testing best encouraged family engagement in engineering practices when coupled with facilitation by museum staff members.

Shivaram et al. considered whether the presence and types of signage in a food pantry promoted learning opportunities for children. They showed that the presence of signs increased the number of conversations between caregivers and children, but only academically-relevant signs engendered high-quality conversations about key learning objectives. Tõugu found that families receiving a worksheet with a prompt to experiment during a museum-based science-related activity about shadows engaged in more experimentation than those not receiving the prompt. However, families receiving the experimentation activity prompt also had children who provided fewer explanations, leading Tõugu to suggest that prompts offered *via* worksheets might actually distract from deep engagement with hands-on exhibits. Joy et al. considered, for example, how children's behaviors in an exhibit varied according to whether it was interactive, showing that interactive exhibits promoted engagement but that non-interactive exhibits prompted more scientific explanations from children. Jee and Anggoro offer ideas about how research on relational thinking can be leveraged through exhibit design to make the comparison of natural specimens and scientific models salient.

Another common thread connecting across several articles in this collection is that storytelling and narratives can reveal and further advance children's learning from experiences in informal educational settings. Callanan et al. used a hands-on animation exhibit to encourage family storytelling during an exhibition experience, finding that families who told stories also engaged in more explanatory science discussions in other areas of the exhibition. Marcus et al. prompted children's narrative reflections immediately after an exhibit experience in a children's museum to gauge how variations in the exhibit program led to different amounts of talk about engineering. Attisano et al. found that older children in their study recalled more about a machine, and seemed more knowledgeable, compared to younger children. Prompts provided to some of the children to focus on the internal parts of the machine did not end up affecting children's talk and learning. Kian et al. analyzed children's autobiographical event memory and knowledge retention following a week-long summer camp at a zoo, finding that age-related differences varied based on the type of information being recounted and whether the experience had more or less self-relevance for the child. Finally, Marble et al. studied how children judged information about animals from experts and non-experts, revealing that children believed positive rather than negative statements about an animal irrespective of expertise, but remembered neutral information best.

FUTURE DIRECTIONS

This collection signals important future directions in research and practice for the field. We highlight two here, but also refer readers to the discussions offered by authors of this collection.

First, the work in this collection points to everyday contexts and practices that can advance children's understanding, and skills in various academic areas. But what we see less of in this collection, and indeed field-wide, is how families from different cultural and social backgrounds learn in informal educational settings, as well as design efforts to support that learning. We need to take further crucial steps to co-develop and co-implement design and facilitation strategies in collaboration with diverse community members, to create informal educational opportunities that better reflect culturally relevant ways of teaching and learning, while being mindful not to promote erroneous deficit viewpoints (see Solis and Callanan, 2016).

The second area of challenge is to understand the conditions that can foster learning transfer across informal settings (e.g., museum to home) and across informal and formal educational settings (e.g., museum to school). Several of the articles in this collection point to how opportunities to reflect on informal experiences can reveal learning, and that chances to tell stories and recount experiences can be important in the process of bridging across learning experiences. Indeed, a critical factor in successful learning and transfer is whether the knowledge that is gained in one setting can be represented or re-represented so that it can be accessed in another context over time (e.g., Bransford and Schwartz, 1999; Jant et al., 2014). Learning transfer is something that many practitioners seek; they want their work to accrue benefits long after, for example, a museum visit is complete. Future work on storytelling and remembering informal learning experiences can help to realize learning transfer. Additionally, there is a paucity of research in which the same families are studied across different informal learning experiences and contexts. Undertaking such work could greatly inform both research and informal learning practice.

AUTHOR CONTRIBUTIONS

TP wrote an initial draft of the editorial which was then edited by all authors. The topic was initiated by TP. TP invited JB and CH to join as co-editors. All authors contributed equally to the proposal of the Research Topic, managed submissions in consultation with each other, and contributed equally to the writing of this editorial.

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Effects of Facilitation vs. Exhibit Labels on Caregiver-Child Interactions at a Museum Exhibit

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In museum settings, caregivers support children's learning as they explore and interact with exhibits. Museums have developed exhibit design and facilitation strategies for promoting families' exploration and inquiry, but these strategies have rarely been contrasted. The goal of the current study was to investigate how prompts offered through staff facilitation vs. labels printed on exhibit components affected how family groups explored a circuit blocks exhibit, particularly whether children set and worked toward their own goals, and how caregivers were involved in children's play. We compared whether children, their caregivers, or both set goals as they played together, and the actions they each took to connect the circuits. We found little difference in how families set goals between the two conditions, but did find significant differences in caregivers' actions, with caregivers in the facilitation condition making fewer actions to connect circuits while using the exhibit, compared to caregivers in the exhibit labels condition. The findings suggest that facilitated and written prompts shape the quality of caregiver-child interactions in distinct ways.

Keywords: caregiver-child interaction, children's museums, facilitation, exhibit labels, exploration, informal learning

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INTRODUCTION

Decades of research on informal STEM learning has advocated for involving learners in actively exploring materials, solving problems, and making discoveries, rather than passively receiving information (see National Research Council, 2009; National Academies of Sciences, Engineering, and Medicine, 2018; for reviews). Active learning experiences allow children to use their direct interactions with the world to construct conceptual understandings and make connections to own their interests and prior knowledge (Zimmerman, 2007; Kuhn, 2011; Miller et al., 2018). Understanding how such learning takes place has informed shifts in curricula and pedagogical approaches toward inquiry- and project-based methods that frame science as a practice and engage learners in asking questions and seeking out answers (Lehrer and Schauble, 2007; Krajcik et al., 2008; National Research Council, 2012, 2013). As interactive learning environments, science centers and children's museums are designed to invite active exploration, and museums have developed well-tested strategies for designing exhibits that promote exploration and inquiry (Gutwill and Allen, 2010; Humphrey and Gutwill, 2017).

Children's interactions with their caregivers are a critical part of this learning process. Research on informal learning in general has articulated how children's conversations and everyday interactions with family members shape their learning across a wide range of settings (Rogoff et al., 2016). Within science centers and children's museums, family groups learn through their exploration of museum exhibits in the larger context of their social interactions, cultures, and everyday lives (Ellenbogen et al., 2004; Gutwill and Allen, 2010; Ash et al., 2012; Falk and Dierking, 2018). Caregivers support children's learning in many ways in these settings—by guiding children's attention or exploration, asking questions, offering explanations, and making connections to children's interests and prior experiences (e.g., Callanan and Jipson, 2001; Crowley et al., 2001; Fender and Crowley, 2007; Haden, 2010; Zimmerman et al., 2010).

Recognizing the value of caregiver-child interactions for children's learning and engagement, museum professionals have developed and refined different strategies for supporting families' interactions, particularly their shared exploration and inquiry. For example, museum exhibits can be designed to prompt active and sustained engagement by encouraging social interactions among members of a group or by requiring multiple people to work together (Humphrey and Gutwill, 2017). Likewise, facilitators in museums guide families' exploration of museum interactives by prompting conversations and encouraging deeper exploration of scientific concepts and phenomena (Piscitelli and Weier, 2002; Tran, 2008; King, 2009; Gutwill et al., 2015). Studies of caregiver-child interactions in museums also suggest that museums can support children's learning by prompting caregivers to use open-ended questions (Haden et al., 2014), by asking caregivers to encourage children's exploration or explanations (Van Schijndel et al., 2010; Willard et al., 2019), by instructing families about relevant scientific principles (Marcus et al., 2018), or by scaffolding families' scientific practices or inquiry behaviors (Gutwill and Allen, 2010).

Although informal learning research has largely focused on the benefits of family interactions, debates continue within the field of education about how much and in what ways adults should guide children's learning (Russ and Berland, 2019). Studies showing the value of caregiver-child interactions in museum settings exist alongside research in cognitive development demonstrating that adult involvement can sometimes limit children's curiosity and exploration. For example, seeing an adult demonstrate how to use a new toy can limit children's own exploration of it (Bonawitz et al., 2011), and children come to different causal conclusions when they make discoveries through their own actions than by watching the same actions performed by someone else (Kushnir and Gopnik, 2005; Sobel and Sommerville, 2010). Research on guided play responds to this tension by arguing that adults should offer guidance in open-ended ways while being attentive to children's own goals and interests (Weisberg et al., 2016; Baroody et al., 2019), and experimental studies tend to support this conclusion (Benjamin et al., 2010; Alfieri et al., 2011; Fisher et al., 2013; Haden et al., 2014).

In museum settings, caregivers interact with their children in many different ways, depending on their motivations for visiting, children's needs, prior knowledge, and cultural backgrounds (Swartz and Crowley, 2004; Gaskins, 2008; Beaumont, 2010; Downey et al., 2010; Fung and Callanan, 2013). Caregivers sometimes prefer to observe while children play, rather than being directly involved, focusing on the ways that children learn by interacting with museum exhibits and with other children (Wood and Wolf, 2010; Letourneau et al., 2017; Luke et al., 2019). Yet, many museums assume that caregivers' involvement in children's play is universally beneficial (Gaskins, 2008), when in fact the research paints a much more complex picture. For example, Medina and Sobel (2020) examined how caregivers and children explored a toy with causal functions, and found that when caregivers and children set goals together, children were more engaged and explored for a longer period of time than children whose caregivers were directive or who let children set their own goals. This work points to the need for more nuance in examining how caregivers' involvement affects children's engagement and learning in informal settings, and how museum practices might affect both the amount and the quality of caregiver-child interactions.

The current study builds on a line of collaborative research conducted in partnership with children's museums that examined caregiver-child interactions at museum exhibits. In one study across three children's museum sites, Callanan et al. (2020) examined children's exploration and caregiver-child explanations as they explored museum exhibits involving sets of gears. This study showed that caregivers' explanations prompted children to spin gears to test their causal properties, but children's causal thinking and persistence in solving problems (i.e., troubleshooting with the gears) was less affected by caregivers' involvement.

In a subsequent study, Sobel et al. (2020) examined whether and how caregiver-child interactions at a circuit block exhibit influenced children's engagement and learning when solving problems on their own with the same exhibit materials. The researchers recorded caregiver-child interactions as families played with a set of circuit blocks. They then asked children to complete a sequence of eight circuit challenges that increased in difficulty. They coded caregiver-child interactions using the same coding scheme as Medina and Sobel (2020), as well as the number of actions caregivers and children made in the 30 s before and the 30 s after completing common circuits, and the number of circuit challenges that children chose to attempt and completed on their own. Results suggested that children's engagement with the challenges was related to caregivers' involvement. Children in caregiver-directed dyads were subsequently less engaged in attempting to solve the challenges than children in child-directed or jointly-directed groups. Moreover, the more actions caregivers engaged in immediately before families completed circuits while playing together, the less able children were to construct those same circuits on their own later. Both of these findings suggest that children's autonomy in setting and completing goals is an important factor in their engagement and learning with this exhibit.

The current research extends this work to focus on the implications for practice—how might the design or facilitation of exhibits affect children's interactions with their caregivers? Specifically, this study aims to address two issues that remain relatively unexplored in research on caregiver-child interactions. The first is how the kinds of open-ended facilitation strategies that are commonly used in museums affect families' interactions. The existing research on facilitation in museum settings has either involved qualitative investigations of the wide range of practices used by facilitators to engage visitors (e.g., Tran, 2008; Gutwill et al., 2015), or experimental investigations of the impact of instructions from museum staff on how caregivers facilitate children's exploration of an exhibit (e.g., Gutwill and Allen, 2010; Van Schijndel et al., 2010; Haden et al., 2014). For example, most studies involve giving caregivers information before families begin exploring exhibits, in the form of written or verbal instructions about how to guide conversations with their children about exhibits (e.g., Benjamin et al., 2010; Haden et al., 2014; Willard et al., 2019), how to support children's exploration (Van Schijndel et al., 2010), or instructions about relevant scientific principles (Benjamin et al., 2010; Haden et al., 2014; Marcus et al., 2017). These types of structured interventions, however, are rarely used by facilitation staff in museums, although similar types of information may be available to families in the form of labels, signage, or multimedia displays. More commonly, facilitators in children's museums and science center's tend to offer brief and open-ended prompts to support and extend families' exploration and conversation throughout their interaction with exhibits.

The second unexplored issue is the relative benefits of facilitation as compared to physical design strategies like exhibit labels for supporting family interactions. Studies in museums have generally contrasted families' exploration of facilitated exhibits with their exploration of the same exhibits without facilitators present. In situations without facilitators, however, museums generally rely on the design features of the exhibit (such as labels or images) to convey information or prompt visitors' exploration.

These gaps in the research are significant because observational studies of facilitators' interactions with families in museum exhibits suggest that facilitators' presence can sometimes limit interactions between caregivers and their children (Pattison et al., 2018), and that caregivers may disengage or reject the assistance of facilitators when their involvement is seen as intrusive or overly didactic (Marino and Koke, 2003; Pattison and Dierking, 2013). More research is needed to examine how facilitation strategies commonly used in museum settings influence caregiver-child interactions in order to gain a more complete understanding of the roles that facilitators can play in supporting children's learning at museum exhibits.

To address these issues, we used the same circuit block exhibit as in Sobel et al. (2020) to examine how prompts offered by a facilitator or by exhibit labels affect the goals that children (ages 4–7, the same age range used in our previous study) and caregivers set as they play together, and the actions they each take to make discoveries with the exhibit. We compared how families played at a circuit block exhibit in which the same set of prompts were offered either by a facilitator or by labels printed on the circuit blocks themselves, making it impossible for families to use the circuit blocks without reading these messages (see **Figure 1** for an example). We based the prompts on the types of open-ended questions that museum practitioners typically asked as families explored the exhibit, and the prompts were generated with input from museum staff. Prompts included open-ended questions to encourage children and caregivers to try connecting the blocks in different ways (e.g., "What can you connect to this?," "How many things can you connect?"), questions to prompt observations that might prompt further exploration (e.g., "How fast can it spin?"), suggestions about things to try with the blocks (e.g., "Can you make two things go at the same time?") and general encouragement to keep exploring (e.g., "It's tricky. Keep trying!," "What else can you try?"). This set of prompts allowed for a more naturalistic experimental intervention that was both informed by and directly relevant to pedagogical practices in children's museums.

We examined whether multiple aspects of caregiver-child interactions differed when families received facilitated vs. written prompts, including: (1) overall caregiver-child interaction style, which reflected whether children, caregivers, or both set goals throughout their entire exploration of the exhibit; (2) the number of goal statements caregivers and children made as they explored the exhibit; and (3) how active children and caregivers were in the moments leading up to completing a circuit (relative to the moments after circuits were completed). We focused on these aspects of caregiver-child interaction because our prior study (Sobel et al., 2020) showed that directive interaction styles were negatively associated with children's engagement, and more actions on the part of caregivers prior to connecting the circuits were negatively associated with children's learning. Therefore, in the current study, we wished to specifically examine whether and how facilitated vs. written prompts affected these same aspects of caregiver-child interactions. Additional analyses of other aspects of dyads' language (e.g., praise, causal connections) are included in the **Supplementary Material** section.

METHODS

Participants

Our sample consisted of 95 children between the ages of 4 and 7 (M_{age} = 72.27 months, SD = 14.26 months, Range = 48.00–96.00 months, 46 girls and 49 boys) each tested with at least one caregiver. Families were recruited and tested at a local children's museum (Providence Children's Museum in Providence, RI, United States) during the families' museum visits. This sample did not include any children who had participated in our previous study with this exhibit (Sobel et al., 2020). This sample size was chosen based on a set of power analyses done in G*Power3.1.9, based on analyses between the two conditions and the three caregiver-child interaction styles (described below), assuming $\alpha = 0.05$ and $\beta = 0.20$ with a medium effect size. These analyses suggested that we needed a sample size between 88 and 108 participants given the analyses we planned on conducting (see below). These data were collected between June-August, 2017. Our final sample size was determined based on the number of visits to the museum we were able to conduct.

Demographics of the Sample

Children were tested with at least one legal guardian present (referred to here as "caregivers"). Thirty-eight children in this sample were tested with only an adult caregiver present. The remaining 57 children were tested with a caregiver as well as other family members. Seventy-nine children were tested with a female caregiver; 16 were tested with a male caregiver. Caregivers

FIGURE 1 | Example circuit block used in Exhibit label condition. See **Table 1** for all block/label pairs.

were asked to fill out a questionnaire to gather demographic information as part of the procedure (see *Procedure*, below); demographic data are summarized in **Table 1**. Caregivers were asked to describe their family's ethnicity and race, as well as languages spoken at home, by writing in open-ended responses. Responses about race were grouped based on the most frequently reported categories in our sample (e.g., caregivers who referred to themselves as "Chinese" were categorized as Asian/Asian American).

Seventy-three caregivers reported that their families spoke only English at home. Four caregivers reported that the primary language spoken in the home was not English (Spanish and Chinese were reported). Fifteen reported that multiple languages were spoken in the home—always English and another language (Spanish, Cantonese, Urdu, Cape Verdean, Dutch, and Portuguese were listed). Three caregivers did not provide this information. Three dyads communicated in Spanish while playing with the exhibit. These videos were transcribed and translated by a native speaker, and coding (described below) was done from those transcripts.

Materials

We constructed two sets of circuit blocks based on the circuit block exhibit at Providence Children's Museum. This exhibit was created as part of a project at the Museum that focused on highlighting the ways that children learn through play and exploration. Each set consisted of eight blocks: two blocks with LED lights (which could light up in two different colors depending on how the blocks were connected), two blocks with motorized spirals, two battery blocks, and two button blocks. A set of blocks was present on the table at the start of the procedure.

Also present on the table at the start of the procedure are a set of alligator clip wires (at least twenty) and a standing sign, which is normally part of the circuit block exhibit (see **Figure 2**). The sign shows a photo of a basic circuit with one battery block, one motor block, and two wires not fully connected, depicted from above, with a label reading, "Need a hint to get started? This activity is about exploring and experimenting. It's tricky. Figure out what works and what doesn't." This image was meant to convey how to connect the circuit blocks, but not to give specific solutions or instructions in order to encourage open-ended exploration. The image appeared on both sides of the sign, and the caption appeared in English on one side and in Spanish on the other. In the facilitation condition, the blocks appeared as they do in **Figure 2**. The exhibit label condition used an identical set of blocks, except that each block had a label printed on it (printed only in English). All messages were in 20 pt. Arial font, printed on bright yellow paper. The labels are shown in **Table 2**.

TABLE 1 | Demographic information.

Variable	Response category	Number of dyads
Household income	Below 30 K	10
	30–50 K	14
	50–70 K	17
	70–90K	11
	90–120 K	16
	Above 120 K	23
	No response	4
Caregivers' education level	Some HS	1
	HS Diploma	10
	Some College/Associates	23
	BA	25
	MA (or equivalent)	26
	PhD (or equivalent)	7
	No response	3
# Museum visits in past year	First-time visitor	23
	1–2 visits	14
	3–5 visits	19
	6–9 times	27
	10 or more visits	6
	No response	6
Caregiver age	21–35	40
	36–49	49
	50–65	3
	Over 65	2
	No response	1
Family ethnicity	Hispanic	19
	Non-hispanic	67
Family race	Black/African American	7
	Asian/Asian American	3
	Native American	0
	White/Caucasian	65
	Mixed/multiple races	11
	No response	9

Procedure

The study procedures were approved under Brown University IRB protocol #1307000890, *Explaining, Exploring and Scientific Reasoning in Museum Settings*. Families were recruited at a local children's museum (Providence Children's Museum). If families agreed to participate, a researcher brought them into the room where the circuit block exhibit was located. The researcher was both a museum staff member and a member of the research lab, and therefore had familiarity with typical museum facilitation strategies with this exhibit.

After giving written consent and verbal assent when necessary[1], families were asked to sit at the table with the exhibit materials, which included the eight circuit blocks, alligator clips, and hint sign. At the start of the procedure, one battery block and one effect block (either a spinner or a light) had an alligator clip attached to it, as an example of how the clips attached to the blocks. No circuits were completed at the start of the study and no two blocks were connected to one another at the start. This parallels the way in which the museum would typically set up the exhibit for regular use in between groups of visitors.

In both conditions, the researcher instructed groups to play with the circuit blocks however they liked, letting them know that they would have up to 15 min to play with the blocks. The researcher started the timer when the participating child approached the table. Groups were allowed to stop playing at any point they wished, but if they did not do so spontaneously, groups were given a 5-min and a 2-min warning before the 15-min was up. Families' interactions with the exhibit were recorded by a single video camera in the corner of the exhibit. The room was small enough that no additional microphones were needed to adequately capture families' conversations.

Because families visited the museum as a group, siblings and other members of the family group were also allowed to play with the circuits at the same time, but only one child per family participated in the study. A set of Squigz toys was available to entertain younger siblings when needed, while the participating child and at least one adult in the group played with the circuits.

Approximately half of the groups ($n = 48$) were randomly assigned to the *exhibit label condition*. In this condition, families were given the eight blocks with the labels on them, as depicted in **Figure 1** and described in **Table 2**. The researcher introduced the activity as described above, and then waited outside the entrance to the room while families played with the circuits so as not to influence their behavior. The researcher only interacted with the dyads to give time limits or when the family indicated that they were finished playing.

The other half of the groups ($n = 47$) were assigned to the *facilitation* condition. In this condition, the blocks had no messages on them (as shown in **Figure 2**). After the researcher introduced the activity and allowed the family to sit at the table, she said "Can you make something go?" and then stepped back to allow families to begin playing, but remained nearby in the room throughout the entire time that the dyad played with the circuits.

In the facilitation condition, the researcher would stand next to the table where families were playing and offer prompts using the same language as what was written on the exhibits in the exhibit label condition whenever there was a pause in dyad's play with the circuits. For example, if the dyad paused after making a working circuit, the researcher would use one of the prompts in **Table 2** to suggest a new action, possibly one that was slightly more complex than what the dyad just completed (e.g., if the dyad had just connected a motor to a battery, the researcher might use the prompts: "How fast can it spin?" or "Can you make two things go at the same time?"). Similarly, if children stopped playing or showed signs of frustration, the researcher would suggest a slightly easier activity, again using the same language as written on the blocks in the exhibit label condition (e.g., if the child paused without connecting any pieces, the researcher might use the prompts: "What can you connect to this?" [pointing to the battery block] or "What color is the light?"). The researcher kept

[1]All families provided written consent to participate. As required by our IRB protocol, 7-year-olds (but not younger children) also needed to provide verbal assent to participate.

FIGURE 2 | Picture of some of the circuit blocks and alligator clips in the facilitation condition (left), and hint sign present on the table in both conditions (right). The circuit blocks in the exhibit label condition were the same, but had yellow signs with black text on them, as in **Figure 1**. Note that not all circuit blocks used in the procedure are depicted. See text for details.

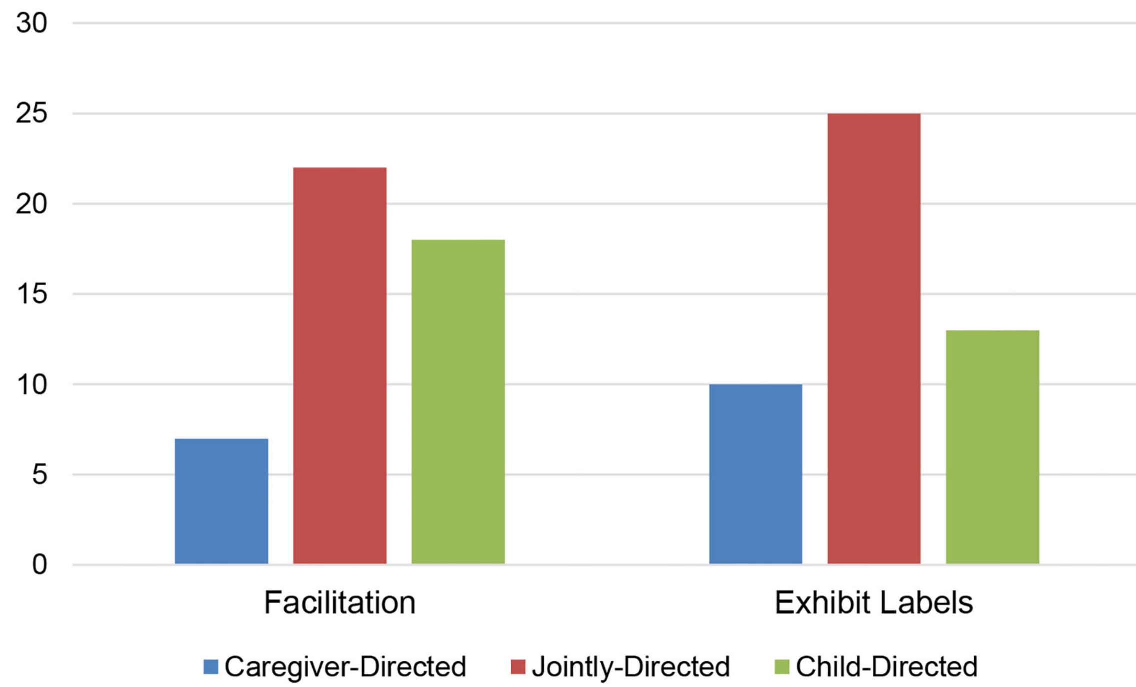

FIGURE 3 | Number of dyads with each caregiver-child interaction style across the two conditions.

track of the prompts that she offered, such that no prompts were repeated, and prompts were provided in only in English. If the caregiver stepped in to help, or if there was no pause in their play, the researcher would not intervene and would wait for a pause before offering another prompt. The researcher would continue offering prompts in this way throughout the entire duration of dyads' play with the exhibit.

The researcher did not provide other help or assistance, and was not involved in families' exploration of the circuit blocks except for observing and offering the verbal prompts

TABLE 2 | Labels printed on each block in the exhibit label condition.

Block type	Label
Battery	What can you connect to this?
Battery	What else can you try?
Button	Can you use this button to make something go?
Button	It's tricky! Keep trying.
Motor block with spiral	How fast can it spin?
Motor block with spiral	Can you make two things go at the same time?
LED	What color is the light?
LED	How many things can you connect?

described above. If families addressed her directly or asked her questions, she would give encouragement to keep trying ("Hm, I'm not sure! See if you can figure it out," "It's tricky, but keep trying") or vague observations or suggestions (e.g., "I wonder why that is," "Maybe you can connect it a different way") without giving away answers or giving direct instructions. Again, these messages were similar to what was written on some of the blocks in the exhibit label condition, and modeled after typical museum facilitation strategies with this exhibit. The goal with these neutral phrases was to allow the facilitator to be responsive to families, without offering praise, using leading questions, or giving any additional information that might influence their exploration.

Finally, if children showed a lot of frustration and wanted to stop, the researcher helped them connect the circuit they were attempting to complete before ending the study, so that children ended the study on a positive note. The majority of children, however, either played for the entire 15 min or indicated that they were ready to stop without showing signs of frustration. The prompts in the facilitation condition therefore varied slightly in their timing and order across the families who participated, in order to allow the researcher's interactions with families to be somewhat naturalistic, but the prompts families received included the same set of statements/questions that appeared in the exhibit label condition, and additional prompts offered by the facilitator in this condition did not contain any additional information about what to do with the circuit blocks or how to interact with them.

In both conditions, after families indicated that they were finished, caregivers were asked to complete a short demographic questionnaire, which included describing their experience visiting the museum, and the Attitudes toward Science questionnaire (Szechter and Carey, 2009), which measured their beliefs about the value of science and scientists. The results of this questionnaire are reported in the **Supplementary Material** section.

Coding

We coded whether children or caregivers took the lead in setting goals for their exploration as they played together (based on overall interaction style and via the number of goal statements made by children and caregivers in their conversations, described below), as well as the number of actions taken by children and caregivers before and after groups completed circuits with the exhibit. We focused on these two coding categories based on the results of Sobel et al. (2020), who found that these measures independently related to children's engagement with or performance on a set of challenges with these exhibit materials. Our goal was to determine whether these aspects of caregiver-child interactions differed across the two conditions. Like Sobel et al., we also considered other facets of caregiver-child interaction, such as the language caregivers and children generated. This coding and analyses based on this coding are described in the **Supplementary Material** section because Sobel et al. (2020) found that it did not predict children's engagement with or learning at the exhibit.

Goal Setting

To measure goal setting, we examined two facets of caregiver-child interactions. First, we used a coding scheme based on work by Fung and Callanan (2013) and used by Sobel et al. (2020), which examined whether caregivers and/or children tended to set goals for their interaction. If multiple family members played with the exhibit, we considered only the actions of the caregiver and participating child in determining this code. Some dyads were *child-directed;* children both set goals and accomplished goals for themselves; these caregivers were passive during the interaction and allowed children to explore freely or simply offered encouragement. Some dyads were *caregiver-directed*; caregivers both set goals for the interaction and either engaged in actions themselves or instructed the child to engage in specific actions to build particular circuits. Finally, some dyads were *jointly-directed*; caregivers let children set goals but facilitated children's exploration by asking questions and making suggestions to help children accomplish their goals. We present more details on this coding scheme in the **Supplementary Material** section.

Second, independent of the caregiver-child interaction style code, we also coded the number of *goal statements* generated by caregivers and children. Goal statements were utterances made by the caregiver or child that stated they had a desire or was working toward a desired outcome regarding the circuits. These statements were marked by the presence of particular verb phrases that directed actions toward the circuits: *going to*, *want to*, *trying to*, *need to*, *have to*, *got to* (or *gotta do*), *will do*, *let's* or the question "What if we <verb denoting action on the circuit blocks>?" Imperatives ("Make the light turn on." or "Now try it.") were not considered goal statements, nor were utterances that contained a goal unrelated to the circuits (e.g, "I want to go play with the water now." "Let's go get a snack.").

Two undergraduate coders, both blind to the hypotheses of the study, coded 20% of the videos for the caregiver-child interaction style code. Agreement was 81% (Kappa = 0.70). Disagreements were resolved through discussion with one of the authors. The remaining videos were then coded by one of these two undergraduate coders individually. Two different undergraduate coders, also blind to the hypotheses of the study, coded a different 20% of the videos for the goal statements. Agreement was 98% (Kappa = 0.88). The remaining videos were then coded by one of these two undergraduates individually.

Actions When Completing a Circuit

Following Sobel et al. (2020), we coded families' play with the exhibit based on whether they constructed each of eight different commonly-constructed circuits. We initially coded videos of dyads' interactions to determine whether groups built any of these circuits, and if so, we noted the time stamp when they completed the circuit in order to demarcate these events for further analysis. Two undergraduate research assistants coded 20% of the data. Agreement was 91% (Kappa = 0.81). Disagreements were resolved by one of the authors. The two undergraduates then proceeded to code the rest of the data independently.

We then counted the number of actions (connecting or disconnecting an alligator clip to a circuit block, or pressing a button) that both the caregiver and the child engaged in during the 30 s before and the 30 s after those circuits were completed. Actions in the 30 s prior to completing the circuit provided a measure of how active caregivers and children were in completing the circuits, and actions in the 30 s immediately afterward served as a control measure for how active caregivers and children were more generally, as these actions did not lead to the completion of circuits in a predictable way. The same 20% of the data were coded by one of the undergraduate research assistants who had coded whether groups completed the circuits, as well as a third undergraduate who had not yet viewed the videos, and both were blind to the hypotheses of the experiment. Agreement (which included all cases where the count was equal or off by 1 action) was 94% (Kappa = 0.91). Disagreements (including all cases where the count was off by 1) were resolved through discussion with one of the authors. These two undergraduates then coded the rest of the data independently.

All other coding is described in the **Supplementary Material** section, and did not relate to goal setting or completion codes described below.

Analysis Strategy

Our analyses focused on the following two questions. First, are there differences between the conditions in caregiver-child interaction style (i.e., whether caregivers, children, or both took the lead in their exploration), in how caregivers or children set goals while playing with the exhibit, or in the actions they each took to complete circuits? Second, does caregiver-child interaction style relate to the actions that caregivers and/or children took to complete the circuits?

Our analyses concentrated on goal setting and actions used to complete a goal because Sobel et al. (2020) found that these two behaviors—as opposed to many others—were directly related to children's engagement with and performance on challenges related to the circuit exhibit. These behaviors also provide two separate pieces of evidence about how involved caregivers were in children's exploration—in directing the goals of what they do with the exhibit, and/or being physically involved in constructing circuits as they played. Other analyses, including analysis of responses to the Attitudes toward Science questionnaire, and other language analyses, are presented in the **Supplementary Material** section. We did not find significant relations between demographic variables and our measures of interest; these analyses are also reported in the **Supplementary Material** section.

RESULTS

We first examined whether there were differences in the way in which caregivers and children played together at the exhibit based on the condition that they were in (facilitation vs. exhibit labels). Our measure of caregiver-child interaction focused on the how goals were set and accomplished while groups explored the exhibit. The distribution of caregiver-child interaction styles (parent-directed, jointly-directed, and child-directed) between the two conditions is shown in **Figure 3**. There was no difference in the distribution of caregiver-child interaction styles between the facilitation and exhibit label conditions, $\chi^2(1, N = 95) = 1.52, p = 0.47$.

We next looked at the proportion of caregivers' and children's utterances that were classified as goal statements. On average, caregivers in the exhibit label condition generated 5.33 goal statements (SD = 6.97) and 7.40 (SD = 8.80) in the facilitation condition. Children generated an average of 2.90 (SD = 3.28) in the exhibit label condition and 4.66 (SD = 4.99) in the facilitation condition. We built Generalized Linear Models, treating the dependent measure as an ordinal response, on both the number of goal statements generated by caregivers and by children, with condition and children's age (in months) as independent variables. Caregivers' goal statements did not differ between the conditions, B = −2.02, SE = 1.58, 95%CI [−5.10, 1.07], Wald $\chi^2(1) = 1.64$, $p = 0.20$, but did differ with children's age with caregivers of younger children generating more goal statements, B = −0.12, SE = 0.06, 95% CI [−0.22, −0.01], Wald $\chi^2(1) = 4.29$, $p = 0.04$. Children's goal statements did not differ with age, B = 0.02, SE = 0.03, 95%CI [−0.04, 0.08], Wald $\chi^2(1) = 0.45$, $p = 0.50$, but did differ between the condition, with children generating more goal statements in the facilitation condition than the exhibit label condition, B = −1.77, SE = 0.85, 95%CI [−3.45, −0.10], Wald $\chi^2(1) = 4.32$, $p = 0.04$.

We looked at children's actions while groups played with the exhibit. Dyads built more of the eight pre-defined circuits in the facilitation condition (M = 5.13, SD = 1.44) than in the exhibit label condition (M = 3.90, SD = 2.24), Mann-Whitney $U = 743.50$, $z = -2.90$, $p = 0.004$, $r = 0.30$. To isolate the unique variance of condition, we ran a Generalized Linear Model on the number of circuits built, treating the dependent measure as an ordinal response, looking at age (in months), condition (facilitation vs. exhibit labels) and caregiver-child interaction style as independent measures. The overall model was significant, Likelihood Ratio $\chi^2(4) = 24.00$, $p < 0.001$. There were significant effects of condition B = −1.20, SE = 0.38. Wald $\chi^2(1) = 9.79$, $p = 0.002$, and of age, B = 0.05, SE = 0.01. Wald $\chi^2(1) = 11.99$, $p = 0.001$. The main effect of caregiver-child interaction style was not significant.

We next documented whether there were differences in children's and caregivers' actions while playing at the exhibit, and in particular, if there was a difference in how active they each were

TABLE 3 | Average number of actions generated by caregivers and children in the 30 s before circuits were completed.

		Caregiver-child interaction style		
Actions by	**Condition**	**Caregiver-directed**	**Jointly-directed**	**Child-directed**
Caregivers	Exhibit labels	4.69 (2.41)	2.47 (2.36)	0.80 (1.62)
	Facilitation	2.50 (2.08)	0.81 (0.86)	0.56 (0.91)
Children	Exhibit labels	2.58 (1.58)	3.30 (1.96)	3.82 (2.79)
	Facilitation	3.05 (1.57)	3.87 (2.29)	3.65 (1.91)

TABLE 4 | Average number of actions generated by caregivers and children in the 30 s after circuits were completed.

		Caregiver-child interaction style		
Actions by	**Condition**	**Caregiver-directed**	**Jointly-directed**	**Child-directed**
Caregivers	Exhibit labels	3.66 (2.63)	1.70 (2.20)	0.42 (1.06)
	Facilitation	2.10 (2.02)	0.61 (0.64)	0.20 (0.39)
Children	Exhibit labels	3.64 (2.16)	3.72 (2.32)	3.01 (2.02)
	Facilitation	2.45 (1.60)	3.52 (2.23)	4.01 (2.12)

leading up to connecting a circuit. For each completed circuit, we counted the number of actions performed by the child and by the adult in the 30 s before and the 30 s after completion of the circuit. This allowed us to contrast how each member of the dyad acted while working toward a goal, and after that goal was completed. These data are shown in **Tables 3**, **4**.

We constructed Generalized Linear Models assuming an ordinal response on the number of actions performed by the adult or child. We considered condition, caregiver-child interaction style, and children's age as independent variables. In each case, factorial models resulted in no significant interactions, and the fit of the model (as measured by BIC) was poorer than a main effect model, so we report only main effect models.

Looking at adults' actions before completion of the circuit, the overall model was significant, Likelihood Ratio $\chi^2(4) = 41.83$, $p < 0.001$. There was a main effect of condition, with adults generating more actions in the exhibit label condition than the facilitation condition overall, B = 1.15, SE = 0.40, Wald $\chi^2(1) = 8.47$, $p = 0.004$. There was also a main effect of caregiver-child interaction style, Wald $\chi^2(2) = 27.61$, $p < 0.001$; adults in caregiver-directed and jointly-directed groups generated more actions than adults in child-directed groups, B = 3.38 and 1.66, SE = 0.64 and 0.49, Wald $\chi^2(1) = 27.58$ and 11.32, both $p \leq 0.001$. Moreover, adults in caregiver-directed groups generated more actions than those in joint-directed groups, B = 1.72, SE = 0.52, Wald $\chi^2(1) = 10.96$, $p = 0.001$. There was not a significant effect of children's age. Looking at adults' actions after circuits were completed, the overall model was significant, Likelihood Ratio $\chi^2(4) = 42.85$, $p < 0.001$. This result was characterized only by a main effect of caregiver-child interaction style, Wald $\chi^2(2) = 31.28$, $p < 0.001$. Again, adults in the caregiver-directed groups generated more actions than adults in the other two groups, and adults in jointly-directed groups generated more actions than adults in child-directed groups, all B-values > 1.75, all Wald $\chi^2(1)$-values > 11.01, all $p \leq 0.001$. Condition was a marginally significant trend, B = 0.78, SE = 0.41, Wald $\chi^2(1) = 3.72$, $p = 0.06$. Age was not significant.

Looking at children's actions before the completion of the circuit, the overall model was significant, Likelihood Ratio $\chi^2(4) = 9.97$, $p = 0.04$, with children's age as the only significant unique predictor of variance, B = 0.04, SE = 0.01, Wald $\chi^2(1) = 6.50$, $p = 0.01$. Neither condition nor caregiver-child interaction style was significant in this model. Looking at children's actions after the completion of the circuit, the overall model was not significant, Likelihood Ratio $\chi^2(4) = 2.31$, $p = 0.68$, and none of the three variables was significant on their own.

Finally, we looked at whether various aspects of the demographic information about the sample related to goal setting or the amount of actions caregivers or children generated before or after they completed a circuit. Most of these findings are non-significant. They are detailed in the **Supplementary Material** section.

DISCUSSION

This study examined caregiver-child interactions at a circuit block exhibit as family groups played together, when prompts were offered either by a facilitator or by written labels on the exhibit components themselves. We investigated whether either condition would affect dyads' overall interaction style—defined based on whether caregivers or children set goals for what they would do with the circuit blocks—and/or the actions they each took to physically connect the circuits. This study builds on prior work showing that when caregivers were more directive in setting goals for the play, children showed less engagement on follow-up circuit-building challenges, and when caregivers were more active in connecting the circuits, children were subsequently less able to reconstruct circuits on their own (Sobel et al., 2020). In the current study, we focused on how facilitated vs. written prompts offered during the exhibit experience would affect caregiver-child interactions. We used a facilitation style similar to practices commonly used in children's museums and science centers, in which facilitators offered open-ended prompts and questions as families explored the exhibit, and used the same prompts in the exhibit label condition.

Receiving prompts from a facilitator or from exhibit labels did not affect whether caregivers, children, or both collaboratively set goals as they played, and other language measures also did not differ across conditions (see **Supplementary Material** for analyses). However, when prompts were given by a facilitator, caregivers engaged in fewer actions to connect the circuits. These findings add nuance to previous studies of museum facilitation, which have found that in some cases, facilitators' presence can disrupt or reduce caregiver-child interactions (Pattison and Dierking, 2012, Pattison et al., 2018). Our findings suggest that the presence of facilitators did not shift families' overall interaction style, compared to the presence of written prompts on exhibit labels, but it did shift how much caregivers physically interacted with the exhibit—caregivers were more "hands-off" in exploring the exhibit when facilitators offered prompts than when families read the prompts on the exhibit itself. This condition difference could indicate that facilitators' presence suggested to caregivers that they should limit their own interaction with the exhibit, and instead allow children to take the lead in using the exhibit materials.

We also found that compared to the exhibit label condition, children in the facilitation condition made more goal statements, and dyads completed more circuits while exploring the exhibit. It is possible that because the facilitator was able to observe families' interactions and interject with prompts that were timed at opportune moments when dyads paused during their play, and chosen based on what they had recently done with the circuit blocks (providing more or less challenging prompts from the set of eight, depending on what had happened before they paused), that this may have extended or deepened some aspects of their exploration. It is also possible that both children and caregivers interpreted prompts on the part of the facilitator as pedagogical instruction to continue playing at the exhibit or to build more and more varied types of circuits. In contrast, although families in the exhibit label condition had access to the same prompts, they were not offered at strategic times or in response to aspects of families' play. Therefore, even though facilitation in this study was heavily scripted, the responsiveness of the facilitator may have played a role in the condition effects that we observed.

Our results suggest that the choices museums make about how to convey information can affect the ways that caregivers are involved in exploring exhibits with their children. These findings have implications for children's engagement and learning with this exhibit. Sobel et al. (2020) found that when caregivers were directive, children were less engaged in a subsequent problem-solving task with these exhibit materials, and when caregivers made more actions to complete circuits while they play with their children, children were subsequently less able to construct circuits on their own. In the present study, the exhibit labels we tested had an impact only on caregivers' actions, and not on the frequency of directive interaction styles. Together, the two studies suggest that choosing facilitation over exhibit labels may support children's performance in such problem-solving tasks, in line with prior work showing the importance of children's own actions in supporting their understanding of causal systems (Kushnir and Gopnik, 2005; Sobel and Sommerville, 2010) and their exploration of novel objects (Bonawitz et al., 2011). In contrast, children's engagement in attempting to solve problems may be more influenced by caregivers' involvement than by the manner in which prompts are given. Although we did not conduct follow-up measures in this study, this hypothesis could be tested in future studies.

On the other hand, the presence of written prompts on exhibit labels seemed to support caregivers in being more physically involved in exploring the exhibit and actively making discoveries with their children. There may be situations when the benefits of this type of shared exploration may outweigh the benefits of allowing children to engage in more actions on their own. In particular, for cultures in which children are expected to learn through observation, this way of interacting may feel more natural and in alignment with families' interactions in other settings (Rogoff et al., 2016). In addition, because studies have found that caregivers support children's learning in a wide variety of ways (Swartz and Crowley, 2004; Gaskins, 2008; Beaumont, 2010; Downey et al., 2010), museums may wish to provide multiple avenues for caregivers to be involved—by setting goals together, by physically exploring together, or both. In these cases, exhibit labels may open up more possibilities for caregivers' participation.

Nevertheless, these two strategies are obviously not mutually exclusive and rarely exist separately in real-world museum settings. One limitation of the current study is that the facilitator offered prompts throughout families' entire interaction with the exhibit, rather than "fading" (offering initial support to families and then letting families continue on their own), a more common approach in many museums. Combining more minimal facilitation with exhibit labels might allow museums to blend the benefits of both approaches and also be more responsive to families' needs and ways of learning. With this in mind, our findings can inform facilitation strategies used in museums by highlighting the potential impact of facilitation on caregivers' involvement, helping facilitators notice aspects of families' interactions when deciding how best to support children and caregivers' exploration of museum exhibits.

A second limitation is that this study focused on only one type of exhibit (a hands-on exhibit with connections to STEM learning). Whether the findings would generalize to exhibits that focus on other types of learning or other forms of play remains an open question. Certain aspects of our coding, however, such as the parent-child interaction style coding and the language analysis that we report in the **Supplementary Material**, have been applied to gear exhibits in multiple museums, as well as other toys with causal properties (Willard et al., 2019; Callanan et al., 2020; Medina and Sobel, 2020), suggesting that similar patterns of interactions are apparent in a range of informal learning contexts. In addition, the specific prompts used in the current study are relevant to exhibit experiences that emphasize hands-on inquiry and open-ended exploration, which are increasingly common in many museum settings (Humphrey and Gutwill, 2017).

Finally, although we did not observe differences in measures of PCI or actions across demographics, the majority of the sample in the current study was highly educated (with 58% of caregivers possessing a BA degree or above) and white (65% of the sample). Additionally, written and verbal prompts were offered only in English, and only one researcher (a white woman) served as a facilitator. Future studies could provide facilitation in other languages or involve a more diverse group of participants and facilitators in order to provide greater opportunities to understand how caregiver-child interactions in informal learning environments might be shaped by families' cultural, socioeconomic, and linguistic backgrounds.

In conclusion, this study brought together prior research on caregiver-child interactions in museum settings and practitioner expertise about the types of exhibit interventions that museums often utilize to support and extend families' interactions and learning. The findings from this line of work deepen our understanding of how museum settings can be designed and facilitated to provide more engaging learning experiences for children and their families. In addition, the methods we used to contrast commonly-used strategies can inform future studies with a range of settings and audiences.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Brown University Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

SL conducted the data collection and oversaw coding with DS. DS performed the data analysis. SL and DS wrote the initial draft. All authors contributed to editing the manuscript and conceptualized the project together.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.637067/full#supplementary-material

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Designing Exhibits to Support Relational Learning in a Science Museum

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Science museums aim to provide educational experiences for both children and adults. To achieve this goal, museum displays must convey scientifically-relevant relationships, such as the similarities that unite members of a natural category, and the connections between scientific models and observable objects and events. In this paper, we explore how research on comparison could be leveraged to support learning about such relationships. We describe how museum displays could promote educationally-relevant comparisons involving natural specimens and scientific models. We also discuss how these comparisons could be supported through the design of a display—in particular, by using similarity, space, and language to facilitate relational thinking for children and their adult companions. Such supports may be pivotal given the informal nature of learning in museums.

Keywords: relational learning, science museum, comparison, informal learning, cognitive support

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INTRODUCTION

Science museums aim to provide visitors with education as well as entertainment. In this paper, we consider how museum exhibits could be designed to promote cognitive processes that are instrumental to science learning. We focus on the process of *comparison*—a powerful mechanism that applies to a wide range of topics. We discuss how museum exhibits can promote comparisons to educate and engage visitors, and describe cognitive supports for comparison that are applicable to museums and other informal learning contexts.

RELATIONAL THINKING IN A SCIENCE MUSEUM

Science learning involves *relational* thinking. For example, understanding the scope and boundaries of natural categories involves recognizing how members of a category are similar to one another and distinct from members of other groups. There are also the deeper evolutionary relationships between organisms that shed light on the process of natural selection. Many other scientific categories are defined by abstract relations, having few (if any) overt features in common (Richland and Simms, 2015; Goldwater and Schalk, 2016). For example, the ripening of a banana bears little resemblance to the melting of arctic permafrost, yet both share the abstract structure of a positive feedback system, a process perpetuated by its own effects. Relational thinking is also involved in learning about scientific models, which represent key properties and relationships inherent to an object or system (Clement, 2008; Sibley, 2009; Kastens and Rivet, 2010; Stull and Hegarty, 2016). Comprehending these models involves understanding the spatial, temporal, and causal structure that is represented, as well as the relationship between the model and the real world (Jee and Anggoro, 2019).

A key question is how to promote scientifically-relevant relational thinking in the context of the museum. We propose a general approach based on cognitive and educational research on relational thinking—namely, the use of *comparison*.

COMPARISON PROMOTES RELATIONAL THINKING

Comparison involves aligning the elements of two representations according to the role they play in a common system of relations—a process of *structural alignment* (Gentner, 1983). For example, in the comparison between the atom (the less-familiar "target" case) and the solar system (the more-familiar "base"), structural relations, like the orbiting of smaller objects around a larger central object, are brought into focus. Superficial features, like the absolute size of the objects involved, fade into the background. Thus, the nucleus of the atom is placed in correspondence with the Sun—not because they look alike, but because these objects occupy a central position and attract surrounding objects in their respective systems. Through comparison, the broader relational structure that unites the two cases—that of a central force system—can be abstracted, forming a new relational concept (Gentner and Smith, 2012; Goldwater and Schalk, 2016). However, if the two cases are not explicitly compared, such abstractions may go unrealized (Gick and Holyoak, 1983; Kurtz et al., 2001; Richland et al., 2007; Star and Rittle-Johnson, 2009; Goldwater and Gentner, 2015).

Comparison is a powerful mechanism that has been used to meet a broad range of educational goals (Richland et al., 2007; Rittle-Johnson and Star, 2007; Alfieri et al., 2013; Jee et al., 2013). Comparison has also proven effective across a range of age levels, enhancing young children's and infants' relational thinking in a variety of domains (Gentner, 2010; Hespos et al., 2020). In the present paper, we explore how museum displays could be designed to promote scientifically-informative comparisons involving widely-used materials: natural specimens and scientific models.

We first consider how pairs of specimens could be used to promote learning of critical category information, including within-category variability, category distinctions, and shared structure that points to deep evolutionary relations. We then turn to learning about real-world causal systems through scientific models, and consider how pairing a model with a second, related representation could clarify the relationship between the model and the real world, and facilitate analogical reasoning about unfamiliar causal systems.

When it comes to museum-based learning—which is more self-directed and less structured than formal instruction (Hurst et al., 2019)—it cannot be taken for granted that visitors will engage in relevant comparisons, even when an informative pair of items is presented in a display. Nor can it be assumed that children's accompanying caregivers will provide appropriate assistance. In fact, parents can be unmotivated to provide an "educational experience" for their children (Collaboration for Ongoing Visitor Experience Studies (COVES), 2018), and may underestimate the educational value of museum exhibits (Song et al., 2017). Methods that promote children's learning, and encourage adults' involvement in this learning, are crucial in this setting (Pattison and Bailey, 2016). Thus, we also consider how aspects of an exhibit display—including the visual appearance of the specimens or models in the display, how the display is structured, and how the display is described in surrounding signs, labels, and captions—could be designed to facilitate the structural alignment process for visitors.

EXHIBITS THAT PROMOTE COMPARISONS INVOLVING NATURAL SPECIMENS

Natural specimens—skeletons, fossils, rocks, shells, etc.—are a hallmark of science museums. These objects provide visitors with the opportunity to observe the diversity of life on Earth, a central aim of current science education frameworks, such as the Next Generation Science Standards (National Research Council, 2012, 2013). Exposure to natural specimens could also help to offset the "taxonomic impediment" identified by the Convention on Biological Diversity—i.e., the decline in taxonomic expertise, resources, and public and policy-maker awareness (e.g., Klopper et al., 2002). Hence, the effective display of natural objects is of central importance to a museum's educational goals.

Natural specimens are displayed in a variety of ways, from crowded display cases to large-scale dioramas that reconstruct scenes from nature. In order to increase the biodiversity on display, museums often prioritize the inclusion of different species over showing multiple specimens of the same kind (Schilthuizen et al., 2015). The Spectrum of Life Display in the Hall of Biodiversity at the American Museum of Natural History, for example, contains ∼1,500 specimens, most of them representing unique species.

Yet, there are potential advantages to displaying multiple examples from the same category. When shown only a single category example, visitors may focus on irrelevant details. Displaying a pair of category members enables visitors to compare them, guiding attention toward relational structure. Indeed, children tend to sort objects in terms of taxonomic relations (e.g., vegetable) over perceptual features (e.g., round) after comparing two category members (Gentner and Namy, 1999). Displaying multiple category examples could also illuminate aspects of natural kinds that may otherwise be overlooked or misunderstood by visitors. For example, people often underestimate the variability that exists within biological categories (Shtulman and Schulz, 2008). Tigers may be thought to have about the same number of stripes, or ladybugs the same number of spots. Adults who underestimate within-category variation tend to have a poorer understanding of evolution (Shtulman and Schulz, 2008). Providing visitors with the opportunity to compare two category members that differ from one another—e.g., a tiger with many stripes vs. one with few—could help them appreciate the amount of variability that exists within biological categories.

Displaying multiple examples can also convey *systematic* variability within a category. For example, biological males and females of a species often have characteristically different traits, known as *sexual dimorphism*. Birds provide a number of striking examples. In northern cardinals, for instance, adult males have a bright red body and black coloring around the beak, whereas adult females are pale brown with reddish wings (**Figure 1A**). In other birds, like mandarin ducks and peacocks, the disparity in coloration is even greater. These within-category differences are driven by natural selection—in particular, females' preference for ornamental coloration in males (e.g., Hill, 2006). Yet, these interesting and informative patterns are effectively ignored when only a single specimen is on display. In fact, visitors may form a skewed impression, because male specimens are displayed approximately twice as often as female specimens (Mendenhall et al., 2020). The comparison of a male and female category member can draw attention to systematic variability, and, if multiple kinds of animal are compared, shed light on broader patterns in nature.

Paired examples can also help visitors distinguish between members of *different* categories. For example, students were better able to learn a geological structure, such as fault, when an example of the category was shown alongside a visually-similar image that did not contain this structure (Jee et al., 2013). Similarly, medical students learned to diagnose diseases from X-rays more accurately when a disease example was shown with a similar but healthy example as they learned (Kok et al., 2013). Encouraging visitors to compare specimens from different categories—*contrasting* cases—could help them to notice key taxonomic differences. This may be especially beneficial when two categories are readily confused. **Figure 1B** shows a display that includes a butterfly and a moth, two insects belonging to the order *Lepidoptera*. Although similar in appearance, butterflies and moths can be distinguished by several anatomical features, including their antennae (butterfly: thin with bulbed ends; moth: feathery/saw-edged), and body shape (butterfly: thin; moth: thick). These category-distinguishing features stand out when the two examples are directly compared. Contrasts can also promote relational concept learning. For example, Strouse and Ganea (2021) found that 3-year-old children were more likely to learn about camouflage from a storybook in which a camouflaged animal (light animal on light background) was compared with a similar, noncamouflaged animal (light animal on dark background).

Finally, pairs of specimens could be used to shed light on the deep, evolutionary connections between different species. For example, dolphins are very different from most other mammals in terms of their appearance and habitat. Displaying the bones of a dolphin flipper alongside those of a human hand permits a comparison that illuminates a remarkably similar skeletal structure. Along these lines, comparing the neck bones of a human and a giraffe (**Figure 1C**) reveals that each has the same number of cervical vertebrae (seven) despite dramatic differences neck length—a phenomenon known as *evolutionary stasis* (e.g., Williams, 1992). It can also be effective to have visitors compare a specimen against their own body. Callanan et al. (2016) found that children and adult museumgoers engaged in deeper conversations about a fossilized mammoth femur when the exhibit enabled a visitor to line up their own leg with the fossil. When the fossil was displayed in a case, visitors often merely labeled it a "bone." When visitors could sit down next to the fossil to compare its massive size against their own leg, they used different terms, including the specific name of the bone ("femur"), and the extinct animal to which it belonged ("mammoth").

Natural specimens can be paired in a number of ways in order to promote scientifically-informative comparisons. In addition to natural objects, museums often display scientific models that represent causal systems, such as plate tectonics, state changes of matter, and planetary motion. Comparisons between multiple models/visual representations could help visitors understand these models and make important connections to the real world.

EXHIBITS THAT PROMOTE COMPARISONS INVOLVING SCIENTIFIC MODELS

Scientific models—such as physical replicas and computer simulations—are representations of real-world systems (National Research Council, 2012). In such models, key elements of a system can be emphasized, and irrelevant details removed; objects that are imperceptibly small or large can be brought into view; events that unfold too quickly or too slowly to notice can be slowed down or sped up. These aspects of models can help to explain how the world works (Clement, 2008; Sibley, 2009; Jee et al., 2010; Kastens and Rivet, 2010; National Research Council, 2012; Stull and Hegarty, 2016). Models and modeling are therefore regarded as important crosscutting concepts in science education (National Research Council, 2012). Models are widespread in science museums—from reconstructions of extinct species to interactive simulations of natural systems and human-made machines. We focus on models of causal processes, especially those that depict real-world systems.

Like a good analogy, a good scientific model reflects the relational structure of the system it represents (Sibley, 2009). The classic science fair volcano—which erupts when vinegar and baking soda are poured into a crater at its top—is a poor scientific model, because it misrepresents the cause of a volcanic eruption. Of course, even well-designed models can be challenging to understand. Museum models that are highly abstract, with little resemblance to nature, can be difficult for visitors to grasp (Afonso and Gilbert, 2007). However, models that are highly realistic may obscure relevant properties or behaviors in a sea of trivial details (Uttal et al., 1997; Goldstone and Son, 2005; Kokkonen and Schalk, 2020). With a single model, it is hard to strike an ideal balance between emphasizing

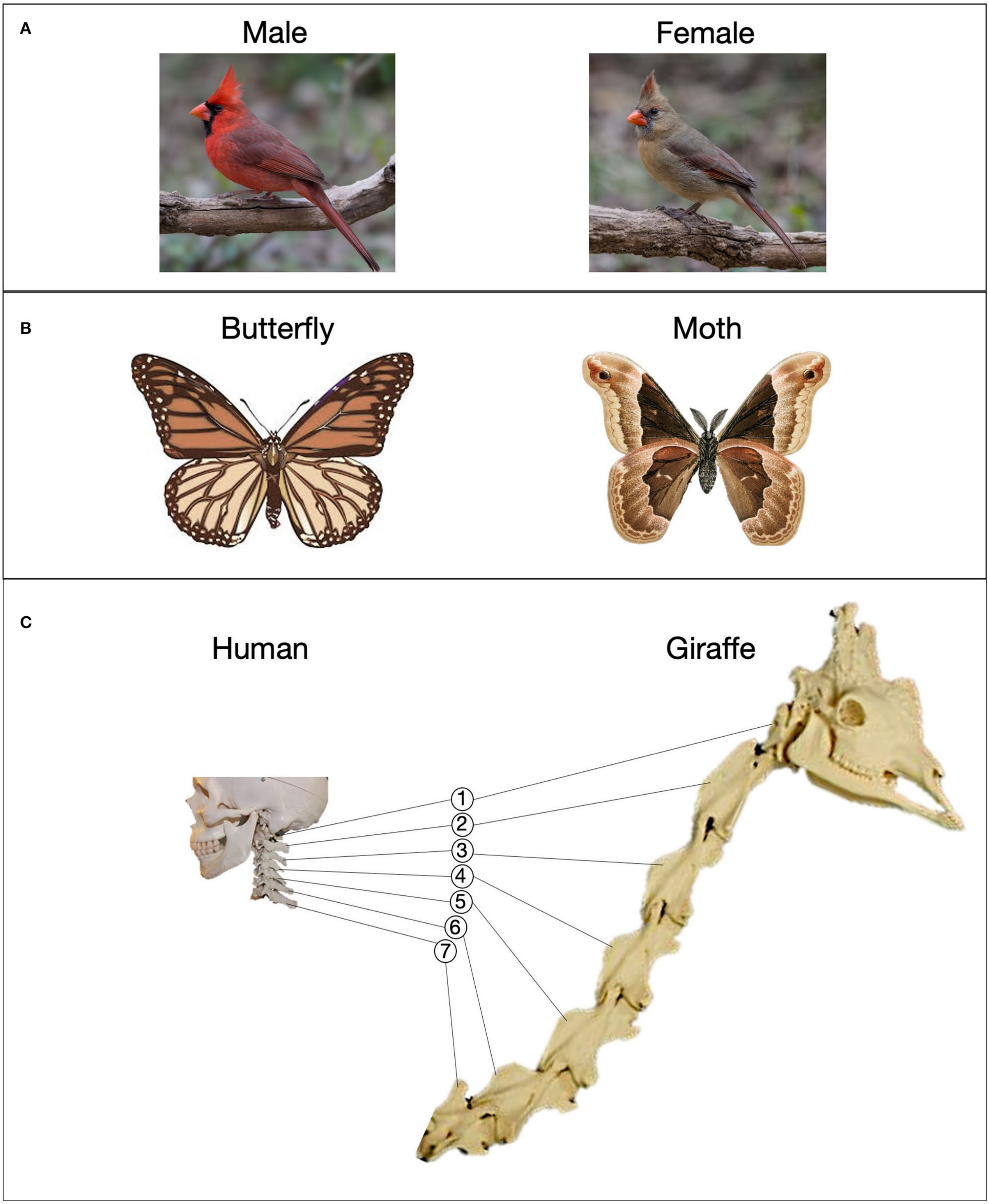

FIGURE 1 | Examples of comparisons involving natural specimens. **(A)** A male and female northern cardinal. Photographs by Andy Morffew; **(B)** a butterfly and a moth; **(C)** the cervical vertebrae of a human and a giraffe.

relational structure—which is central to deep learning—and retaining realistic surface details—which ground the model in the real world (Fyfe et al., 2014). Displays that enable visitors to compare a model with another model or visual representation could provide a way to overcome this challenge.

Displaying multiple representations of the same object or system—one showing how the object or system appears in real life, and the other emphasizing relational structure—could be effective in many cases. For example, geological structures can be difficult for novices to distinguish in natural contexts (Jee et al., 2014). Showing a photo of a geological structure along with an abstract model of the structure, as in **Figure 2A** (from Marshak, 2009), can help students make the connection between realistic and abstract representations. Designing an exhibit such that a concrete/perceptually-rich model is shown *before* an abstract/idealized model may be especially helpful—a sequence known as *concreteness fading* (Goldstone and Son, 2005; Fyfe et al., 2014). Encountering a perceptually-rich representation first can help to ground and disambiguate the more abstract model that is seen later on. In terms of structural alignment, the concrete representation serves as the base, and the more abstract representation, the target (Kokkonen and Schalk, 2020). In a museum, concreteness fading could be accomplished in a number of ways—a digital display that transitions from concrete to abstract at the push of a button or slide of a bar, or using a projector to overlay a realistic image onto an abstract physical model, etc.

When scientific models depict imperceptible objects or events, such as molecular structures or planetary motion, it may be crucial to connect the model to objects and events that *can* be experienced in everyday life. Displaying the behavior of the model alongside a related observable event could allow visitors to better appreciate these connections. In a recent study, 3rd-grade students were instructed to compare a model of Earth rotation alongside a synced-up video of the Sun's apparent motion in the sky. This enabled the students to see how the sunrise we observe when a location on Earth becomes exposed to sunlight is due to our planet's eastward rotation. The students who could compare the modeled and observable events learned more about the cause of the day/night cycle than students who received lessons involving only the model (Jee and Anggoro, 2019). A similar approach could be implemented in a museum using a solar system model synced with a nearby display of the "sky" as in **Figure 2B**. As Earth rotates in the model solar system, the accompanying display shows the view from a location on Earth's surface. Other counterintuitive scientific ideas, such as the link between molecular activity and state changes of matter, could be facilitated through similar pairings of models and more familiar or intuitive visual representations (e.g., Samarapungavan et al., 2017; Stieff, 2019).

The use of multiple models/representations could also enhance cross-domain analogies—comparisons between examples from different subject areas. When a model represents an unfamiliar system (the target), an analogy to a familiar example (the base) can help visitors understand how the model works. For example, sound waves may be compared to ripples in a pond; the mitochondria of a cell may be compared to a power plant; the convection of Earth's mantle to a boiling pot of water, etc. Analogies like these are often used to communicate scientific ideas (e.g., Glynn, 1991; Harrison and Treagust, 2006; Jee et al., 2010; Holyoak and Lee, 2017; see also the crowd-sourced list of science analogies at https://tinyurl.com/wrcp725). In museum exhibits, analogies often appear in text form, such as a sign or caption for a display (Valle and Callanan, 2006). However, text-based analogies rely on a visitor's accurate recollection of the base domain, and also their ability to map the base and target. Both of these processes are resource-demanding and error-prone (Richland et al., 2007; Simms et al., 2018). Adding a visual representation of the base can help learners grasp an analogy, and reduce the cognitive burden of retrieval and mapping (Richland and McDonough, 2010). Indeed, 4th-grade students gained more knowledge from analogical instruction about scientific processes when both the base and target cases were visually represented as opposed to showing the target alone (Matlen et al., 2011). **Figure 2C** shows one of the visual analogies from Matlen and colleagues' study—a boiling pot of water (base) and mantle convection (target). When an exhibit includes cross-domain analogies such as this, adding a visual representation of the source example may help visitors perform the intended structural alignment.

EXHIBIT-BASED SUPPORTS FOR COMPARISON AND ALIGNMENT

Exhibits that display multiple specimens, models, and other visual representations provide visitors with the opportunity to engage in scientifically-informative comparisons. Yet, visitors may require additional cognitive supports to fully benefit from these opportunities. In the informal learning context of a museum, it may be crucial to incorporate supports for comparison into the exhibit itself.

A number of exhibit-based supports could facilitate comparisons involving natural specimens and models. Surface similarity is one key factor. Superficially similar items are easier to align, and are helpful for initiating relational learning (Thompson and Opfer, 2010; Gentner et al., 2011; Jee et al., 2013). If the goal is to highlight differences, high-similarity contrasting items can draw a visitor's attention to the features that vary between the items (Gentner and Markman, 1994; Sagi et al., 2012; Strouse and Ganea, 2021). Though natural specimens are not entirely manipulable, it may be possible to select examples with high overall similarity to help visitors perform the intended comparison. The cardinals in **Figure 1A**, for example, are similar in many respects—size, orientation, background, etc.—which helps to draw attention to the difference in color. Likewise, the size, color, material, and other aspects of a model could be controlled to enhance its similarity to other representations in a display. For example, when a museum display included models of a stable and unstable building that were highly similar in height, color, construction materials, etc., 6–8-year-olds were more likely to learn the key feature of the stable building—a diagonal brace (Gentner et al., 2016). If increasing the perceptual similarity of the two models is not a viable option, comparison can be supported by adding a third example that is halfway between the two in terms of its appearance. The inclusion of an

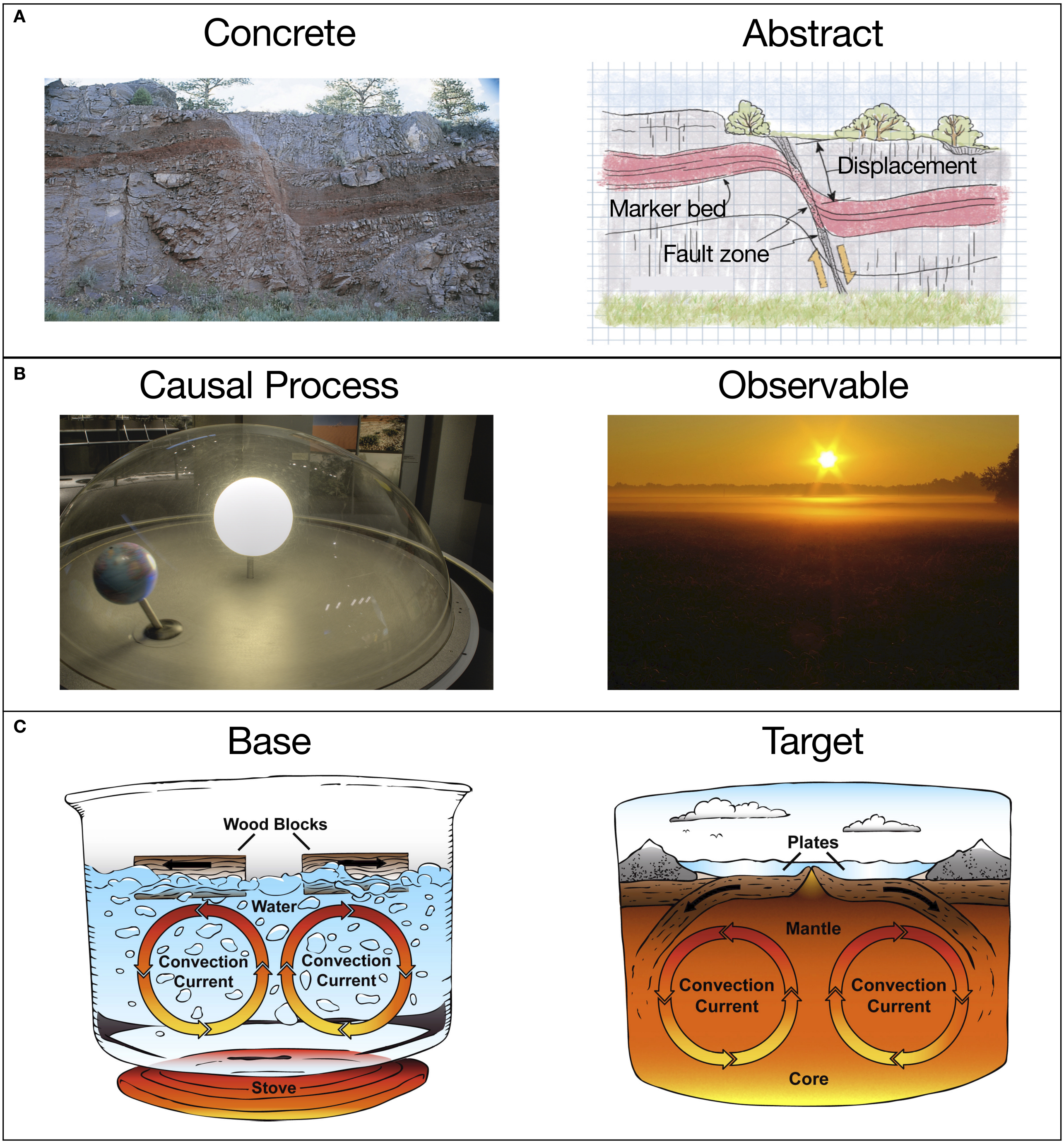

FIGURE 2 | Examples of comparisons involving scientific models. **(A)** A concrete and abstract representation of a geological structure. Excerpted from Essentials of Geology, 3rd Edition. Copyright © 2009 by Stephen Marshak. Used with permission of the publisher, W. W. Norton & Company, Inc. All rights reserved. **(B)** a model solar system and an observation from Earth's surface; **(C)** a visual analogy between a boiling pot of water (base) and mantle convection (target).

intermediate case establishes a bridging analogy that clarifies the connection between the more extreme pair (Clement, 1993).

Another consideration is how a pair of related items are arranged in space. To facilitate comparison, two objects should be placed in close proximity, and perhaps visually segregated from other items in a display, e.g., by placing a boundary around them. This spatial contiguity could help visitors to realize that a meaningful relationship exists, and makes it easier to examine the two cases simultaneously (Mayer and Moreno, 2003). Another spatial consideration is the relative placement of the items in the display (Richland et al., 2007; Richland and Simms, 2015; Matlen et al., 2020). For pairs of specimens or models with a vertical orientation (e.g., part A *above* part B, etc.), side-by-side placement is optimal for comparison (Matlen et al., 2020). For those with a horizontal orientation (part A *beside* part B, etc.), placing one above the other is optimal. In **Figure 1C**, for example, the human and giraffe pair are placed in optimal fashion for alignment—specimens with vertical orientation placed next to each other.

Spatial factors can also support relational thinking and learning from interactive exhibits. For exhibits in which visitors are invited to compare themselves against a museum specimen—a dinosaur's footprint, a condor's wingspan, a mammoth's leg bone, etc.—deeper learning is more likely to occur when the visitor can place their body in an optimal position for the alignment (Callanan et al., 2016). Exhibits that include levers, knobs, and buttons can be easier to understand and control when they conform to commonplace metaphors between space and quantity, such as "more is up" and "less is down" (Lakoff and Johnson, 1980; Allen, 2004). Spatial structure can also support reasoning about relational rules that govern a natural or artificial system. For example, 3-year-olds were more likely to infer a relational rule—e.g., that two of the same objects were needed to activate a machine—when the two objects were inserted into openings at either side of the machine (highlighting their relation) as opposed to being placed on top of it (Walker et al., 2020).

Language provides another useful support for comparison. Labels, captions, and other verbal information can clarify connections between examples. Even young children benefit from verbal prompts to compare, and learn abstract relational categories more efficiently when category members are labeled with the same term (Waxman and Markow, 1995; Gentner and Namy, 1999; Gentner et al., 2011). When causal processes are displayed in multiple visual representations, children learn more when prompted to think about the relationships between the representations (Hansen and Richland, 2020). Labels, captions, instructions, etc. can also benefit pre-literate children by influencing how their older caregivers behave at an exhibit. Simple signs in a display can help parents appreciate the educational value of museum exhibits (Song et al., 2017). This awareness could lead caregivers to capitalize on educational opportunities that they and their child might otherwise miss.

When children engage in an exhibit together with an adult caregiver, they tend to demonstrate more critical scientific thinking, such as comparing different sources of evidence (Crowley et al., 2001). Parents may produce spontaneous analogies to help their children grasp the scientific ideas they encounter (Valle and Callanan, 2006). Children also learn more when their parent uses language that highlights key features or relations—e.g., referring to diagonal bracing ("angle," "brace," "cross-beam," "diagonal") while building a model tower (Gentner et al., 2016). Parents' nonverbal cues, such as gestures, could also help to draw attention to relevant relationships and support the alignment process (Alibali et al., 2013; Richland, 2015).

Labels and other text may be most effective when placed within a display, in close proximity to related specimens and models, as opposed to outside the display on a placard—another application of the spatial contiguity principle (Mayer and Moreno, 2003). This proximity can help to ensure that visitors notice the verbal information *before* engaging with the exhibit materials. Indeed, parents' use of causal language predicted their children's productive use of exhibit materials (e.g., building machines with gears) only if it occurred before children used the materials (Callanan et al., 2019).

FURTHER THOUGHTS ON COMPARISON AND SCIENCE LEARNING

Our discussion of comparison emphasized the educational potential of promoting an underutilized cognitive tool through the design of museum displays. As we move to test our comparison-based approach in a museum setting, we recognize that designing a successful exhibit involves numerous considerations besides meeting educational goals. Children's museum exhibits should be interesting and entertaining, they should engage visitors at different age levels who may interact with an exhibit alone or together (Rigney and Callanan, 2011), and they should be accessible to children and adults with diverse backgrounds and abilities (Shaby et al., 2016). Ideally, methods that promote informative comparisons in a museum will enhance children's thinking and learning without sacrificing their enjoyment, exploration, and engagement. Indeed, without willful engagement, visitors have little chance of benefiting from even the most effective visual displays. Thus, to better evaluate the comparison-based approach, we must use metrics relevant to museum exhibit practitioners, such as tracking visitor groups' time spent at the exhibit, their verbal and nonverbal references to the materials in an exhibit, and the roles that caregivers take in supporting children's learning (Crowley et al., 2001; Haden et al., 2016; Callanan et al., 2017; Horn, 2018).

Though our focus is on museum-based learning, methods that promote relational thinking could be applied broadly in education. Research on math and science learning has revealed that relatively small changes to existing materials—such as the number and type of practice problems that students receive, or the spatial layout of a science diagram—can make a difference in students' mastery of the material (Higgins, 2020). Encouragingly, when an instructional sequence sets the stage for structural alignment, children can recognize and transfer relational structure without explicit guidance (Sidney, 2020). By further incorporating cognitive supports into educational materials and lessons, remote and independent student learning—which have soared during the COVID-19 pandemic—could be made more effective and manageable for teachers, students, and caregivers. More broadly, this approach would make science more accessible for young children who may otherwise receive little instructional support at home or at school.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

BJ and FA share first authorship in light of their comparable contributions to this project. Both authors approved the final version of the manuscript for submission.

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Understanding Parents' Roles in Children's Learning and Engagement in Informal Science Learning Sites

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Informal science learning sites (ISLS) create opportunities for children to learn about science outside of the classroom. This study analyzed children's learning behaviors in ISLS using video recordings of family visits to a zoo, children's museum, or aquarium. Furthermore, parent behaviors, features of the exhibits and the presence of an educator were also examined in relation to children's behaviors. Participants included 63 children (60.3% female) and 44 parents in 31 family groups. Results showed that parents' science questions and explanations were positively related to children observing the exhibit. Parents' science explanations were also negatively related to children's science explanations. Furthermore, children were more likely to provide science explanations when the exhibit was not interactive. Lastly there were no differences in children's behaviors based on whether an educator was present at the exhibit. This study provides further evidence that children's interactions with others and their environment are important for children's learning behaviors.

Keywords: informal science learning, science education, parents, family visits, children

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INTRODUCTION

Informal science learning sites (ISLS), such as museums and zoos, are central resources where both children and adults can learn about science (National Research Council, 2009). Findings suggest that optional science experiences outside of formal school environments are associated with science attitudes and knowledge (Liu and Schunn, 2018). Further, recent research with ISLS visitors highlights that children and adults perceived that they learned more when interacting with an educator, especially a youth educator (e.g., a teen docent), rather than the exhibit alone (Mulvey et al., 2020). Additionally, parent-child interactions in informal science learning environments can create important opportunities for learning (Benjamin et al., 2010; Callanan et al., 2017, 2020). Furthermore, according to Social Cognitive Theory the environment and the behaviors of others can play an influential role in children's learning (Bandura, 1986). Therefore, the aim of the current study was to analyze how parents' behaviors foster children's opportunities for learning in different informal learning sites and examine how the interactive features of the exhibits, as well as whether an educator is present at the exhibit, are related to children's learning behaviors.

Abbreviations: ISLS, informal science learning sites; STEM, science, technology, engineering, and mathematics.

Theoretical Framework

This work was informed by Social Cognitive Theory, which describes how behaviors, environments, and personal characteristics influence the learning process (Bandura, 1986). Prior research has used Social Cognitive Theory to study children's learning in more formal settings, for instance in schools (Burns et al., 2018). This research has focused on students' academic achievement, and career orientation, with attention to factors such as social support from peers and parents and teachers and personal factors such as self-efficacy and perceived control (Nugent et al., 2015; Burns et al., 2018). However, Social Cognitive Theory can also be used to understand children's behaviors in informal learning sites such as science museums. In these settings the environment can influence children's behaviors. For example, many ISLS have specific environments structured to foster learning, for example these sites include exhibits where children can engage in learning behaviors such as physically interacting with and manipulating structures (Sandifer, 2003; Shaby et al., 2017). Additionally, these exhibits often have educators present who will help children understand how to use these interactive exhibits and also encourage science conversations. Furthermore, social interactions between children and parents can also be influential for children's behaviors. At these sites, parents' behaviors can be especially important as they can help children learn and acquire new skills. For example, when parents used questions to guide their children's learning, children were more likely to engage in scientific processes such as predicting and evaluating (Vandermaas-Peeler et al., 2018). Therefore, Social Cognitive Theory was applied to the current study to evaluate relationships between behaviors (parents' questions and explanations), the environment (exhibit features and presence of an educator) and children's learning in ISLS.

Children's Learning Behaviors in ISLS

Traditionally, learning has been measured as an accumulation of new information (Hooper-Greenhill, 2003). However, in line with Social Cognitive Theory, children's behaviors are also important indicators of learning (Bandura, 1986). In ISLS, behaviors such as observing the exhibit, engaging with the exhibit, asking questions, and giving explanations can demonstrate that children are learning.

Children can learn in ISLS by exploring an exhibit in many different ways. Barriault and Pearson (2010) considered behaviors such as observing the exhibit or physically interacting with the exhibit to be "initiation behaviors"–the first steps in learning. There are many opportunities for children to interact with the ISLS through physical manipulation of elements and/or participatory activities. Interactive exhibits in ISLS that place emphasis on hands on learning, have been shown to be very effective in promoting learning in children (Andre et al., 2017). Furthermore, hands-on exploration can also involve using prior knowledge to make connections or understand causal relationships (Legare, 2014). Therefore, children can engage with an exhibit through physical interaction or making connections to other knowledge. These experience-rich environments, that encourage children's exploration, allow for the use of processes such as evaluation and comprehension, which have been associated with children's cognitive development (French, 2004).

As indicated above, children's social interactions in ISLS are essential for their learning. The conversations that children have with educators or their parents may allow them to think more deeply about the information in the exhibits. When children ask questions or give explanations, they explore and make meaning of new information and ideas (Barriault and Pearson, 2010). In these types of interactions children advance their understanding of the concepts encountered in the ISLS, which can promote their science engagement and learning. In the current study, we aim to examine how learning behaviors exhibited by children visiting ISLS with their family are associated with environmental factors, parental behaviors, as well as the prescence of an educator. Although some prior research has examined environmental factors, such as the exhibit features (Barriault and Pearson, 2010; Shaby et al., 2017), explored children's learning with attention to the role of the parents (Benjamin et al., 2010; Callanan et al., 2020), and other research has examined children's interactions with educators in ISLS (Shaby et al., 2019), scant research has attended to both caregivers and educators as well as environmental factors in concert.

Environmental Factors Related to Children's Learning

In addition to considering the role of parents and educators, it may also be important to focus on environmental features when examining children's learning in ISLS. Although we often think of learning environments with attention to formal classroom spaces, informal spaces are rich environments that can create opportunities for learning. When families visit ISLS, they are exposed to a range of ways to engage with novel environments in exhibits, providing ample opportunities for science learning to occur. Although many visitors report that the primary reason why they visit ISLS is for entertainment (Tofield et al., 2003), ISLS also provide opportunities for science learning (National Research Council, 2009; Shouse et al., 2010). Research has focused on the academic- and science-related outcomes of visiting ISLS, including attention to learning during school group (Tal and Morag, 2007; Shaby and Vedder-Weiss, 2019; Shaby et al., 2019) and family visits (Benjamin et al., 2010; Haden, 2010; Callanan et al., 2017, 2020; Pattison et al., 2018).

Students can gain critical science skills and have opportunities for practical application when they visit ISLS (Bell et al., 2009). Experiences in ISLS also provide other academic benefits including increased academic aspirations, increased interest in math and science, and feelings of competency in science (Lin and Schunn, 2016; Goff et al., 2019). Furthermore, there are often multiple interactive features in ISLS, and this interactivity is associated with longer visitor engagement (Sandifer, 2003; Shaby et al., 2017). Interactive exhibits may have features which children can physically interact with, whereas non-interactive exhibits facilitate observing behaviors. A study that analyzed parent-child dyads at an ISLS found that parents and children spent more time at exhibits that were interactive compared to non-interactive exhibits (Szechter and Carey, 2009). Therefore, interactive exhibits are critical for visitor engagement. Not only are the interactions with the exhibit influential, but the social interactions that occur in ISLS are also key factors associated with science learning in children. In the present study, we examined environmental factors across a range of different types of ISLS and exhibits, including exhibits in a zoo, a children's museum and an aquarium. Thus, we further extend prior work, which has often examined children's learning within one type of setting. Our aim was, in part, to document what environmental factors are associated with children's learning across different types of settings and exhibits. This is a critical new direction for research as it can help to document best practices for museum design and exhibit development that reach across the silos that are often formed within particular types of learning settings.

What Role Do Educators Play in Children's Learning?

Educators can aid visitor learning by providing explanations, asking questions, and instructing visitors on how to use the exhibit. For example, in one study, when educators gave tips on how to build a structure in a building activity, children used more science-related talk when recalling their museum visit compared to children who did not receive any tips (Haden et al., 2014). Additionally, Mulvey et al. (2020) found that child and adult visitors felt that they learned more from their experiences in ISLS after interacting with an educator rather than just the exhibit. Visitors in that study also reported greater interest in the topic after interacting with a youth educator compared to an adult educator. Educators also encourage learning by emotionally engaging with guests to increase interest in the exhibits (Shaby et al., 2019). Furthermore, another study found that, compared to visitors in a greeting condition, in which educators simply greeted guests when they approached an interactive math exhibit, visitors who interacted in more substantial ways with educators spent more time at the exhibit, felt more satisfied with their experience, and had a better understanding of the content, including mathematical reasoning in particular (Pattison et al., 2018). However, this study also found that, when educators were present, parents and children were less likely to communicate with each other. This suggests that in the presence of educators, instead of talking to each other, parents and children may direct questions and comments toward the educators which may hinder key parent-child interactions that are important for children's learning. Therefore, it is important to explore both educators' and parents' behaviors in ISLS together.

How Are Parents' Behaviors Related to Their Children's Learning?

Parent-child conversations can promote children's learning (Crowley et al., 2001; Fender and Crowley, 2007). For example, in one study, parents' use of explanatory conversations, such as providing scientific explanations or asking questions, was positively related to their children's use of explanatory conversations at an evolution exhibit (Tare et al., 2011). These types of conversations can help keep children engaged and promote children's scientific dialog. However, parents' explanations and questions can elicit different behaviors for their children.

In a study exploring children's and parents' conversations in a museum, parents' requests for explanations from their children were positively related to children's engaged talk (requests and explanations), but parents' explanations were negatively related to children's engaged talk (Callanan et al., 2017). Furthermore, when parents were instructed to provide either scientific questions or statements, children whose parents asked more scientific questions responded more to their parents compared to children whose parents gave scientific statements (Chandler-Campbell et al., 2020). Additionally, when parents asked scientific questions, their children were more likely to answer with scientific responses. However, parents' explanations have been shown to often be incomplete or incorrect (Snow and Kurland, 1996; Crowley et al., 2001) parents may not know enough about certain concepts to accurately explain them, which can create more confusion and misunderstanding for their children.

When parents ask their children questions, rather than just providing answers, they are more likely to create meaningful conversations (Callanan et al., 2017). Asking questions, especially open-ended questions, can help parents and other educators to understand what children know while facilitating children's learning of new information (Haden, 2010). Although parents' explanations may not always promote learning, children's use of explanations can (Booth et al., 2020). Research has also shown that parents' invitations to their children to provide their own causal explanations were related to their children's scientific literacy (Booth et al., 2020). Thus, creating opportunities that allow children to think critically and engage with the material promotes children's learning (Haden, 2010). The present study extends previous work on the effectiveness of parents' explanations and requests on their children's own scientific talk.

CURRENT STUDY

Informed by Social Cognitive Theory, the present study used observational video-based data to analyze how the environment and the presence of educators at ISLS as well as parents' behaviors are related to children's learning behaviors. The children's behaviors we evaluated were children's observations of the exhibit, engagement with the exhibit, requests for science information, and use of science explanations. Thus, we evaluated how parent-child conversations, the presence of an educator, the length of time of the visit, and how interactive exhibits in ISLS relate to children's conversations and behaviors.

Hypotheses

(1) Based on findings from Mulvey et al. (2020), we expected that the presence of an educator would be positively related to all children outcome variables (children observing the exhibit, children engaging with the exhibit, children's requests for science information, and children's science explanations).

(2) In a non-interactive exhibit in which parents use more science explanations we expected that children would be more likely to observe the exhibit (Callanan et al., 2017).
(3) Given prior research that demonstrates how effective interactive exhibits are for children's learning (Andre et al., 2017), we expected that if the exhibit is interactive, children would be more likely to engage with the exhibit.
(4) As findings suggest that when parents ask questions, children are more likely to engage in explanatory conversations (Tare et al., 2011), we expected that parents' requests for science information would be associated with more requests for science information and explanations from children.
(5) Moreover, in line with findings from Callanan et al. (2017), we expected that parents' science explanations would be associated with fewer requests for science information and explanations from children.

MATERIALS AND METHODS

Participants

In this study we analyzed 31 video recordings of the interactions between children, their parents, educators and the exhibit itself. Thirteen of the videos had an educator present at the exhibit. Participants included 31 families of 63 children (∼60.3% female) and 44 parents (∼76.9% female). Twenty-one family groups included more than one child and the average number of children per family group was 2.03. We were unable to directly request demographic data from families and thus demographic information including age, gender, and ethnicity were coded based on inferences made by the research assistants coding the videos. We estimated that roughly 43% of youth visitors were in early childhood (3–8 years), 44% percent were in middle childhood (9–13 years), and 13% were 14 or older. We also estimated that roughly 60% of families were White. All participants spoke English in the videos.

Procedure

This research was approved as Exempt by the Institutional Review Board at the University of South Carolina with an Inter-Institutional Agreement by North Carolina State University. Participants were recruited from three different ISLS: a zoo, an aquarium, and a children's museum (see **Table 1** for descriptions of exhibits) in the Southeastern United States. Signs were posted about the research project at the entrance to the exhibits and participants were invited to participate by a research assistant and provided with a notification letter about the study. If the family agreed to participate, they were asked to wear a microphone headset and were video recorded while visiting selected exhibits. Educators also wore a lapel microphone. Video cameras were placed in three locations at each exhibit to ensure that the full family visit was recorded.

Coding and Transcription

All data were transcribed by trained research assistants and videos were coded in Atlas.ti (ATLAS.ti Scientific Software Development GmbH) using a coding system developed based on those used in two prior studies (Barriault and Pearson, 2010; Callanan et al., 2017). Each interaction (see **Table 2** for descriptions of measures coded) for each person was coded once in 30s intervals. For example, if a child asked two science requests in the first 30s of the video, the code of "science request" for that child was used once for that interval. Scores for each interaction type were determined by summing the instances of the behavior for parents and children during the time spent at the exhibit. Each video was coded by two research assistants, and the interrater reliability (as calculated

TABLE 1 | Exhibit descriptions.

Site	Number of Videos at Site	Exhibits	Type of Exhibit	Description
Aquarium	11	Reptile Exhibit	Non-interactive	Visitors were able to view animals such as a Komodo dragon and a Tomistoma. Exhibit signage provided information on the habitats and ecology of the animals. Educators were at times present to provide additional information about the species and their ecology.
Children's Museum	8	Flight Exhibit	Interactive	Visitors could make a paper airplane and could test out their airplanes by throwing them through hoops hung from the ceiling. Educators would help visitors build their paper airplanes and discuss principles of flight. Visitors could also use a flight simulator to pretend to fly an airplane.
Zoo	12	Gorilla Exhibit	Interactive	Visitors could view the gorillas in an outdoor exhibit, use interactive maps and other displays to learn about the specific gorillas at the zoo as well as the dangers facing wild gorillas. Educators at this exhibit taught using "biofacts" such as a gorilla skull and share information, also available on exhibit signage, about the places that gorillas live, the food they eat, and other information about gorillas.
		Sea Lion and Seal Exhibit	Interactive	Visitors could observe the sea lions and seal on two levels, through large glass panels. The exhibit included an artistic display of trash found in the ocean that visitors could look at and touch. This display was used to demonstrate the pollution in the ocean. Educators also provide interpretation, sharing similar information about sea lion and seal ecology as is found on exhibit signage.

TABLE 2 | Descriptions of measures.

Measure	Definitions
Children Observing the Exhibit	Refers to when someone is looking at the exhibit without interacting or talking, or looking at others engaging with the exhibit.
Children Engaging with the Exhibit	Refers to when someone is physically using the devices or educational materials at an exhibit or when someone is providing additional information that connects to prior knowledge. Example: children could make a paper airplane in the flight exhibit. Example: "I read about Gorillas in a book, they live there."
Children and Parents' Requests for Science Information	Defined as asking for an explanation relevant to the science exhibit or requesting evidence for a claim/conclusion. Example: (Flight exhibit) "What is knots? Is it like a measurement?"
Children and Parents' Science Explanations	Defined as making an explanation relevant to the science exhibit or using evidence to draw a conclusion. Example: (Gorilla exhibit) "That is a termite mound. The gorillas will use their teeth to make tools which they will stick inside of the termite mound."
Interactive Exhibit	Interactive exhibits featured objects that visitors could touch or activities that visitors could participate in, whereas non-interactive exhibits could only be observed.
Duration	The total length of time in seconds that a child spent at the exhibit.
Educator Condition	Videos were coded for whether an adult, youth, or no educator was present during the children's visit to the exhibits.

in Atlas.ti) was 82.54%. The duration of each video ranged from 30 s to 7 min.

Data Analysis Plan

Since participants visited different ISLS sites, and as children were nested in family groups, multilevel modeling was used to account for the nesting of data. Furthermore, multi-level modeling approaches are robust with as few as 10 groups in level 2, especially if restricted maximum likelihood and the Satterthwaite approximation are used (Huang, 2018). Multilevel models were fit using the MIXED command in SPSS with restricted maximum likelihood and the Satterthwaite approximation in order to assess children's science explanations, requests for science information, and whether they were engaging with the exhibit, and observing the exhibit. Educator condition (no educator, youth educator, adult educator), interactive exhibit (yes, no), parents' science explanations, parents' requests for science information, and duration spent at the exhibit were used as fixed effects. The site ID and family ID were used as random effects. The equations for the multilevel models were as follows:

$$\gamma_{ijk} = \gamma_{00} + \gamma_{01}ParentsSciRequest_{ij} + \gamma_{02}ParentsSci$$
$$Explanation_{ij} + \gamma_{000}Duration_{j} + \gamma_{002}InteractiveExhibit_{j}$$
$$+ \gamma_{003}EducatorCondition_{j} + e_{0ijk} + u_{0jk} + u_{00}$$

The outcome for the *i*th visitor in the *j*th site and *k*th family group is modeled as main effect of parents' science requests (γ_{01}), parents' science explanations (γ_{02}), duration in seconds spent at the exhibit (γ_{000}), interactive exhibit (γ_{002}), and educator exhibit (γ_{003}), with γ_{00} as the overall mean and u_{0jk} and u_{00} as the family group and site residuals and e_{0ijk} as the individual residuals. This general equation was tested for each of the dependent variables (**Table 3**).

RESULTS

Descriptives

Parents gave more science explanations when an educator was not present, $t(61) = 4.73$, $p < 0.001$, and parents made less requests for science information when an educator was not present, $t(61) = -2.54$, $p < 0.001$. In fact, parents only made requests for science information when an educator was present. Children also gave more science explanations when an educator was not present, $t(61) = 1.66$, $p = 0.001$. Although not significant, children observed the exhibit more and made more requests for science information when an educator was present, however they engaged with the exhibit more when an educator was not present (**Table 4**). Additionally, children observing the exhibit was negatively associated with their exhibit engagement and positively associated with parents' requests for science information (**Table 5**).

TABLE 3 | Intra-class correlation coefficients accounting for family group and site level variance in key dependent variables.

Dependent Variable	Family Group ICC	Site ICC
Children Observing the Exhibit	0.42	0.05
Children Engaging with the Exhibit	0.89	0.61
Children's Requests for Science Information	0.16	0.06
Children's Science Explanations	0.06	0.13

Children Observing the Exhibit

Parents' science explanations ($b = 0.74$, $t = 2.19$, $p = 0.04$) and requests for science information ($b = 0.54$, $t = 3.67$, $p = 0.001$) were related to children observing the exhibit. When children were observing the exhibit, parents were more likely to request science information and give more science explanations. No other variables were significantly related to children observing the exhibit (**Table 6**).

Children Engaging With the Exhibit

Interactive exhibit ($b = -1.56$, $t = -2.18$, $p = 0.04$) and duration ($b = 0.44$, $t = 3.72$, $p = 0.001$) were significantly related to children engaging with the exhibit. If the exhibit was not interactive, children were less likely to engage with the exhibit and the longer children spent at the exhibit the more likely they were to engage with the exhibit. No other variables were significantly related to children engaging with the exhibit (**Table 6**).

TABLE 4 | Means and ranges for children's and parents' behaviors when an educator was present or not.

	Children Observing the Exhibit	Children Engaging with the Exhibit	Children's Requests for Science Information	Children's Science Explanations	Parents' Requests for Science Information	Parents' Science Explanations	Duration
Educator Present	1.09	1.40	0.24	0.04	0.78	0.11	148.80
No Educator	0.61	1.44	0.17	0.22	0.00	0.78	81.6
Range	0–5	0–8	0–2	0–2	0–5	0–2	30–420

Means represent the sum of the number of instances across the exhibit visit of the particular behavior. Duration is measured in seconds.

TABLE 5 | Correlations.

Variable	1	2	3	4	5	6	7	8	9
Children Observing the Exhibit	–								
Children Engaging with the Exhibit	−0.24*	–							
Children's Requests for Science Information	−0.05	0.11	–						
Children's Science Explanations	−0.06	−0.01	−0.10	–					
Parents' Requests for Science Information	0.55**	−0.13	0.01	−0.08	–				
Parents' Science Explanations	0.24	0.16	0.09	−0.13	−0.01	–			
Interactive Exhibit	−0.13	0.04	0.16	−0.26*	−0.22	−0.33**	–		
Duration	0.34**	0.58**	0.01	−0.13	0.36**	0.23	−0.13	–	
Educator Condition	0.03	−0.10	0.00	−0.16	0.17	−0.51**	0.09	0.06	–

$^*p < 0.05$, $^{**}p < 0.01$.

TABLE 6 | Unstandardized coefficients (and standard errors) of multilevel models of children's behaviors.

Effect	Parameter	Children Observing the Exhibit	Children Engaging with the Exhibit	Children's Requests for Science Information	Children's Science Explanations
Intercept	γ00	0.47(0.37)	0.78(0.70)	0.38(0.20)	−0.05(0.11)
Parents' Requests for Science Information	γ01	0.54**(0.15)	−0.47(0.27)	0.003(0.08)	−0.03(0.05)
Parents' Science Explanations	γ02	0.74*(0.34)	−0.67(0.62)	0.30(0.19)	−0.29**(0.11)
Duration	γ001	0.003(0.06)	0.44**(0.12)	−0.02(0.03)	0.001(0.02)
Interactive Exhibit	γ002	−1.67(0.37)	−1.56*(0.71)	−0.26(0.21)	0.31**(0.01)
Educator Condition	γ003	0.20(0.42)	−0.66(0.78)	0.00(0.23)	0.11(0.12)
Random Effects					
Family ID		0.88**,***(0.20)	0.47**,***(0.12)	0.24**,***(0.06)	0.12**,***(0.02)
Site ID		0.24(0.19)	2.26**(0.71)	0.08(0.07)	0.00(0.00)

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Children's Requests for Science Information

Children's requests for science information were not related to any of the variables (**Table 6**).

Children's Science Explanation

There was a significant effect of interactive exhibit ($b = 0.31$, $t = 2.71$, $p = 0.01$) on children's science explanation. If the exhibit was not interactive, children were more likely to give science explanations. There was also a significant negative effect of parents' science explanation ($b = -0.29$, $t = -2.76$, $p = 0.01$) on children's science explanations. This suggests that the more parents gave science explanations the less children gave science explanations. No other variables were significantly related to children's science explanation (**Table 6**).

DISCUSSION

This study evaluated the interactions between parents and children in ISLS, by examining how parents' scientific questions and statements, as well as the aspects of the exhibit such as the presence of educators and interactive materials, are related to children's learning behaviors. Importantly, this study examined children's learning across different types of exhibits and sites, documenting common patterns of learning across an aquarium, a zoo and a children's museum. Consistent with Social Cognitive Theory (Bandura, 1986), we found that behaviors and environment are related to learning: parents' requests for science information and interactive exhibits may be important factors associated with learning behaviors in children. Results showed that when parents asked more science questions, children were more likely to observe the exhibit. Parents' frequency of science explanations was also positively related to children observing the exhibit, but they were negatively related to children's science explanations. None of the variables were related to children's requests for science information and duration was only related to children engaging with the exhibit. Furthermore, if the exhibit was not interactive, children were more likely to provide science explanations and were less likely to engage with the exhibit. We did not find differences in children's behaviors based on whether an educator was present at the exhibit. This was somewhat surprising given previous studies that reported feelings of learning more at an exhibit when an educator was present–especially a youth educator (Mulvey et al., 2020).

Interactive Exhibits

As expected based on Social Cognitive Theory, we found that environment plays an important role in the types of learning behaviors children display. Children were more engaged, through physical interaction or providing additional information, with the exhibit when the exhibit included interactive elements. This is consistent with findings that show that when ISLS allow for exploration, visitors are more likely to be engaged through their interactions with the exhibits (Sandifer, 2003; Shaby et al., 2017). We also found that the longer children spent at an exhibit, the more likely they were to engage with the exhibit, which supports previous findings that visitors tend to spend more time at an exhibit that is interactive (Szechter and Carey, 2009). Hands-on exhibits like these, where children get to interact with the exhibits, can help facilitate the first steps of children's learning (Barriault and Pearson, 2010). However, it is important to note that learning does occur in different ways. When exhibits were not interactive, children were more likely to provide scientific explanations. Thus, it may be that when children encounter non-interactive exhibits, they spend more time considering scientific concepts or generating explanations related to the exhibit content.

The Presence of Educators

There were no significant relationships between the presence of educators and children's behaviors. Although not significantly different, descriptive data showed a trend of children asking more science questions when an educator was present. For example, the following illustrates a conversation between a child and an adult educator at the gorilla exhibit at the zoo:

> Child: "Do they [gorillas and chimpanzees] live in two places?"
> Adult Educator: "Yes the Lowland Gorillas live here [pointing to map], and the chimpanzees live in central Africa, but both of them live in Western Africa."

Therefore, future research may more carefully explore educator behaviors that encourage children's requests for science information. As prior research has documented the relationship between educators and visitors' understanding of science concepts and use of science related dialog (Haden et al., 2014; Pattison et al., 2018), it is important that future work continue to explore what types of learning educators foster. We also did not find differences based on whether an educator was present or not for children's observation or any other outcomes. This may be because educators vary in the ways that they engage with visitors. For example, it may be interesting for future research to examine differences in educators' use of science requests and explanations.

How Parents' Behaviors Are Related to Their Children's Learning

Also in alignment with Social Cognitive Theory, we found that parents' behaviors, specifically their use of science explanations and requests for science information were related to children's behaviors. Parents' science explanations and requests for science information were positively related to children observing the exhibit. Instances where the child observes animals while parents explain or ask questions were common, since two of our sites were a zoo and an aquarium. Observing animals is a crucial part of these exhibits; thus, this behavior, in this context, may provide rich opportunities for learning. Previous research has shown that when visitors observed scientists conducting research with animals at an exhibit, they reported greater perceived learning (Waller et al., 2012). Through observing exhibits like these, children are able to learn about the animals' needs, their environments, and research and conservation efforts to protect the species (Tofield et al., 2003).

Although we were unable to quantitatively analyze the data to indicate the directionality of the behaviors between parents and children, this example demonstrates that parents' behaviors would often promote their children's behaviors. The following interaction from the aquarium shows a parent's explanation of science information preceding a child observing the exhibit.

> A parent approaches the Komodo dragon exhibit and gives a short description of the animal to their child: "That's a Komodo dragon. They like to eat dead animals." The child then approaches the exhibit and observes the animal.

Therefore, observations are important behaviors that allow for the opportunity to learn new information. Our findings reveal the important role of parents while children are observing exhibits–the more parents asked questions and provided science explanations, the more children observed the exhibit. This extends previous research by demonstrating that parents' science explanations may offer some benefits by encouraging children to engage with exhibits through observation.

We also found that children were less likely to give science explanations when their parents gave science explanations. This finding supports previous research that showed that parents' science explanations were negatively related to children's requests and explanations (Callanan et al., 2017). Our finding suggests that for children to be more engaged with the exhibit and express their own knowledge, parents should consider offering fewer explanations and instead let their children lead the exploration more directly. This is demonstrated by the following interaction at the aquarium:

> As a child and parent approach the Komodo dragon exhibit, the parent does not immediately offer information about the exhibit. Instead, the child explains while the parent listens: "It's a giant lizard. They're really fast, did you know that? Look at the bottom of its neck, you can see it breathing. It's shedding its skin."

Interactions like this one allow the child to guide the discussion and display their own knowledge of the exhibit, which can create engaged conversations between parents and children.

Although there was not a significant effect of parents' requests for science information on children's science explanations, prior research has documented that asking children questions was related to more scientific and engaged talk from children (Callanan et al., 2017; Chandler-Campbell et al., 2020). However, previous research has also shown that many parents may not know what to ask their children or how to explain certain concepts (Snow and Kurland, 1996; Crowley et al., 2001), which is demonstrated in the example below from the flight exhibit at the children's museum in which the child is using a flight simulator to fly a plane:

Child: "What is knots? Is Knots like a measurement?"
Parent: "It's a measurement, for speed, I guess. . .. or distance."

In this example the child asked their parent a science related question pertaining to the activity they are engaged in. The parent gives wavering science explanations–one of which is incorrect. This example demonstrates how parents may try to explain concepts but may not always have high perceptions of their own competence in, or foundational knowledge of, these domains. Therefore, providing parents with information regarding the exhibits may be helpful for these conversations.

Studies have shown that providing parents with information or prompts to guide their conversations with their children helps create parent-child conversations (Harris and Winterbottom, 2018). For example, when educators suggested that parents ask more "What?, Why?, Where?, and How?" parents asked twice as many questions to their children, compared to parents who did not receive any conversation instructions (Haden et al., 2014). Thus, instructions or suggestions that provide parents with examples of questions to ask could be very effective in creating conversations between parents and children.

LIMITATIONS AND FUTURE DIRECTIONS

Although our findings provide insight into children and parents' behaviors in ISLS, we must acknowledge the limitations of our study. This study focused on demonstrating the benefits of spending more time at exhibits, however future research should continue to explore duration as there may be a time point for how long families should spend at an exhibit for optimal learning. Additionally, we were unable to ask families to directly report participant demographics, and thus, were unable to confidently analyze findings based on these. However, it was estimated that the majority of participants were White families, therefore more work is needed that includes members from diverse groups. Further, prior research demonstrates that ethnic minority families often report that ISLS are not "for them" (Dawson, 2014). It would be important for future research to examine differences in parent-child interactions for families of different ethnic backgrounds, as this may provide additional insight into why ethnic minority families feel unwelcome in these sites. Finally, Mulvey et al. (2020) found that visitors felt they learned more when interacting with an educator rather than with just the exhibit. Although we examined the presence and absence of an educator; future research might more carefully examine the specific educator behaviors that encourage children's learning opportunities. For example, based on our means both children and parents used more requests for science information when an educator was present. Therefore, future research could try to code for the types of educator behaviors that may elicit these responses from visitors.

CONCLUSION

This study provides support for Social Cognitive Theory by demonstrating that parents' behaviors and environment are important factors related to children's behaviors. It also further expands our understanding of parent-child interactions in ISLS by showing that parents' science explanations are both positively and negatively associated with children's learning behaviors. If parents' goals are to encourage their children's learning through observations, then providing science explanations would be helpful. However, parents should consider offering fewer explanations in order to encourage children to ask questions or explain concepts. Furthermore, the findings from this study can be used to shape exhibits in ISLS. Our results revealed that children were more likely to provide science explanations when an exhibit was non-interactive, however they were more likely to physically interact with the exhibit or provide additional information when the exhibit was interactive. Therefore, ISLS should focus on creating spaces that have a balance of interactive and non-interactive components as both have their own benefits for children's learning behaviors. By promoting the use of interactive exhibits, visitors' can gain more opportunities for learning and engagement. Additionally, ISLS could provide parents with important information about, or discussion prompts for, the exhibits to help guide their discussions and create more meaningful conversations with their children. In sum, these findings document the ways in which parents and children interact in ISLS and reveal the important role that parents play, even when educators are also present in ISLS.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of South Carolina with institutional agreement from North Carolina State University Institutional Review Boards. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AJ developed the hypotheses, supervised the coding of the videos, performed the statistical analysis, coordinated and drafted the manuscript. FL participated in the study design and development of the coding system and helped to draft the manuscript. LM, MW, and GF participated in the study design and helped to draft the manuscript. CM helped to draft the manuscript. AH-R and AR led the study design and helped to draft the manuscript. KM led the study design and data analytic approach, and helped to draft the manuscript. All authors read and approved the final manuscript.

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Motivation for the Family Visit and On-the-Spot Activities Shape Children's Learning Experience in a Science Center

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Children's learning often happens in the interactions with more knowledgeable members of the society, frequently parents, as stated by the sociocultural theory. Parent-child conversations provide children with a new understanding and foster knowledge development, especially in informal learning contexts. However, the family conversations in museums and science centers can be contingent on the motivation for the family visit or the activities organized on the spot. In order to establish how family motivation and on-the-spot activities influence children's informal learning experience, the present study was carried out in a family science center. The study focused on children's learning experience in a hands-on exhibit featuring objects that allow for the exploration of the concepts of sound waves and light. Thirty-nine 7–10-year-old children (21 boys and 18 girls) and their families participated in the study. Twenty families received a worksheet to prompt an experimentation activity with one of the light exhibits. Motivation for the family visit was probed at the end of the visit. The target children of the families wore a GoPro HERO 5 camera attached to a chest harness throughout their visit. The video was coded for family interaction and experimentation with the light exhibit. Family conversations were coded for open-ended questions, responses to open-ended questions, explanations, associations, attention directing, and reading signage aloud. Family motivation for the visit was related to the quality of family conversation during the visit. The experimentation activity prompt did not affect the likelihood of noticing and engaging with the particular exhibit. At the same time, it did affect the quality of engagement: children who received the experimentation activity prompt were more likely to explore the effects the exhibit provided and experiment rather than play with the exhibit. Family motivation and on-the-spot activities are discussed as two possible factors to influence children's learning experience in science centers.

Keywords: informal learning, parent-child conversation, science centers, encouraging experimentation, motivation

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INTRODUCTION

Museums and other informal learning institutions provide a unique engaging learning space for children and families. Museums nowadays embrace their role as educational agents for children and often keep children and families in mind when designing exhibits and providing interactive and hands-on learning opportunities (Allen, 2004; Heath et al., 2005; Müller, 2013). When families visit informal education institutions with children, learning most often takes place when parents scaffold the experience providing structure and helping children to make sense of the learning opportunities (Haden, 2010; Andre et al., 2017). Parents' motivation to do so, on the one hand, and the structure provided by the museum (i.e., exhibit design, on-the-spot activities, additional material and signage, etc.), on the other, could influence the resulting experience of children. The present study focuses on family visits to a science center to establish how parent's motivation for the visit and the on-the-spot activity relate to family interaction and exploration that shape children's learning experience.

Prior research has identified parent-child interaction in informal settings as the mechanism for learning (Crowley et al., 2001a; Fender and Crowley, 2007; Benjamin et al., 2010; Rigney and Callanan, 2011; Andre et al., 2017). Such research is rooted in the sociocultural theory stating that learning mostly happens in activities, where children engage and interact with more knowledgeable members of the society (Vygotsky, 1978). In parent-child interaction, several structural elements have been identified as cognitively demanding science talk that improves children's understanding of the world and helps them to construct knowledge. These structural elements include questions, explanations, use of analogies and associations, and suggestions to test hypothesis (Crowley et al., 2001b; Tenenbaum and Leaper, 2003; Tenenbaum et al., 2005; Valle and Callanan, 2006; Tare et al., 2011). Parents' questions and associations to prior knowledge have also been linked to children's improved learning in the museum and memory for the experience (Benjamin et al., 2010).

In informal learning institutions, the family conversations, in particular the explanations, associations, and open-ended questions, often go hand in hand with the exploration of the exhibit, both supporting learning and meaning making (Gutwill and Allen, 2010; Callanan et al., 2020). Different exhibits have different affordances for exploration. Studies seem to suggest that adding an opportunity to manipulate objects could be engaging and even beneficial for the children of the visiting family. For example, Jant et al. (2014) have shown that an opportunity to manipulate objects accompanied by prompts to parents to ask wh-questions leads to richer parent-child interaction and improved learning and memory for the experience. At the same time, the exploration of hands-on displays could give rise to more learning opportunities when children receive some scaffolding of experience. Crowley et al. (2001a) showed that children who studied a hands-on exhibit with a parent had a broader and more focused exploration as parents explicitly made connections and provided explanations to help children understand the phenomena. This seems to suggest that providing some structure for children's free exploration of exhibits could be advantageous for their learning experience.

Different on-the-spot activities in the museum are often successful in creating enhanced learning opportunities. The activities to support such learning can be very different and the examples are manifold. For example, engaging families in play with numerical prompts leads to more spontaneous focus on numbers afterward (Braham et al., 2018). Inquiry games, especially the ones that involve the whole family, have been shown to deepen the conversations and learning at a science museum (Gutwill and Allen, 2010). Instructing parents to either encourage exploration or explanation with their children results in longer explorations or more discussion, respectively (Willard et al., 2019). Providing families with topical activities increases talk on the topic in the exhibit (Tenenbaum et al., 2010). Providing exhibit relevant information to parents and inviting them to use open-ended questions brings about more science, technology, engineering, and math (STEM) talk focused conversations during the museum activities and more STEM talk in recollections of the experience (Benjamin et al., 2010; Haden et al., 2014; Marcus et al., 2017). Adding questions to signage boosts metacognition (Gutwill and Dancstep, 2017) and family conversations (Land-Zandstra et al., 2020). All in all these intervention studies seem to indicate that providing some structural support or guidance to otherwise open-ended museum visits could magnify the learning opportunity for the children as it brings about deeper and more focused conversations.

Motivation is closely related to learning in general, and learning in informal settings is no exception. Visitors may come to the museum for a large variety of reasons, e.g., social reasons, interest in the subject, entertainment etc. (Falk et al., 1998; Rowe and Nickels, 2011; Ji et al., 2014). Motivation for the museum visit has been shown to shape the informal learning experience for adults and to affect their learning outcome (Falk et al., 1998; Moussouri and Roussos, 2013). Adults with a learning motivation remember more concepts at the end of the visit as compared to adults without such motivation (Falk et al., 1998) and spend their time mostly visiting exhibits rather than socializing (Moussouri and Roussos, 2013). There is not any information available about how parents' motivation for the museum visit relates to children's experience and learning.

The Present Study

The present study was carried out in The Energy Discovery Center in Tallinn, Estonia. It is a family science center, where one can discover, play, and learn (www.energiakeskus.ee). The center is popular with families and engaging for children with their hands-on exhibits to discover the principles of electricity, light, sound, and other physics phenomena. The present study focused on children's learning experience in a hands-on exhibit featuring objects that allow for the exploration of the concept of sound waves and light.

The aim of the study was to establish how parental motivation for the visit and the on-the-spot experimentation activity prompt relate to the behavior and conversations of the family at the exhibit. Prior research has consistently shown that on-the-spot interventions and activities successfully shape the learning experience of the family and children. Therefore, it was expected that providing a specific experimentation activity prompt would elicit more engagement and experimentation with the exhibit. In addition, family motivation for the science center visit could affect their behavior in the center. In particular, families with a learning motivation could engage in different learning and teaching behaviors more often than families with a different focus.

MATERIALS AND METHODS

Participants

Forty children (22 boys and 18 girls) with their families participated in the study. The average age of the participating children was 8 years (range 7–10). In 19 cases, the child visited the science center with one parent, and in other cases, there were two or more adults with the family. Eight children were only children in the family group; the rest of the families had siblings along for the visit. For 31 families, this was the very first visit to The Energy Discovery Centre; nine families had visited the center before. Additional demographic data (e.g., socioeconomic status) about the families was not collected. Due to a technical mishap, video data of one participant are missing, resulting in full data about the visit of 39 families. In the analyses, the data of the family are deleted listwise.

Procedure

Participants were recruited as they entered the exhibit: families with children in the age range of 7–10 years were approached and invited to participate in the study. Consent to participate in research was obtained from adults and children. Once children agreed, a GoPro HERO 5 camera was attached to them using the Junior Chesty chest mount. All the families were told to take their time and explore the exhibit as they normally would. By random assignment, half of the participants ($n = 20$) also received a worksheet with an experimentation activity prompt. They were told to see if they can find answers to the prompts on the worksheet during their visit and asked to fill it during their exploration. Other than that, their instruction was identical to the families not receiving the experimentation activity prompt. After the visit, as the family was ready to leave, the parent filled in a short questionnaire providing background information, including the motivation (recreation, fun, to learn something new etc.), for their visit.

Measures

Motivation

Motivation for the family visit was probed at the end of the visit with a questionnaire. Five possible motivations (e.g., to have fun, to learn something new, etc.) and an option to fill in their motivation for the visit was listed, and the parent was instructed to indicate up to three.

Experimentation Activity Prompt

The experimentation activity prompt focused on the concept of shadow that was featured in one of the exhibits in the center (Shadow theater). The prompt contained a playful task to indicate what is necessary for the shadow to appear (children had to circle the necessary objects), and two multiple choice questions that could sprout experimentation: what happens to a shadow when (a) the object is moved closer to the light and (b) when the object is turned?

Coding

Conversations

The videos captured with GoPro HERO 5 were coded using the Noldus Observer XT program. The coding scheme was the same for adults and children. In order to reveal the learning conversations of the families, the following types of instances were coded as they occurred:

- Directing attention: utterances that directed the other person's attention to a particular exhibit or an aspect of the exhibit, e.g., "*Look at this!*"; "*Hear this!*"; "*You should look at this here!*"; and "*The light goes here, see!*"
- Open-ended questions: wh-questions asking about a particular exhibit or an aspect of the exhibit, e.g., "*What does this do?*"; "*What do you see?*"; and "*What happens when you do that?*"
- Responses to open-ended questions: verbal responses to the wh-questions about particular exhibits or aspects of the exhibit.
- Explanations: utterances that went beyond describing the objects and focused on why a particular phenomenon occurred or how an exhibit displayed the particular phenomenon, e.g., "*The light deceives you, see, these edges make it look like it is much deeper than it actually is*" and "*See, these are solar panels on the wings -- light turns into energy there and makes the propeller move.*"
- Reading aloud: instances of reading the signage at the exhibits aloud either to themselves (children) or to the children (adults).
- Associations: e.g., "*This is like a small earthquake!*" (about thunder soundwaves) and "*This is like the solar panels our house has.*"

The conversational codes were assigned to the children and adults of the family. All conversations that included the target child were coded including conversations with other family members and siblings. Two people coded 15% of the videos; the interrater agreement Kappa was 0.78 on the average for parents' conversational codes and 0.76 for children's conversational codes with no single value below 0.7. Disagreements were resolved in discussion and the author proceeded to code the rest of the videos.

Child Engagement With the Experimentation Activity Exhibit

The experimentation activity prompt included open-ended questions that could be explored at the shadow theater exhibit (**Figure 1**). In order to investigate children's engagement with the particular exhibit, two aspects were coded. First, it was

FIGURE 1 | The Shadow theater.

coded whether the children noticed the shadow theater or not. Noticing the exhibit was coded when either (a) the child or parent picked up the trafarets and placed them against the screen or (b) tried to make shadow animals on the screen (as also shown on a signage at the exhibit) or (c) verbally commented on the shadow theater. Secondly, it was coded whether the children or parents experimented and explained the qualities of the shadow, moving the trafarets closer and further or turning them sidewise to show how the shadow changed. Two people coded the engagement with the experimentation activity exhibit from the video for 15% of the videos. There were no disagreements and the author proceeded to code the rest of the videos.

RESULTS

Families spent 38 min (*SD* = 12, range 18–69 min) on average in the hands-on exhibit at the science center. The length of the visit did not differ for boys and girls or families with and without the experimentation activity prompt or for the families who reported the learning motivation as compared to those who did not. Correlation analysis revealed that family size was not related to the length of the visit, but it was negatively associated with some of the parental conversational variables, namely open-ended questions, associations, attention directing, and reading signage aloud [$rs = -0.32 - (-0.38)$, $ps = 0.02–0.04$].

Motivation

Families were instructed to indicate three main motivations for the visit from a list of possible reasons. Families selected 1–4 motives ($M = 2.68$, $SD = 1.05$). **Table 1** displays the reasons for the visit and the number of families that selected the reason. Chi-square analyses were run for the different types of motivation separately to see if they were related to the gender of the child or the fact that the family received the experimentation activity prompt. Different motivations reported by the adult were not related to child gender [χ^2-s (1, $N = 39$) = 0.04–1.36, $ps = 0.24–0.84$]. Neither did the reported motivations differ for families who received the prompt and for those who did not [χ^2-s (1, $N = 39$) = 0.44–1.91, $ps = 0.17–0.51$]. Motivation to learn something new was indicated by 16 families (40%), and this was used as a grouping variable for the analyses of the conversational codes.

TABLE 1 | Family motivation for the visit.

Motivation	Number of families indicating the motivation	Percentage of families indicating the motivation
They have been here before and enjoy the particular science center	6	15%
They wanted to do something together	30	75%
They wanted to learn something new	16	40%
They wanted to have fun	26	65%
It seemed like an interesting place to visit	28	70%

Conversations

Conversational codes were collapsed for children of the family and adults of the family. Many of the conversational codes were infrequent (see **Table 2**) and the distribution of all the conversational variables did not adhere to normal distribution. Therefore, median split was used to create categorical variables for all the conversational codes and define groups of children and adults who used the variable often as compared to those who rarely used the variable. For the variables with a median of 0 (see **Table 2**), groups were defined as children/adults who did not use the particular conversational variable vs. children/adults who used the conversational variable at least once. First, possible gender differences in the use of conversational variables were studied. Chi-square analysis showed a significant association between child gender and adult explanations ($\chi^2(1) = 4.31$, $p < 0.05$) and child gender and child attention directing ($\chi^2(1) = 4.31$, $p < 0.05$). Sixty-one percent of girls (11/18), whereas only 38% of boys (8/21), received at least one explanation from their parents. Girls were more likely to use attention directing more often: 67% of girls (12/18) and only 33% of boys (7/21) belonged to the group that used attention directing above the median. The other conversational variables were not associated with child gender [χ^2-s (1, $N = 39$) = 0.08–2.92, $ps = 0.09–0.81$].

For testing the hypothesis, three-way log-linear models including experimentation activity prompt (Yes/No) and learning motivation as reported by parent (Yes/No) were built for each of the conversational variable for parents and children. For the analysis of parent's Open-Ended questions, the three-way log-linear model analysis produced a final model that retained the Motivation x Open-Ended Questions interaction. The likelihood ratio of this model was $\chi^2(4) = 4.05$, $p = 0.40$, and the Motivation x Open-Ended Questions interaction was

TABLE 2 | Median and range for the total number of conversational codes for children and parents.

Conversational variables	Parents *Median (Min-Max)*	Children *Median (Min-Max)*
Responses to questions	2 (0–13)	1 (0–6)
Open-ended questions	2 (0–15)	7 (1–37)
Attention directing	9 (0–35)	10 (1–24)
Explanations	0 (0–15)	0 (0–2)
Associations	0 (0–8)	0 (0–2)
Reading aloud	1 (0–28)	0 (0–15)

TABLE 3 | Crosstabulation of adults who asked and answered two or less or more than two open-ended questions by their learning motivation.

Conversational variable	Groups	Number and % of adults reporting a learning motivation	Number and % of adults not reporting a learning motivation
Open-ended questions	Number of adults who asked more than 2	10 (62.5%)	6 (27.5%)
	Number of adults who asked 2 or less	6 (26%)	17 (74%)
Responses to open-ended questions	Number of adults who responded to more than 2	10 (62.5%)	6 (27.5%)
	Number of adults who responded to 2 or less	6 (26%)	17 (74%)

significant, $\chi^2(1) = 5.23$, $p < 0.05$. The odds ratio indicated that the odds of parents asking more than two open-ended questions were 4.8 times higher when they also reported a learning motivation for the visit. The analysis of parent's Responses to Open-Ended Questions produced a final model that retained the Motivation x Responses to open-Ended Questions interaction. The likelihood ratio of this model was $\chi^2(4) = 4.05$, $p = 0.40$, and the Motivation x Open-Ended Questions interaction was significant, $\chi^2(1) = 5.23$, $p < 0.05$. The odds ratio indicated that the odds of parents responding to more than two open-ended questions were 4.8 times higher when they reported a learning motivation for the visit. The count of parents with and without learning motivation using these conversational variables is provided in **Table 3**. The models for parent's use of Directing Attention, Explanations, Associations, and Reading Aloud did not provide statistically significant results.

For the analyses of children's Associations, the three-way log-linear model analysis produced a final model that retained the Experimentation Activity Prompt x Association interaction. The likelihood ratio of this model was $\chi^2(4) = 4.72$, $p = 0.32$, and the Experimentation Activity Prompt x Association interaction was significant, $\chi^2(1) = 6.63$, $p < 0.05$. The odds ratio indicated that the odds of children making an association were 11.6 times higher when they had not received the experimentation activity prompt. The analysis of children's Explanations produced a final model that retained the Experimentation Activity Prompt x Explanations interaction. The likelihood ratio of this model was $\chi^2(4) = 5.68$, $p = 0.22$, and the Experimentation Activity Prompt x Explanations interaction was significant, $\chi^2(1) = 4.12$, $p < 0.05$. The odds ratio indicated that the odds of children providing explanations were 5.3 times higher when they had not received the experimentation activity prompt. The count of children with or without experimentation activity prompt using these conversational variables is provided in **Table 4**. Models for Directing Attention, Open-Ended Questions, Responses to Open-Ended Questions, Explanations, and Reading Aloud did not provide statistically significant results.

Child Engagement With the Experimentation Activity Exhibit

Most of the children and families ($n = 32$, 80% of all the families) noticed the Shadow theater exhibit. Chi square analyses were run to check for the gender differences in noticing the Shadow theater and to see if the families with an experimentation activity prompt were more likely to notice the Shadow theater. There were no gender differences in engaging with the exhibit [$\chi^2(1, N = 39) = 3.49$, $p = 0.09$], neither were the families with the prompt more likely to notice the Shadow theater [$\chi^2(1, N = 39) = 0.24$, $p = 0.62$]. Fifteen families also experimented with the shadow and explained the effects. Chi square analyses were run to see if receiving the experimentation activities prompt was related to the experimentation. Receiving the prompt was related to the experimentation [$\chi^2(1, N = 39) = 17.25$, $p < 0.001$]. Seventy percent of the families who got the experimentation activity prompt (14/20) compared to 5% of the families who did not get the prompt (1/19) engaged in experimentation and explanation of the effects at the Shadow theater.

DISCUSSION

The present study investigated children's learning experience in a science center with the aim to establish how the different learning behaviors relate to family motivation for the visit and the on-the-spot activities. The hypothesis proposed that families with a learning motivation would engage in more teaching and learning behaviors. Indeed, the results indicated that parents, who reported a motivation to learn something new, asked more open-ended questions and responded to their children's questions more than parents reporting other motivations for the visit. In addition, it was expected that families with the experimentation activity prompt would engage more with the particular exhibit. Indeed, families receiving a prompt to experiment were more likely to do so compared to families who did not receive such a prompt.

Prior research has revealed open-ended questions and responses to such questions to be important mechanisms for memory formation especially for young children (Hedrick et al., 2009a,b). Questions and answers are also a common pedagogical device (Cotton, 1988). In the present study, learning motivation was related to parental questions and responses. Therefore, it seems that adults recognize questions and answers as an inherent learning mechanism and engage in them more if their aim is to gain or provide new knowledge. This is reassuring, on the

TABLE 4 | Crosstabulation of children using explanations or not and receiving experimentation activity prompt or not.

Conversational variable	Groups	With prompt (*n*, %)	No prompt (*n*, %)
Associations	Number of children who made at least one	1 (12.5%)	7 (87.5%)
	Number of children who did not make any	19 (61%)	12 (39%)
Explanations	Number of children who used at least one	2 (22%)	7 (78%)
	Number of children who did not use any	18 (60%)	12 (40%)

one hand, as parents with a learning motivation seem to be acting in a way that supports their children's learning and memory. On the other hand, there is reason to contemplate how to help parents recognize other conversational devices (e.g., making associations) as beneficial for children's learning. There are data to suggest that after a certain level of expertise is acquired by children, questions that parents pose act as tests of that knowledge rather than mechanisms to move the knowledge further (Palmquist and Crowley, 2007).

A wide variety of methods may be used to prompt deeper engagement, i.e., experimentation or prolonged discussion of the phenomena in informal learning contexts (e.g., Braham et al., 2018; Callanan et al., 2020; Land-Zandstra et al., 2020). Prior research has indicated that on-the-spot activities help children to experience more conversation on the topic (Tenenbaum et al., 2010) and remember the experience better (Jant et al., 2014). The results of the present study demonstrated a relationship between receiving an experimentation activity prompt and active experimentation and deeper exploration of the concept. At the same time, the prompt was not related to positive changes in family learning interaction that would generalize over the whole visit. On the contrary, children with the experimentation activity prompt were less likely to use associations and explanations.

Hence, using prompts in the form of worksheets in a hands-on exhibit seems to be a double-edged sword. On the one hand, the families with the prompt clearly engaged in more experimentation and explored the concept of shadow to a larger extent than families without the prompt. On the other hand, children with the prompt were less likely to use associations and explanations and consequently engaged with other exhibits less at a verbal level. This could be a sign of concern as it could indicate that the prompt in the form of a worksheet distracts them from fully focusing on the exhibits and engaging with them on a deeper cognitive level. Indeed, it was observed from the videos that sometimes children had trouble with carrying the worksheet along and did not know where to put it when engaging with the hands-on exhibits.

Therefore, the question for the informal education specialists remains how to make experimentation an integral part of the exhibit. Several studies indicate that building interactive exhibits that invite iteration and experimentation engage parents and children in science and engineering learning talk (Tscholl and Lindgren, 2016; Pagano et al., 2020). Interactive exhibits without these qualities could hinder interaction and learning (Heath et al., 2005). With some exhibits like the Shadow theater, in the case of the present study, the opportunity for experimentation could be less eminent. Researchers have successfully incorporated open-questions in the signage to boost metacognition (Gutwill and Dancstep, 2017) and family conversations (Land-Zandstra et al., 2020). Perhaps integrating questions in the exhibit or signage could also prompt experimentation in a hands-on exhibit.

It is worth noting that the study revealed a gender difference in the parent interactions based on the gender of the child with parents more likely to explain to girls. A few studies have reported that parents talk to girls and boys differently when discussing science related topics (Crowley et al., 2001b; Tenenbaum and Leaper, 2003; Tenenbaum et al., 2005). These studies have generally pointed out that parents talk to and explain to girls less as compared to boys when the topic is science related. The present study found evidence to the contrary. In addition, gender was associated to one children's conversational variable: girls were likely to use more attention directing than boys. It is possible that these findings are related to child behavior in the science center in general. The present study did not focus on the time children spent in the company of their parents and the time they explored alone. Yet, based on the impression from the videos, it is possible that boys were more likely to wonder off and explore by themselves and, therefore, possibly spent less time in the company of their parents. This could be the reason some of them did not point different exhibits out to the parents as often and were simply not around to hear explanations. This aspect should be addressed in more detail in future studies.

There are several limitations to the study. The sample is rather small and does not allow for the thorough investigation of three way interactions including, for example, child gender. In addition, the study focused on parent reported motivation for the visit and not children's motivation. Children may have their own agendas that guide their visit (Anderson et al., 2008). Motivation was inquired at the end of the visit; hence, it is possible that the experience of the visit itself guided the selection of motives to some extent. Whether this is possible, should be addressed in larger visitor motivation studies. Other factors, such as parental prior knowledge (Franse et al., 2020) and parents' ideas about if and how children should gain knowledge from such visits (Gaskins, 2008) could guide their activities and conversations with their children. These aspects should be studied alongside motivation for the visit in the future.

Nevertheless, the study provides an understanding how parental motivation is linked to their conversation with their children in a science center and shows how an on-the-spot activity could shape the family visit. These findings carry several implications. First, science centers and other informal learning environments (such as zoos and aquariums) are well-established as locations for family recreational activities. It may be useful to try and activate the learning motivation of the visiting families as it may bring about conversations that create more learning opportunities for children. In a similar vein, creating circumstances that would allow parents to make associations and to provide explanations with ease might take children's learning opportunities even a step further. Second, the results also imply that it is important to choose fitting on-the-spot interventions, and it may be useful to integrate suggestions to experiment in the exhibits rather than use worksheets in hands-on science centers. This could also provide a guide for parents who otherwise may fail to provide children with learning opportunities *via* explanations and associations due to lack of knowledge or museum fatigue (Allen, 2004).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research Ethics Committee of the University of Tartu. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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Components and Mechanisms: How Children Talk About Machines in Museum Exhibits

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The current investigation examines children's (*N* = 61; 4- to 8-year old) learning about a novel machine in a local history museum. Parent–child dyads were audio-recorded as they navigated an exhibit that contained a novel artifact: a coffee grinder from the turn of the 20th century. Prior to entering the exhibit, children were randomly assigned to receive an experimental "component" prompt that focused their attention on the machine's internal mechanisms or a control "history" prompt. First, we audio-recorded children and their caregivers while they freely explored the exhibit, and then, we measured children's learning by asking them two questions in a test phase. Children of all ages, regardless of the prompt given, discussed most aspects of the machine, including the whole machine, its parts, and, to a lesser extent, its mechanisms. In the test phase, older children recalled more information than younger children about all aspects of the machine and appeared more knowledgeable to adult coders. Overall, this suggests that children of all ages were motivated to discuss all aspects of a machine, but some scaffolding may be necessary to help the youngest children take full advantage of these learning opportunities. While the prompts did not significantly influence the number of children who discussed the machine's mechanisms, children who received the component prompt were rated as more knowledgeable about the machine in the test phase, suggesting that this prompt influenced what they learned. Implications for visitor experience and exhibit design are discussed.

Keywords: informal learning, cognitive development, machines, mechanisms, museums

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INTRODUCTION

When encountering a new artifact, children have much to learn, including facts relevant to the whole artifact, such as its name and purpose, and facts about its components such as the role of specific parts in its operation. Mechanical machines provide a particularly unique learning challenge for young children, as they consist of not only external parts but also internal parts and mechanisms that are unseen but critical to their functioning (e.g., Leuchter and Naber, 2018; Reuter and Leuchter, 2020). Reflecting this fact, early childhood science curricula emphasize the importance of teaching young children about mechanical machines and forces during grade school (e.g., Ontario Ministry of Education, 2007; Michigan Department of Education, 2015). For developmental scientists, mechanical machines provide an opportunity to explore children's causal reasoning (e.g., Legare et al., 2010; Sobel et al., 2020). The present investigation seeks to understand how children learn about mechanical machines during interactions with their caregivers in more informal, naturalistic contexts than those of schools or laboratories.

Our main questions are what information do children discuss when learning about novel mechanical artifacts in museum exhibits and how might short verbal instructions or prompts influence children's discussions and learning? To do this, we examined how children talk and learn about a novel artifact – a coffee grinder (circa 1914) found in a local social history museum. We provided children with one of two verbal prompts directing their attention to the internal mechanisms of the machine (experimental prompt) or a neutral control prompt. We focus on an informal learning environment because the minimal educational structure can reveal how learning about such artifacts unfolds when primarily driven by unstructured exploration (e.g., Sobel and Jipson, 2016). This unstructured exploration in a living history exhibit, which is not specifically geared toward learning about novel causal mechanisms, may provide insight into how children acquire these concepts in the course of their everyday lives. It also provides information for educators and designers in these spaces who hope to promote particularly rich and varied learning opportunities for children.

Our first aim was to document how children talk about mechanical machines in museums when visiting with their families. When examining a novel machine, a child might choose to focus on the whole machine (such as its name, what it is made out of, and its function and purpose), the machine's parts (both external and internal), and the mechanism of its operation. All of these aspects are important for understanding the machine's operation. Previous work has documented that children are particularly adept at learning about an artifact's function and purpose (Casler and Kelemen, 2005, 2007). Children also expect people to use artifacts in a normative way, as opposed to in atypical ways (Casler et al., 2009; Weatherhead and Nancekivell, 2018). From a young age, children view the function and purpose of an artifact as important features to learn (Kemler Nelson et al., 2004; Greif et al., 2006), along with the artifact's identity (Kelemen, 1999; Matan and Carey, 2001; German and Johnson, 2002). Additionally, children as young as 3 years old in laboratory tasks acknowledge that the insides of an artifact are important to its function and identity (Gelman and Wellman, 1991).

A great deal of work in cognitive development has focused on children's reasoning about, and attention to, artifacts' internal mechanisms (e.g., Sobel et al., 2007; Ahl and Keil, 2017; Ahl et al., 2020). For example, 4-year-old understands that an object's internal component can activate a machine, and they expect other objects with the same internal component to work in similar ways (Sobel et al., 2007, see also Walker et al., 2014). Children are also able to reason about the diversity of a machine's functions and how this relates to the complexity of a machine's insides (Ahl and Keil, 2017, see also Erb et al., 2013 for related findings). Further to this, children understand that complex objects require expert knowledge to be used or fixed (Kominsky et al., 2018). Some research has also focused on children's understanding of the internal mechanisms of machines in museum settings. This work shows that parents play a vital role in directing children's attention to important features of machines (e.g., Callanan et al., 2020; Medina and Sobel, 2020; Pagano et al., 2020). For example, children will discover more properties and gain a deeper understanding of the underlying mechanisms and internal components of a machine when they explore with their parent, rather than on their own or with a peer (Crowley et al., 2001; Fender and Crowley, 2007).

Together, this work highlights the importance of examining children's understanding of machines and their components, as they relate to causal reasoning and STEM education. Because the machines at the museum in this article are from the early 20th century, they are novel and involve only manual parts and mechanisms, allowing children to identify the problem these machines solve and hypothesize about how their parts and internal components aid in its operation, all of which children have been shown to have an appreciation for laboratory settings (e.g., Casler and Kelemen, 2005; Ahl and Keil, 2017). This practice provides foundational knowledge for understanding the more complex machines and technology found in the 21st century.

Our second aim was to understand how providing a minimal verbal prompt to children might affect their discussions with their parents about a machine in a museum exhibit. Prior work has established that children are more engaged when adults provide explanations (Frazier et al., 2009) and produce more on-topic utterances when their parent asks them causal questions (Benjamin et al., 2010; Rowe et al., 2017; Chandler-Campbell et al., 2020). As such, prior work has focused on how providing parents and children with supplementary materials and prompts can enhance their learning in exhibits (e.g., Benjamin et al., 2010; Haden et al., 2014; Callanan et al., 2017; Chandler-Campbell et al., 2020; Pagano et al., 2020). Most of this work employs conversational cue cards to parents to encourage them to interact with and explain information to their child. For example, in an African history exhibit, giving families materials suggesting what to look for in the exhibit (i.e., written prompts) and prompts related to the exhibit influenced the amount of time spent at the exhibit (Tenenbaum et al., 2010). Similarly, a prompt on a cue card encouraging parents to promote explanations in their children leads children to spend more time testing the causal mechanisms of the gears in a gear exhibit, whereas a prompt to encourage exploration leads children to spend more time building complex gear machines (Willard et al., 2019). This suggests that prompting explanations leads to a greater causal understanding of how a machine operates, whereas a prompt to explore leads to increased engagement in the exhibit. Moreover, the presence of physical objects that parent–child dyads are able to manipulate also impacts how they engage with exhibits in a natural history museum (Jant et al., 2014; also see findings about "conversation cards").

These studies show that directing interventions at both parents and children influences how children engage in exhibits.

At the same time, minimal verbal prompts directed specifically at children in laboratory settings have successfully guided their learning toward causal properties of artifacts. For example, asking a child to explain why a block did not activate a machine, rather than recall if the block activated the machine, led children to privilege causal properties over perceptual similarity when making novel inferences (Walker et al., 2014). Therefore, we aimed to connect these findings from laboratory settings to informal learning environments by examining whether prompts directed only at children in informal settings will also influence their learning.

The Present Study

Building on this work, we examined children's learning about a novel artifact in a living history museum. We had children explore the exhibit with parents present, because this is how children would typically engage in this museum and because previous literature suggests that the presence of parents is beneficial to children's learning in museums (Crowley et al., 2001; Fender and Crowley, 2007). The study began with a prompt phase, where we provided only children with one of two minimal verbal prompts (experimental or control). While previous studies have provided prompts to parents and children (e.g., Benjamin et al., 2010; Haden et al., 2014), we were interested in examining whether providing a prompt directly and exclusively to the children would influence their talk and learning for two reasons: First, this ensures that any effect of the prompt is driven by children, deconfounding this from contributions that might come from the parent. Second, this also benefits our partner museum, as children visit the museum with varying degrees of adult support, sometimes attending with their families or friends and sometimes on school trips. Following the prompt phase, children explored the artifact (learning phase) with their parents and with museum staff present, with audio recorded. Finally, in a test phase, children were asked two open-ended questions: one that probed all information they gained about the artifact and another that probed an explanation of how the artifact worked.

The Setting

We undertook this investigation in a local social history museum and specifically examined how children learn about a coffee grinder in use in 1914. Most research examining children's learning in informal environments occurs in highly interactive children's museums or science exhibits explicitly aimed to engage and teach children about science concepts (e.g., Sobel and Jipson, 2016). In contrast, the historical museum we targeted promotes visitor-driven learning and exploration for people of all ages, not directly aimed at science learning. The museum where the experiment took place contains an indoor exhibit that describes the history of the Waterloo Region, as well as a 60 acre living history exhibit that aims to teach children and their families about local social, economic, and technological history by transporting visitors to the year 1914. This particular setting is a middle ground between a museum exhibit and the real world, as it contains hundreds of novel artifacts to discover and learn about, but it also resembles everyday life where children encounter scientific concepts. In a historical museum, a recent interest of staff and management is to identify the wide variety of learning opportunities to children, including those relating to scientific concepts.

The museum is located in a suburban area of a midsized Canadian city (Kitchener-Waterloo, Ontario). Admission is $11 CAD for adults and $5 CAD for children aged 5- to 12-year old, with free parking. Passes to visit the museum for free are also made available through local city libraries. The exhibits in the living history village are buildings that immerse visitors in 1914. Here, learning is mainly driven by the visitor themselves including their ability to ask questions, read accompanying guidebooks, and/or physically explore the space. There is little to no educational signage or direction provided to visitors, except for strategically positioned staff members,[1] to maintain the illusion to visitors that they have been transported to the year 1914. As such, our goal of testing the impact of *verbal prompts* was particularly useful for our partner museum and any other museums with similar constraints.

MATERIALS AND METHODS

Participants

All participants were recruited from Southwestern Ontario *via* onsite recruitment, social media advertisements, and a university database. All experiments were conducted with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. All procedures involving human subjects in this study were approved by the University of Waterloo Research Ethics Board. Participants include 61 parent–child dyads. Children were between the ages of 4- and 8-year old, randomly assigned to two conditions: a component prompt and a control prompt. Demographic information was completed on behalf of children by their accompanying parent or guardian. In the final sample, 45 participants were identified as White, 33 participants reported an annual household income of over $100,000 CND, and 39 participants reported that the primary caregiver attended a 4-year university or held an advanced/professional designation. Please see https://osf.io/dxg7h/ for full participant demographic information.

Participants were tested between June and August 2019, as this encompasses a single season in the museum, which only operates in summer months. Thus, we aimed to test as many children as possible over this period, with the expectation of testing at least 30 children per condition. Prior work

[1]Staffs are dressed in 1914 garb and are an integral part of the experience. They are familiar with the historical period and the artifacts. They are generally trained to greet visitors entering an exhibit and to respond to visitors' questions but to be otherwise unobtrusive. There was a staff member present during each parent–child interaction to preserve the typical experience for visitors (and maintain ecological validity), and thus, the child talk was directed at parents and/or staff.

employing similar open-ended investigations in museums suggests that this sample size was adequate for investigating the present questions (e.g., Benjamin et al., 2010; Chandler-Campbell et al., 2020). As a thank you for participating, participants were given a family pass to come back to the museum, valued at $25 CAD. Fifteen additional dyads were tested but not included in the analyses for the following reasons: parental reported developmental disorder (8), parents answering test questions for their child (3), and child noncompliance (4; e.g., indicating they did not wish to participate anymore). Some participants had siblings present when they arrived to complete the study; if this was the case, siblings stayed away from the exhibit.

Materials and Procedures

Participants were greeted by the experimenter upon entering the museum, where written informed consent was acquired. Therefore, participants did not enter the exhibit that day before the experiment took place.

Participants were led to the general store, where the machine (i.e., coffee grinder) was located. All interactions were audio-recorded using a Zoom Q2n-4k camera fitted to the child's chest using a GoPro Junior Chesty with the camera lens blocked. The experiment was broken into three phases; the prompt phase, the learning phase, and the test phase (see **Figure 1** for a schematic of the procedure).

The Machine

The machine was a coffee grinder in use in 1914 (see **Figure 2** as well as the supplement for an expert explanation of the coffee grinder's operation). This machine was made of cast iron with two large wheels on either side. The top of the machine contained a tin with a lid, where one puts the coffee beans into the machine. The beans would then fall deeper in the machine to the grinders. One would need to turn the two large wheels on the side to activate the machine and grind the coffee beans. The grinds would fall out of the machine and get collected in a bin.

Prompt Phase

Prior to the learning phase, outside of the general store where the coffee grinder was located, children were briefly separated from their parent and given one of two prompts. Thirty children (12 males, M_{age} = 6.634 years, SD = 1.463)[2] received the experimental component prompt "This is a machine. The parts inside of it make it work the way it does. Go inside and see what you can learn about this machine." This prompt was designed to focus children on the machine's mechanisms, while avoiding the jargon "mechanism," which young children may not know. Previous experimental paradigms reveal that both

[2]An independent sample's t-test was conducted to ensure that age was not significantly different between conditions, $t(52.7) = 1.659$, $p = 0.103$.

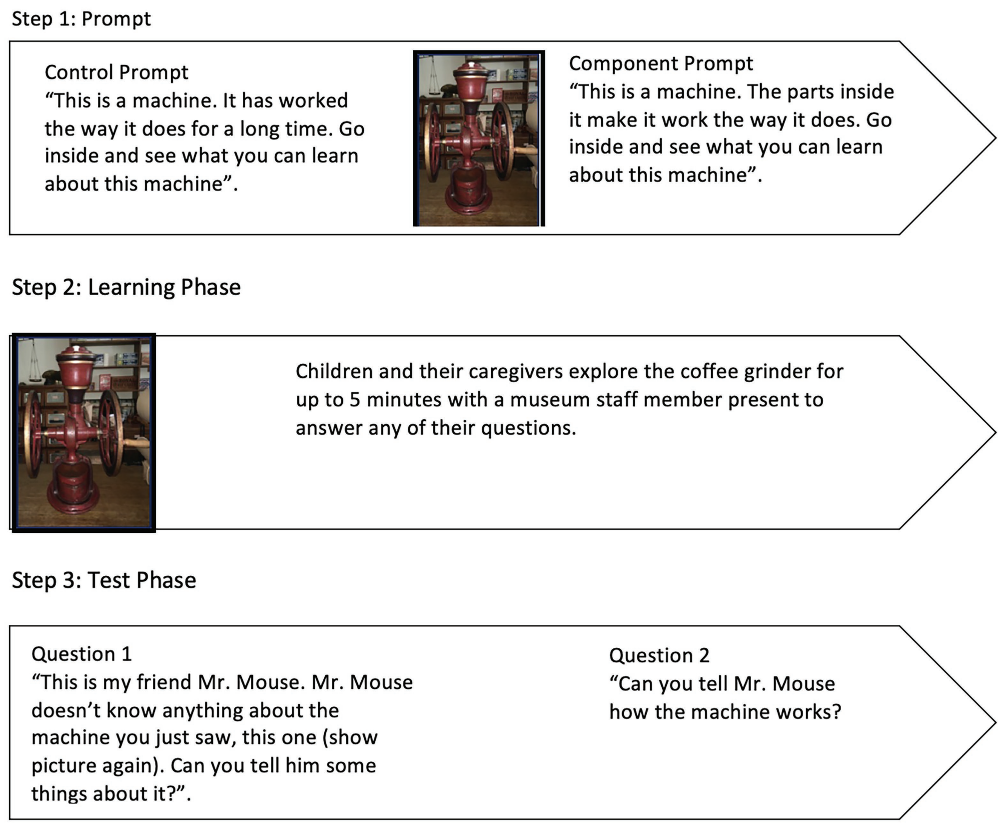

FIGURE 1 | Visual schematic of the procedure.

FIGURE 2 | Coffee grinder used in this experiment.

adults and children as young as 5-year old rated characters who provide mechanistic explanations about mechanical machines as more knowledgeable than those that provide non-mechanistic explanations (Lockhart et al., 2019) and believe this mechanistic knowledge should be generalizable to related machines (Chuey et al., 2020). This suggests that children privilege mechanistic explanations, therefore prompting children to focus on mechanisms, will increase their talk about mechanisms and lead them to recall more mechanistic information at test.

Thirty-one dyads (13 males, M_{age} = 6.089 years, SD = 1.058) received a control prompt "This is a machine. It has worked the way it does for a long time. Go inside and see what you can learn about this machine." This neutral control prompt was designed to be as equivalent as possible to the component prompt. That is, it still references a machine "working" but is otherwise neutral against the historical backdrop of the immersive museum experience and does not reference the critical "parts inside" (i.e., the mechanisms).

Learning Phase

After children received the prompt, parents and children entered the store to explore the machine. While we only measured and reported the verbal discussions of children and their parents, they were free to explore the machine in any way they wanted, which included touching the coffee grinder and moving it physically, although this was not captured due to recording audio only. Parents were told "You and your children will explore the coffee grinder at the Dry Goods and Grocery Store. You can talk about any aspect of the coffee grinder; feel free to interact with your child as you normally would. You can talk about the coffee grinder as long as you would like, I'll come get you when time is up." The experimenter was on the opposite side of the store, turned away from the participants, and appeared to be sorting through paperwork. Museum staff was present to answer questions from the parents or children. Beforehand, museum staff was instructed to interact with participants as they normally would: to provide information when requested and to otherwise let them discuss the machine themselves. Dyads were given a maximum of 5 min to discuss about the machine. At the 5-min mark or when the dyad indicated they were done investigating, the experimenter would begin the test phase.

Test Phase

After the learning phase, experimenters took the child either to the other side of the store or outside the store, depending on weather and the number of visitors in the space to complete the test phase. In the test phase, children were asked two test questions to assess how much and what they had learned. Parents were nearby and were instructed by the experimenter to not assist their child in answering the questions. To ensure that children's beliefs about the experimenter's prior knowledge did not influence the findings, the questions were asked on behalf of "Mr. Mouse" (a puppet), a naive learner. The first question was included to assess what children had learned about the machine and to extract as much information from each child as possible: "This is my friend Mr. Mouse. Mr. Mouse does not know anything about the machine you just saw, this one (show picture of the coffee grinder). Can you tell him some things about it?" The experimenter continued to prompt the child, using the interview probing technique, "Can you tell him something else?" until the child indicated they had nothing more to say.

The second question was designed to more directly target children's ability to explain how the machine worked in a succinct explanation and thus targeted what children believed was *causally important* for the machine's operation (as opposed to the quantity of what they knew as in question 1): "Can you tell Mr. Mouse how the machine works?" For this question, children were not repeatedly prompted as in question 1.

Transcription and Coding

Each participant's audio recording was transcribed and then broken into utterances by a research assistant. An utterance was operationalized as a continuous unit of speech without pauses, interruptions, or changes in subject (e.g., typically an independent clause). A second research assistant reviewed the transcripts for errors. The transcripts were found to be accurate by the second research assistant. This process resulted in the identification of 1,627 utterances spoken by children.

To prevent bias, age, gender, and condition of the child and identity of the parent were removed from transcripts before coding. The primary coder was unaware of the hypotheses of the study, whereas the first author was the secondary coder. Prior to coding, the primary and secondary coders coded five of the excluded participants for training purposes. The test phase was also coded separately from the learning phase (i.e., on a different day), at which time the coder could not see any data from the learning phase. The secondary coder reliability coded 30% of the participants.

Learning Phase Coding

The following coding was done for child speakers.

Total Talk

As a first step, a research assistant identified utterances that were related to the coffee grinder. This was done to filter out talk not directly related to the artifact of interest (e.g., talk about the store and other artifacts present). Through this process, 1,233 child utterances were identified as pertaining to the machine. Reliability was excellent with a kappa of 0.987 (Landis and Koch, 1977). A subset of this talk (507 utterances) consisted of content-free responses to adults, such as "yes" or "mhmm." Although this was technically related to the artifact due to the context provided by the caregiver or staff person, these were not coded into the schemes that follow. Therefore, a total of 726 utterances are used in the following analyses.

Talk About the Whole Machine vs. Talk About Its Parts/ Components

Utterances referring to the whole object included what a coffee grinder is, its name, history, its appearance and/or what it was made of ("It's way older," "It's made of metal and steel"). Utterances referring to parts or components of the coffee grinder included its handle, gears, and wheels ("You spin this handle here," "The stuff goes in the top here"). Reliability was excellent with a kappa of 0.962 (Landis and Koch, 1977).

Mechanistic Talk

The third scheme aimed to capture talk about the components or mechanisms that underlie the operation of the coffee grinder. For an utterance to be defined as mechanistic, it must identify a component of the coffee grinder and explain how or why that particular component operates the way it does ("So you turn, what you see when I'm turning right here. Then it grinds the coffee, the gears inside of it," Lockhart et al., 2019). From this, speakers were given a score of 0 (indicating there were no mechanistic utterances) or 1 (indicating there was at least 1 mechanistic utterance). We used this binary coding because very few speakers made mechanistic utterances (18 participants), and those that did tended to make multiple such utterances. To prevent a small number of participants from skewing the data, we used binary coding rather than counts. Reliability was excellent with a kappa of 1 (Landis and Koch, 1977).

Learning Phase Hypotheses

This coding allowed us to explore which aspects of the machine children were most drawn to discussing, how children's discussions evolve with age, and how the prompts influenced them. In terms of our prompts, we predicted that children who received the components prompt would have their attention drawn to the mechanisms of the coffee grinder. This might also result in them producing more utterances about the parts of the machine than children who received the history (control) prompt. The whole talk variable was included to examine how much children this age talk about the whole artifact, with no specific predictions about how the prompts might affect this talk, given that neither prompt was specifically designed to influence whole talk. Thus, this variable was included to examine whether the components or history prompt might have inadvertently influenced another variable (i.e., it is important to ensure that the experimental prompt did not inflate all types of relevant talk or that the control prompt did not somehow inflate whole object talk, pulling focus away from the mechanisms and internal part talk). Additionally, we anticipate effects of age, with older children having more discussions about the parts of the machine, and more mechanistic utterances, as this is in line with previously documented gains in education research (Reuter and Leuchter, 2020).

Test Phase Coding

Children's answers to the two test questions were coded on different days by the primary coder to prevent one set of codes from influencing another.

Question 1 of the test phase, which asked children to recall facts about the machine ["Can you tell him (Mr. Mouse) some things about it?"], was coded similarly to the learning phase, with some notable exceptions: Total talk was not included, as all child utterances should be related to the coffee grinder. Reliability was excellent with a kappa of 0.965 for whole and part talk and excellent with a kappa of 0.948 for mechanistic talk (Landis and Koch, 1977).

Question 2 of the test phase, which asked children to explain how the machine worked ("Can you tell Mr. Mouse how the machine works?"), was coded using the same coding as question 1,[3] as well as a global knowledgeability rating of the produced explanation. This knowledgeability rating aimed to capture the quality of children's explanations by having two coders, naïve to study hypotheses, and rate on a 0–5 scale how knowledgeable the child was about the workings of the machine. As it was a judgment rating, the primary coder and another coder who was also unaware of the hypotheses of the study coded 100% of the participants. Both coders were given explanations as to how the coffee grinder operated by the first author (see Supplementary File). Coders gave the child a score from 0 to 5, with 0 indicating that the child did not answer the question, 1 indicating that the child did not know much about the coffee grinder, and 5 indicating that the child knew almost everything (see Supplementary File for examples). As the coders

[3]Thanks to the anonymous reviewer for this suggestion.

ratings were highly correlated ($r = 0.870$, $p < 0.001$), an average of the two scores was used for subsequent analyses.

Test Phase Hypotheses

This coding scheme allowed us to test which facts about the machine children learned, how their learning evolves with age, and how their learning was influenced by our prompts. We predicted that children who heard the component prompt would recall more facts about the parts and mechanisms of the machine in both questions compared to children who heard the control prompt. We also predicted that these children would be rated as more knowledgeable in question 2 than those that received the control prompt. Coders did not rate knowledgeability for question 1, because the key aim of the knowledgeability rating was to determine whether children became more knowledgeable specifically about the workings of the machine, and question 1 prompted children to divulge all aspects of the information they gained. We predicted that children who received the component prompt would be rated as more knowledgeable because prior work shows that explanations that reference the internal mechanisms and parts of a machine tend to appear more knowledgeable than those that provide non-mechanistic explanations (Lockhart et al., 2019; Chuey et al., 2020). Again, we also predicted the effects of age, with older children recalling more about the machine's parts and mechanisms (Reuter and Leuchter, 2020).

RESULTS

All data and supplementary information can be found at: https://osf.io/dxg7h/.

Learning Phase

When learning about the machine, children discussed most aspects of the machine, producing 11.902 relevant utterances ($SD = 8.833$) on average. In terms of talk about the whole machine, children discussed what it was made of, where it was made, and how old it is ($M = 4.246$ utterances, $SD = 3.585$). When learning about its parts, children discussed the opening where you add coffee beans, the bin where you collect the grinds, and its wheel ($M = 4.738$, $SD = 4.423$). Mechanistic utterances included identified a component of the coffee grinder and explained how or why that particular component operates the way it does ($M = 0.295$, $SD = 0.459$).

We ran a series of generalized linear models (GLMs) to test our hypotheses. For all analyses, frequency of target talk (i.e., total, part, whole, and mechanistic) was the dependent variable, condition (component vs. control prompt) was entered as a between subjects factor, and age in months entered as a mean-centered covariate, to control for any effects of age on the other variables of interest. Here and in the test phase, the total amounts of talk, amounts of whole object talk, and amounts of talk about object components were analyzed using a quasi-Poisson-based model. We planned to use a Poisson-based model, but there was significant over-dispersion for all of these dependent variables (they violated the Poisson model's assumption of mean = variance), making quasi-Poisson-based models a better and more conservative choice. Children's mechanistic scores (coded as 0/1) were analyzed using a binary logistic model.

For the GLMs for each dependent variable, there were no main effects of condition, no main effects of age, and no interactions for any of the dependent variables, except for a main effect of age for total talk[4] ($t = 2.862$, $p = 0.006$) and whole talk ($t = 2.900$, $p = 0.005$; see **Table 1** for all statistical tests).

One potential concern is that the control prompt might have focused children's attention to historical information about the machine or about the setting more broadly, taking focus away from mechanisms in that condition. Thus, historical utterances were coded for both children and parents/staff in the learning phase (see supplement for parental analyses).[5] The coder was instructed to code any references to how old the machine was, using phrases such as "a long time ago," "back in the olden days," "1914," or comparisons between old vs. new, then vs. now. For children, when analyzed using a quasi-Poisson GLM ($M = 0.361$, $SD = 1.081$), we found no main effect of age ($t = 0.497$, $p = 0.621$), condition ($t = 0.503$, $p = 0.617$) or condition by age interaction ($t = 1.001$, $p = 0.321$). Therefore, the control prompt did not lead children to discuss the more historical aspects of the machine at higher rates.

Learning Phase Correlations

Next, we examined how parent and museum staff engagement was related to children's engagement. We coded parent and staff utterances using the same coding scheme as with children. The number of children who discussed about the machine in general ($r = 0.304$, $p < 0.001$), the whole machine ($r = 0.546$, $p < 0.001$), and its components ($r = 0.460$, $p < 0.001$) was correlated with the parent and museum staff discussions of each respective type of talk. Children's mechanistic score was not related to the parent and museum staff's mechanistic score ($r = 0.153$, $p = 0.239$).

Test Phase

The second aim of the investigation was to determine whether the verbal prompts differentially influenced children's learning about machines.

For test question 1, all types of talk increased with age (see **Table 2**). When children recalled facts about the whole machine, they recalled what it was called and how old it was ("It's a hundred and 5 years old," $M = 1.213$, $SD = 1.462$). When recalling the facts about the machine's parts, they recalled the handles and wheels of the machine ("It grinds more coffee

[4]This was also examined using all child utterances that were on topic (including utterances such as "yeah" and "mhm." We found no significant main effect of age ($t = 1.707$, $p = 0.093$), condition ($t = 0.798$, $p = 0.428$), or condition by age interaction ($t = 0.157$, $p = 0.876$). This amount of children's total talk was also significantly correlated with parent/staff total talk ($r = 0.462$, $p < 0.001$).
[5]We again thank the anonymous reviewer for this suggestion. We created this coding scheme in response to his/her concern.

TABLE 1 | Learning phase statistical tests and means.

		Statistical test		Control prompt mean (SD; range)	Component prompt mean (SD; range)	Total mean (SD)
		t	*p*			
Total						
	Age	2.862	0.006**	10.548	13.3	11.902
	Condition	−0.448	0.656	(6.908)	(10.396)	(8.833)
	Condition × age	−0.307	0.760	(0–27)	(1–45)	
Whole						
	Age	2.900	0.005**	4.226	4.267	4.246
	Condition	0.901	0.371	(3.253)	(3.956)	(3.585)
	Condition × age	0.764	0.448	(0–15)	(0–17)	
Part						
	Age	1.732	0.089	3.903	5.600	4.738
	Condition	−1.08	0.285	(3.986)	(4.746)	(4.423)
	Condition × age	0.311	0.757	(0–14)	(0–22)	
Mechanistic						
	Age	0.353	0.553	0.258	0.333	0.295
	Condition	0.202	0.653	(0.445)	(0.479)	(0.459)
	Condition × age	0.168	0.682			

*Mechanistic data are binary and are analyzed using a binary logistic model generalized linear model (GLM). Therefore, it is reported with a WaldX². **p < 0.01.*

every time you roll the wheels," M = 2.819, SD = 2.306). Mechanistic utterances included discussions about mechanisms ("You spin the wheel and it grinds the beans," 22 participants, M = 0.361, SD = 0.484). There was no main effect of condition and no interaction (see **Table 2**).

For test question 2, both part (M = 1.984, SD = 1.512) and mechanistic (16 participants, M = 0.262, SD = 0.443) talk increased with age (see **Table 2**). There were no whole talk utterances for any participant for this question. This is unsurprising, as children were directed to explain how the machine operated.

Knowledge ratings were analyzed using a linear model with the average ratings (0–5) as the dependent variable. There was a main effect of age [$WaldX^2$ (df = 1) = 24.935, $p < 0.001$] and a main effect of condition: children who received the component prompt (M = 2.967, SD = 1.332) were rated as more knowledgeable than children who received the control prompt [M = 2.129, SD = 0.991; $WaldX^2$ (df = 1) = 4.902, p = 0.027]. There was no condition by age interaction $WaldX^2$ (df = 1) = 0.043, p = 0.836.

Next, we examined how children's talk in test question 1 related to their knowledge rating in test question 2. Whole talk was not significantly correlated with children's knowledge rating (p = 0.080). However, both part talk (r = 0.383, p = 0.002) and mechanistic scores (r = 0.267, p = 0.037) were significantly correlated with children's knowledge ratings. Children who recalled more facts about parts and mechanisms when asked about the machine more globally are likely to produce an explanation in the next phase that seems to convey high knowledgeability. Additionally, we examined how children's talk in test question 2 related to their knowledge rating in question 2. Both part talk (r = 0.665, $p < 0.001$) and mechanistic scores (r = 0.649, $p < 0.001$) were significantly correlated with children's knowledge ratings.

DISCUSSION

The first aim of this study was to understand how children talk and learn about machines in museums when visiting with their families. Children generally talked about all aspects of the machine in the learning phase. While they increased their discussions about the whole machine with age, at all ages children were discussing the machine's parts, such as its wheels, gears, and handles, and, to a lesser extent, its mechanisms. This finding supports the idea that from a young age, children are interested in and motivated to learn not only the facts about an entire artifact but also its less obvious parts and mechanisms (Sobel et al., 2007; Lockhart et al., 2019; Chuey et al., 2020).

However, in the test phase, interesting age effects emerged as older children had greater recall of facts about the whole machine, its parts, and mechanisms and appeared more knowledgeable. This could be due to a combination of factors: First, children from 4 to 8 years make notable gains in understanding how machines work (Leuchter and Naber, 2018; Reuter and Leuchter, 2020), and thus, they would likely know more about all these factors at baseline. Second, older children have better developed memory and other executive functions than younger children (Gathercole, 1998; Ghetti and Angelini, 2008), which may aid in their better recall for all aspects of the machine than younger children. Third, parents and museum staff may have directed children's learning to these topics more with older children, given that adults likely assume that older children can handle a larger quantity of information and perhaps greater complexity. This possibility is supported by the fact that children's total, whole, and part talk in the learning phase were related to parent and staff discussions of these respective types of talk, This also supports that some scaffolding may be necessary to draw younger children's attention to these features and take advantage of the learning opportunities presented to them

TABLE 2 | Test phase statistical tests and means.

		Statistical test		Control prompt mean (SD; range)	Component prompt mean (SD; range)	Total mean (SD)
		t	*p*			
Question 1 whole						
	Age	2.726	0.008**	1.193	1.233	1.213
	Condition	0.295	0.769	(1.492)	(1.455)	(1.462)
	Condition × Age	0.810	0.421	(0–6)	(0–5)	
Question 1 part						
	Age	2.403	0.019*	2.548	3.100	2.819
	Condition	−0.700	0.486	(2.488)	(2.107)	(2.306)
	Condition × age	1.620	0.111	(0–8)	(0–7)	
Question 1 mechanistic						
	Age	4.588	0.032*	0.355	0.367	0.361
	Condition	0.143	0.706	(0.486)	(0.490)	(0.484)
	Condition × age	0.351	0.554			
Question 2 part						
	Age	4.532	<0.0001**	1.710	2.267	1.984
	Condition	−0.547	0.587	(1.553)	(1.437)	(1.512)
	Condition × age	0.676	0.502	(0–6)	(0–5)	
Question 2 mechanistic						
	Age	7.678	0.006**	0.194	0.333	0.262
	Condition	0.297	0.586	(0.402)	(0.479)	(0.443)
	Condition × age	0.207	0.649			
Knowledge						
	Age	24.935	<0.001**	2.129	2.967	2.541
	Condition	4.902	0.027*	(0.991)	(1.332)	(1.236)
	Condition × age	0.043	0.836	(0–3.5)	(0–5)	

*Mechanistic data are binary and are analyzed using a binary logistic model GLM, while knowledge ratings are analyzed using a linear model GLM. Therefore, both are reported with a WaldX^2. *$p < 0.05$; **$p < 0.01$.*

(Crowley et al., 2001; Fender and Crowley, 2007; Treagust and Duit, 2008; Ferrara et al., 2011; Weisberg et al., 2016). Future work could investigate which aspects of these age-related changes in children's recall are driven by children or parents and museum staff.

The second aim was to see whether providing a verbal prompt directed to children about mechanisms might affect children's talk and learning. In general, many children talked about and recalled the facts about the internal parts of the machine, although talk about the machine's mechanisms occurred less frequently. We found that children that received the component prompt did not discuss parts of the machine or its mechanisms more than participants who received the control prompt during the learning phase or in the test phase. We had hypothesized that focusing children's attention on the parts of the machine would lead them to discuss its mechanisms more. Future work might explore this relation further by examining how to encourage children to focus on how the components of a machine relate to its internal mechanisms. Because it seems that the minimal verbal prompt did not affect children's talk, it may have been helpful to scaffold the parents as well so that they could better support their children's learning. This could have been in the form of a verbal prompt or through the use of cue cards. This museum contains artifacts that may be unfamiliar to 21st century parents, and so, they may have needed additional information or suggestions about the questions to ask staff or the kinds of things they could say to their children to draw their attention to important features.

However, we did find that children who received the component prompt were rated as more knowledgeable than those who received the control prompt by naïve coders. Further, children's knowledge rating in question 2 was positively correlated with their part and mechanistic utterances in question 1 and question 2. These correlations provide further support for laboratory work showing that discussing internal components and mechanisms in explanations makes one appear more knowledgeable (Lockhart et al., 2019) and that prompting children to explain increases their causal understanding (e.g., Walker et al., 2014).

So why do the subjective knowledge ratings of the children's explanations differ by condition when the number of part utterances and the number of children generating mechanistic utterances in those explanations did not? We suspect that while the overall number of children making mechanistic utterances about these topics did not differ statistically by condition, the *quality* of their part and mechanistic utterances might differ. As is the case with much of our perception and cognition, examining the sum of children's explanations may have revealed something more interesting than examining their parts. Based on these findings, children who received a prompt directing their attention to parts and mechanisms may have produced more coherent and logical explanations about those aspects, even if they did not mention them at higher rates.

In general, the effects of the prompts were minimal. What might explain this? First, prior work (e.g., Gelman and Wellman, 1991) suggests that young children understand that the insides of an artifact are important to an artifact's function and identity. Thus, children in the component prompt condition may not have been as influenced as we had hoped to focus on insides, because they may already be well aware of their importance. However, given that so few children referenced mechanisms in the present dataset, this interpretation is perhaps unlikely. A second possibility is that the prompt was simply too short or subtle or that the control prompt was too well matched to the experimental prompt to reveal differences. That is, both prompts contained the sentence, "go inside and see what you can learn about this machine," and both prompts referenced the machine "working," which could have masked differences across conditions. The neutral control prompt was designed to be as equivalent as possible to the component prompt and to direct children's learning to the machine rather than the store itself. This allowed us to highlight the "inside parts of the machine" specifically in just one prompt to see if that would increase their discussions about mechanisms. On the contrary, a separate potential concern about our prompts was that the control prompt may have directed children's attention to the historical aspects of the setting. We ruled out this possibility by showing that children in the control prompt condition did not discuss the historical aspect of the setting more than children in the component prompt condition. Future research could investigate whether there are differences in children's discussions between a component prompt condition vs. a baseline "no prompt" condition. However, pilot data from a previous study conducted by our laboratory in the same setting suggest that a baseline "no prompt" condition may not be a viable option. In that work, we discovered that some small instruction to learn, talk, or ask questions was necessary to get the youngest children to engage in the visit meaningfully. Another option could be to provide a more heavy-handed component prompt, or perhaps a prompt directed at both parents and children, as these findings, compared to previous findings, hint toward the possibility that providing the prompt to both parents and children might be critical to influence engagement in these settings.

This study had a number of limitations; here, we will discuss a few: first, there was a non-significant age difference between the two conditions, where the component prompt condition contained more older children than that in the control prompt condition. This occurred due to random assignment to conditions. When parents inquired about participating, we only asked whether the child fell in the age range of the study, and we alternated condition assignment. In the future, a pseudo-random approach, where children are signed to alternating conditions based on their age in years would reduce age imbalances. However, age was statistically controlled for throughout analyses by entering age in months as a covariate, which alleviates some of this concern. Second, there is a limitation on the generalizability of the current findings given the narrow demographics of our sample (mostly White, highly educated, and high income). Finally, our analyses are also limited to participants' speech and to assessments of their recall of information. This does not take into account if there were differences in the amount of time children spent exploring the machine or manually interacting with it. It also does not allow for any other measures that might have shown a greater understanding of mechanisms than the ones we used here, such as asking children simple forced-choice questions about what they learned. Parents and museum staff could have also scaffolded children's learning through gestures and showing children how the machine physically operates. These additional factors could not be examined using the participants' speech alone.

These findings have implications for visitor experience and exhibit design in historical museums. They confirmed for this specific museum that their exhibits are supporting young children's learning, including learning about machines and mechanisms, which is well aligned with the local science curricular expectations for grades K-2. This research informed us as well as our partner museum about the potential importance of including some scaffolding or additional information to direct discussions toward mechanisms of machines in their exhibits. Fostering this type of science learning can lead to potential funding opportunities for the museum. For example, we were granted a Partnership Engage Grant from our federal government to examine how children learn in these spaces. This knowledge can open the museum up to exploring funding opportunities for science learning in this space, which is currently a priority area in the funding landscape. At the same time, this is a valuable opportunity for cognitive developmental psychologists, who often conduct work in laboratories to see how learning unfolds in everyday settings and how this aligns with in-lab effects. Notably, we did not find as much (spontaneous) mechanistic talk as we had expected. This finding is in contrast to prior experimental work in the laboratory that suggests that children by early preschool know that internal mechanisms are important to a machine's operation (e.g., Sobel et al., 2007; Ahl and Keil, 2017; Ahl et al., 2020). This difference demonstrates the value of examining children's behavior in real-world learning settings.

These findings also show how a simple verbal prompt accompanying an exhibit can influence children's learning, as it resulted in children producing higher quality explanations of how the machine worked. This finding was particularly valuable for the museum staff as their exhibits are embedded in an outdoor historical village, which cannot take advantage of "traditional exhibit features" that are typically used to enhance learning (e.g., plaques or interactive electronic features). When the museum staff embarks on an explanation about a machine's functioning in the exhibits, they can begin by drawing children's attention explicitly to the inside of machines. Afterward, staff could ask children to explain to them how the artifact operates to draw their attention to the mechanistic information about the artifact. This approach could be taken in similar museums, with the use of age-appropriate pamphlets or prompt cards for the parents to use with their children.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/dxg7h/.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Waterloo Research Ethics Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

EA, SN, and SD conceived of the presented idea, planned the experiments, created the coding scheme, and contributed to the data analytic plan. EA ran the participants, acted as a secondary coder, ran the analyses, and wrote the first draft of the manuscript, and all authors contributed to critical feedback, writing, and editing of subsequent drafts. All authors contributed to the article and approved the submitted version.

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Children's Informant Judgments and Recall of Valenced Facts at a Science Center

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In laboratory-based research, children recognize who is an expert and demonstrate an interest in learning from that person. However, children prefer positive information in the moment and sometimes prioritize positivity over expertise. To what extent do these social judgments (e.g., a preference for positivity) relate to information that children remember? We investigated the relation between these judgments and memory at a local science center to better understand children's learning outcomes in naturalistic settings. We examined the extent to which 4- to 8-year-olds accepted facts about an unfamiliar animal from a zookeeper informant (i.e., expert) and a maternal figure (i.e., non-expert) when these facts were positive, negative, or neutral. Children endorsed positive information as correct, regardless of expertise, but demonstrated the strongest memory for neutral information. We discuss the implications of this dissociation for learning outcomes in naturalistic contexts as well as theoretical frameworks regarding children's learning from others.

Keywords: social cognition, expertise, positivity bias, memory, museum learning

INTRODUCTION

Children's trips to science centers and museums promote educational interactions with parents and provide access to experts. Therefore, it is important to understand the factors that influence children's perceptions of these individuals as sources of information. Indeed, children recognize both parents and experts as reliable (e.g., Kruglanski et al., 2005). During middle childhood, children are increasingly attentive to expertise (e.g., Danovitch and Keil, 2004), but sometimes disregard accurate information from knowledgeable people in favor of information that promotes a positive view of the world (i.e., positivity bias; Boseovski, 2010; Landrum et al., 2013). In some circumstances, the valence of information (i.e., positive or negative) also impacts children's learning (e.g., acquisition of abstract words; Ponari et al., 2020) and emotional arousal or valence can impact visitors' memories of science center exhibits (e.g., Falk and Gillespie, 2009). This influence of valence, coupled with children's sensitivity to expertise, may shape children's science center learning outcomes.

In the present study, we examined the extent to which expertise and valence influence children's judgments of parents and experts as well as children's memory for exhibit information. Children evaluated positive, negative, and neutral facts that a zookeeper informant (i.e., expert) and a maternal figure (i.e., non-expert) provided about a novel animal at a local science center. Children judged which individual was correct about the animal. We also examined children's attributions of knowledge toward parents and experts for information that was unrelated to the animal (i.e., knowledge boundary judgments). Finally, we examined whether the information that children remembered about the animal was influenced by its valence or the expertise of the informant (i.e., source).

Children's Learning From Experts and Parents

We focused on children's evaluation of parents and experts in the present study for several reasons. First, both parents and experts are readily available interaction partners in naturalistic science center settings (e.g., Pattison et al., 2017). Second, children demonstrate awareness of expertise but continue to prefer parents as sources of information even in domains where a parent lacks expertise (e.g., Raviv et al., 1990). By age 4, children distinguish experts from non-experts and understand that the expert is a better source of information (e.g., Koenig and Jaswal, 2011). During middle childhood, children build on this ability to evaluate whether an expert's knowledge is relevant for a particular context (e.g., Danovitch and Keil, 2007). Despite young children's sensitivity to expertise cues (e.g., labels such as "animal expert"; Taylor et al., 1994), many children view their parents as reliable sources of information about the world in general (Fonagy et al., 2007). Young children tend to trust a parent over a stranger (Corriveau et al., 2009), and between ages 4 and 10, children judge their parents to be trustworthy sources across several domains (e.g., social issues and school subjects; Raviv et al., 1990). In fact, children continue to view parents as knowledgeable despite experience with individuals who are more informed (e.g., a science teacher; Kruglanski et al., 2005). Finally, the contrast between parents and experts was of interest in the present study because parents and experts (e.g., zookeepers or science educators) influence children's attitudes about wildlife through the transmission of positive and negative descriptions of animals (e.g., Reames and Rajecki, 1988; Muris et al., 2010).

Despite children's perceptions of parent and expert knowledge, children's acceptance of information from these individuals is influenced by its valence (see Marble and Boseovski, 2020). Children's judgments of parents and experts may not coincide with their actual behavior when valence and expertise are salient. In one study, Boseovski and Thurman (2014) investigated whether 3- to 7-year-olds accepted positive and negative facts about an unfamiliar animal. The experimenter introduced a novel animal (e.g., a cuscus) with a few neutral facts and a photograph of the animal. Then, the experimenter displayed photographs of a zookeeper (i.e., expert) and a maternal figure (i.e., non-expert) and told children what each individual said about the animal. Half of the children heard a positive statement from the zookeeper (e.g., it is "friendly" and "loves playing with children") and a negative statement from the maternal figure (e.g., it is "dirty and smelly" and "carries lots of germs"); this contingency was reversed for the other half of the children. Children were asked which person they thought was correct about the animal and were invited to "touch" the animal (unbeknownst to the children, it was a stuffed toy in an opaque crate). Three- to 5-year-olds accepted the expert's statements as correct irrespective of whether she provided positive or negative facts but reached more readily into the crate when the maternal figure provided positive information about the animal. This finding highlights a dissociation between young children's judgments and their actual behavior. In contrast and consistent with a positivity bias, 6- to 7-year-olds endorsed whichever source stated positive facts regardless of expertise. Older children were also more likely to reach into the crate when they endorsed positive information as correct. These findings from the older children indicate that 6- to 7-year-olds have difficulty accepting correct, negative information from qualified experts and may favor a non-expert in some contexts.

In addition to the influence of valence and source characteristics (e.g., expertise) on children's judgments and behavior, valence and source characteristics (e.g., context and similarity) can also impact children's memory (Foley, 2014; Van Bergen et al., 2015). In a science center context, judgments about the accuracy of an expert or a parent may operate as a notable source characteristic that biases children's attention toward information from one of these sources (i.e., expert or parent) and increases memory for what that person says. In contrast, if children's evaluation of correctness is a distinct process from any processes that facilitate recall, perhaps source characteristics such as expertise, would have less influence on memory performance relative to the valence of the information. The examination of this relation during real-time learning may inform how children's beliefs about, and behavior toward, wildlife develop. Therefore, it is important to extend this paradigm to a naturalistic setting that involves live informants.

In everyday situations, children may socialize with adults who do not fit neatly into a single category. These real-world categorizations may influence children's inferences about what parents and experts know, which in turn might affect who children endorse as correct during learning experiences. For example, some parents hold a dual role as both a caregiver and an expert in a separate domain. Children who are aware of this context may use it to compare knowledge between adults with overlapping roles (e.g., a zookeeper who is also a parent) or to judge whether an individual is knowledgeable across multiple domains. In contrast, many parents may not have expertise relevant to a science center setting. In this case, boundaries between parent and expert roles should inform children's evaluation of each individual's knowledge in a science center setting. Children who are not sensitive to these differences might overgeneralize what parents and experts know. Indeed, developmental differences in children's reasoning about categorical hierarchies might influence these knowledge judgments (Blewitt, 1994).

Beginning in the preschool period, children make some inferences about an individual's behavior and mental states according to that person's membership in a particular category (e.g., a gender category; Rhodes et al., 2014). With regard to children's judgments about expertise, children may use occupation information to make category-level inferences about what zookeepers know (in general) compared to what parents know (in general). The salience of these potential knowledge differences between experts and parents might be amplified in a science center context. In addition, there is age-related improvement in children's understanding of appropriate generalizations concerning what an expert knows outside of his or her domain of expertise (e.g., Taylor et al., 1994; Keil et al., 2008; Danovitch and Noles, 2014). If children's reasoning about boundaries to parent knowledge follows a similar pattern to children's reasoning about boundaries to expertise, children might be most likely to rely on an expert to reconcile conflicting information provided by the expert versus a parent. However, science centers also promote informal learning with parents (e.g., Callanan et al., 2017), which in turn may promote the integration of information shared by both zookeepers and parents into children's knowledge.

Children's Memory in Science Center and Museum Settings

The social context provided by parents and experts in science centers may impact children's memory for those experiences. Children may weigh what parents and experts say (i.e., content) in these settings against beliefs about whether parents and experts are qualified sources of information (i.e., knowledgeable) in science center contexts. Indeed, parent and museum staff facilitation of children's engagement and learning in science center contexts is of strong practical interest to museum educators (e.g., Pattison et al., 2017). In recent research, interactions between parents and children during exhibit exploration have been a focal point (Benjamin et al., 2010; Jant et al., 2014). Parents' conversation style is one factor that is related to children's memory for events (Nelson and Fivush, 2004; Fivush et al., 2006). In museum contexts, children whose parents asked more open-ended *Wh*-questions during exhibit conversations remembered more about the experience later that day and after a 2-week delay (Benjamin et al., 2010; Jant et al., 2014). In this way, children's conversations with parents can provide social support for learning at exhibits. With age, children recall increasing amounts of event detail, need fewer cues to recall an event and are better able to discern when some types of cues are helpful, and demonstrate an improved ability to remember events after longer delays (Bauer, 2007; Reese et al., 2011; Selmeczy and Ghetti, 2019). Taken together with the important role that parents have in museum-based conversations and learning, these age-related changes may have an important effect on children's memory for exhibit information.

Specifically, age-related improvements in source memory, defined as memory for perceptual and contextual information of an event (Johnson et al., 1993), might be particularly important in a science center context. The ability to remember the source of information improves between ages four and seven (Drummey and Newcombe, 2002; Riggins, 2014; for review, see Foley, 2014) and may facilitate recall of factual information (Bemis et al., 2013). In science center settings, children encounter a variety of sources, including both parents and experts. Similarity between sources (e.g., appearance of a person and type of information shared) may make it difficult for children to attribute accurate source information (e.g., Lindsay et al., 1991). Salient differences between sources (e.g., expertise level and information valence) may help children distinguish between the sources and organize facts to facilitate later recall, especially if these differences highlight familiar categories (e.g., experts vs. non-experts) or align with preexisting learning preferences (e.g., bias toward positive information). Given the age-related improvements in source memory, older children may be more likely than preschoolers to take advantage of these cues during recall, but to our knowledge, there has been no research on the effect of source expertise on memory in these settings.

In addition to children's ability to leverage source information, children's strengthening preference for positivity during middle childhood (Boseovski, 2010) may explain mixed findings regarding developmental differences in the effect of valenced content on children's memory. For example, children sometimes demonstrate better memory for negative information (e.g., threatening social behavior, Baltazar et al., 2012; traumatic events, Pezdek and Taylor, 2002), but in other circumstances, children demonstrate a bias for positive information during recall (e.g., word list; Brainerd et al., 2010). It is possible that in certain situations, valenced information is salient overall and remembered better relative to neutral information. Indeed, children remember positive and negative personal events equally well most of the time (Fivush, 1998) and both positive valence and negative valence help children acquire abstract concept words (e.g., Ponari et al., 2018). Young children may be sensitive to emotionally salient content about people or animals, regardless of the valence of that content. In one study, 4- to 6-year-olds heard several stories about animal characters that experienced a positive, negative, or neutral event. One hour later, children were asked what they could recall from the stories. Children's memory was better for positive and negative contents relative to neutral content, but best for negative content overall (Van Bergen et al., 2015). It may be beneficial for children to remember negative messages that contain safety warnings, threats to self, or threats to animals when learning about wildlife (Boseovski and Thurman, 2014; Burris et al., 2019) and yet 6- to 7-year-olds have demonstrated a bias for positive information about animals (Boseovski and Thurman, 2014). Indeed, 7- and 11-year-olds recall positive and neutral words better than negative words in laboratory-based, list recall tasks (e.g., Howe et al., 2010) and 8- to 9-year-olds are more accurate when tested for their acquisition of novel abstract words that are positive relative to neutral (Ponari et al., 2020).

This pattern of age-related increase in recall of positive content aligns with a general developmental trend to endorse positive feedback and positive testimony from others (Marble and Boseovski, 2020). Taken together, these findings across literatures may suggest that children's judgments about informant sources could influence children's memory for the information those sources provide. Both positive information and negative information might be salient for recall: Positive information aligns with a strengthening preference for positivity, whereas negative information violates this preference. Another possibility is that the mixed findings regarding how valence influences memory indicate a dissociation between children's correctness judgments and the processes that influence children's memory. The relation between valence, expertise, and memory is particularly important for children's learning in science center settings given that children's early positive or negative experiences with animals are thought to lay the foundation for attitudes toward wildlife later in life (Kidd and Kidd, 1996).

Current Study

We examined whether 4- to 8-year-olds' acceptance of information about an unfamiliar animal differed based on the expertise of the informant (i.e., zookeeper vs. non-expert maternal figure) and the valence of the informants' statements (i.e., positive, neutral, or negative). We extended the paradigm used by Boseovski and Thurman (2014) in two ways. First, we adapted the paradigm to examine the effect of "live" experts and non-experts in a naturalistic setting (i.e., a local science center). Second, we included a memory assessment to examine whether the effect of expertise and valence on children's learning of information was similar or distinct from the effect on judgments of source correctness (i.e., correctness judgments). Consistent with a strengthening positivity bias across middle childhood (Boseovski, 2010; see Boseovski and Thurman, 2014), we anticipated that 4- to 5-year-olds might accept more of the expert's facts regardless of valence relative to 6- to 8-year-olds. We predicted that 6- to 8-year-olds would perform better than 4- to 5-year-olds when asked to infer other types of knowledge for the informants (i.e., knowledge boundary judgments) and that these older children would recall more facts (memory assessment). We did not have specific predictions regarding the interaction of valence and expertise on recall performance, given evidence that both positive and negative experiences are remembered (Wolins et al., 1992; Kidd and Kidd, 1996).

MATERIALS AND METHODS

Participants

Eighty 4- to 8-year-olds (M = 77.36 months, SD = 17.30 months; 36 girls) were recruited from the local science center or a database of volunteers from the community. This sample size was estimated based on the paradigm adapted from Boseovski and Thurman (2014) that produced between a medium and large effect for similar main measures (η_p^2 = 0.14). Demographics of the sample reflected the overall visitor demographics of the local science center where testing took place. With regard to participant race, 77.5% reported this information and these parents identified their children as White (80.6%), Black (9.7%), Asian (1.6%), or bi-racial (8.1%).

With regard to annual household income, 71.3% reported this information and the majority of these household incomes were above the city average at the time of data collection (42.1% reported above $90,000; 22.8% as $60,000–$90,000). Families who approached the indoor aquarium and animal exhibits were asked whether they would like to participate in a research opportunity and were provided with basic information about the exhibit of interest. Parents provided written consent for their children's participation, and children 7 years of age and older provided written assent. Approval for this study was obtained from the university's institutional review board, and a memorandum with the science center was completed.

Materials

The informants were trained researchers playing the roles of a zookeeper and a maternal figure. There were four total researchers who were trained for this role, but only two researchers acted in these roles per participant (i.e., one zookeeper and one maternal figure). The zookeeper informant wore a black polo shirt with khaki pants and carried a clipboard and a walkie-talkie. The maternal figure informant wore a black blouse with jeans and carried a purse and a map of the science center. The informants provided information about the tamandua, a species of anteater native to Central and South America that was on exhibit at the science center.

Design

A 2 (age: 4- to 5-year-olds vs. 6- to 8-year-olds) × 3 (fact valence: positive, neutral, and negative) × 2 (informant status: zookeeper expert vs. maternal figure non-expert) mixed design was used with fact valence and informant status as the within-subjects factors.

Procedure

After consent was obtained, the experimenter escorted participants to the exhibit that housed the tamandua. During this time, the experimenter confirmed that participants had no prior knowledge of tamanduas. At the exhibit, the experimenter said, "This is Jess, and this is Kim. They want to tell you what they know about the tamandua." The zookeeper introduced herself with the statement: "I am a zookeeper. I work with many different kinds of animals. I know a lot about all kinds of animals that most other people don't know about." The maternal figure introduced herself with the statement: "I am a mom just like any regular mom. I have two kids around your age. I know a lot about being a mom, just like any regular mom does" (adapted from Boseovski and Thurman, 2014). The order of introductions was counterbalanced. The informant role played by each researcher was counterbalanced, and half of the participants were introduced to "Jess the zookeeper and Kim the mom" and the other half were introduced to "Kim the zookeeper and Jess the mom."

Next, the experimenter said, "Now Jess the zookeeper is going to tell you what she knows about the tamandua." The informant guided participants closer to the window of the exhibit. Thus, participants had a "live" view of the animal, which was typically sleeping and partially obscured in a leaf-covered area of the exhibit. The informant pointed out the tamandua and presented her facts about the animal to participants (e.g., "Tamanduas live in tropical rain forests"; see **Table 1** for full scripts). The other informant stood out

TABLE 1 | Full scripts, sorted by valence and conflicting facts, for each informant.

Script A: Non-conflicting facts	Script B: Non-conflicting facts
Positive	
Baby tamanduas are cute and cuddly	Tamanduas have a great sense of smell
They are good climbers	They have strong arms and legs
Tamanduas also have really good hearing and hear from far away	Mother tamanduas take good care of their babies and give them piggy back rides
Negative	
Brother and sister tamanduas do not get along and push and fight each other	Tamanduas also have bad vision and cannot see far away
They are smellier than a skunk	Adult tamanduas are slow and lazy
They have long, sharp claws	They are bad runners
Neutral	
They are nocturnal, meaning they are awake at night	Their fur can be many colors
They live in nests on the ground	They live in a tropical rain forest
Babies do not look like parents	Tamanduas can swim in lakes and rivers
Script A: Conflicting facts	**Script B: Conflicting facts**
Positive in Script A conflicts with negative in Script B	
Tamanduas are gentle and purr softly	They are mean and roar loudly
Tamanduas love to live in homes as pets	Tamanduas hate to live in homes as pets
They also have big brains and remember a lot	Tamanduas have small brains and forget often
Negative in Script A conflicts with positive in Script B	
Tamanduas are very dirty and carry germs	They are very clean and healthy
Tamanduas fight a lot with other animals	They are very friendly with other animals
They have a hard, scaly tail that they use to break things around them	They also have a soft, furry tail that they use as a pillow to sleep
Neutral	
Other than zoos, they only live in Argentina	Other than zoos, tamanduas only live in Brazil
Their favorite food is termites	Their favorite food is beetles
Also, their babies are born with their eyes closed	Their babies are born with their eyes open

of earshot. After the first informant finished telling participants everything she knew about the tamandua, the second informant approached the participants to present her facts about the tamandua. The order in which informants shared facts and the script assigned to each informant were counterbalanced across participants.

The informant scripts (Script A and Script B) each consisted of 18 facts about the tamandua. Twenty-four randomized versions of each script were used. Each script contained: six positive facts (e.g., "Baby tamanduas are cute and cuddly"), six negative facts (e.g., "Tamanduas are smellier than a skunk"), and six neutral facts (e.g., "Tamanduas can swim in lakes and rivers"). Nine of the facts in a script, three of each valence, conflicted with the nine facts on the same topics in the other script. For example, one informant told the participants "Tamanduas are mean and roar loudly" but the other informant told the participants "Tamanduas are gentle and purr softly" (adapted from Boseovski and Thurman, 2014; see **Table 1**).

After each informant spoke to the participants, the experimenter escorted the participants to a private room nearby to complete three assessments, described below (correctness judgments, knowledge boundary judgments, and a memory assessment). The correctness judgments and knowledge boundary judgments were conceptualized as two parts of a social cognition task. The order in which this social cognition set versus the memory assessment was administered was counterbalanced across participants, and participants' responses were recorded on an iPad by the experimenter. Photographs of the informants were displayed as a reference for the participants during these assessments (see **Figure 1**).

Correctness Judgments

These items evaluated how children judged the correctness of conflicting facts presented by the zookeeper informant and the maternal figure. The questions pertained to the nine conflicting facts presented by the informants (see **Table 1**). Participants were shown the photographs of each informant and reminded which informant told them each of these nine facts (e.g., "Jess the zookeeper said that tamanduas are gentle and purr softly but Kim the mom said they are mean and roar loudly"). Then, participants were asked a forced-choice question "Who do you think is right?" (answer options: zookeeper or maternal figure). Participants' responses were summed across each combination of informant status and fact valence to reflect the number of times participants endorsed the zookeeper when she presented a positive fact, when she presented a negative fact, and when she presented a neutral fact; and the number of times participants endorsed the maternal figure when she presented a positive fact, when she presented a negative fact, and when she presented a neutral fact. For example, if a participant endorsed all three positive facts presented by the maternal figure, that participant would receive a "3" for the maternal-positive fact set but that would mean that the same participant endorsed zero negative facts presented by the zookeeper informant and would receive a "0" for the zookeeper-negative fact set (see **Table 1**). Collapsed across informant status, participants' responses could be summed out of a possible total of six valence-specific endorsements (i.e., endorsement of positive, neutral, or negative facts). Collapsed across fact valence, participants' responses could be summed out of a possible total of nine informant-specific endorsements (e.g., a participant who endorsed the zookeeper informant for all the conflicting facts would receive a "9" for zookeeper correctness judgments but "0" for maternal figure correctness judgments).

Knowledge Boundary Judgments

This assessment evaluated children's understanding of the boundaries of expertise and consisted of 17 questions, which served as a supplemental measure to examine whether children extended informant knowledge beyond knowledge of tamanduas; the valence of these facts was not manipulated, and items were randomized across subsets during presentation. There were

FIGURE 1 | Sample photographs of "Jess the zookeeper" and "Kim the mom," the trained researchers who acted in informant roles for the purpose of the study.

three subsets of questions: four questions about topics most related to a zookeeper's expertise (e.g., "Who knows more about why fish live in water?"), four questions about topics most related to a mother's knowledge (e.g., "Who knows more about how to strap in a car seat?"), and nine questions about topics that reflect general knowledge (e.g., "Who knows more about why we tell the truth?"). In each set, there were three answer choices (zookeeper informant, maternal figure, or both informants would know about the topic) and participants received a score of 1 for each question where they indicated the expected choice (i.e., "zookeeper" for the zookeeper subset, "mom" for the mother's knowledge subset, and "both" for the general knowledge items). All other answers received a score of 0. Previous studies regarding children's inferences about knowledge related to biological and social psychology principles were consulted to inform the creation of these items (e.g., Danovitch and Keil, 2004, 2007). In addition, the research team members who created these items obtained informal feedback from other members of the laboratory regarding how reasonable it would be to expect most adults to know some of these items to justify the expected answer choice of "both" and informal feedback regarding knowledge that would be specific to mothers/parents. Participants' responses were summed for each subset to produce three scores (out of 4 points, 4 points, and 9 points, respectively).

Memory Assessment

This assessment included an open-ended free recall prompt ["You heard information about tamanduas from (Informant 1) and (Informant 2). What did you learn about the tamandua?"] followed by six, topic-based cued recall questions (e.g., "Now I'm going to ask some questions, some of which you already talked about. Just answer them the best that you can. Okay, ready? What do you remember about where tamanduas live? What do you remember about what tamanduas look like? What do you remember about what tamanduas are good or bad at?"). Participants could recall information for up to 36 facts (18 facts per informant, divided equally across valence, and including conflicting facts). Participants could receive points for recalling a fact that was stated by the zookeeper, the maternal figure, or recalling what both informants said. In addition, participants could respond with more than one fact to address each cued recall question to maximize reports of any information that children could remember. For example, the question "What do you remember about how tamanduas act?" could be answered by recalling information that informants provided about interactions with other animals and/or information provided about how tamanduas sleep (i.e., not participants' observations while at the exhibit).

Participants were scored based on the amount of accurate detail that they provided about a recalled fact to provide the most generous scoring for the youngest participants (4-year-olds), who might only be able to recall partial facts or partial details or might only be able to report partial facts due to language ability. We adapted a scoring scheme from the vocabulary section of the Wechsler Abbreviated Scale of Intelligence (WASI-II; Wechsler, 2011). Participants could receive a total score out of a possible 72 points: Participants received 2 points for each fact that they remembered fully (i.e., complete detail from the informant's statement); participants received 1 point if they remembered the general statement accurately but without full detail. For example, one informant stated that tamanduas eat beetles. For the question "What do you remember about what tamanduas eat?" a participant who responded "beetles" received 2 points, but a participant who responded "bugs" received 1 point for providing generally correct information. Participants did not receive any points if they gave incorrect statements (i.e., information that did not resemble either informant's statement) or unrelated filler statements (e.g., "I don't know"). One member of the research team scored all these responses, and a second research assistant scored 50% of these responses. Interrater agreement for classifying these responses was strong, 1-point responses: ICC (2,2) = 0.995; 2-point responses: ICC (2,2) = 0.963. Disagreements were resolved by a third member of the research team.

After testing was complete, participants were debriefed. They were told that the informants were not really a zookeeper or a mom and the experimenter ensured that children understood the informants had been "pretending" just for that day. The experimenter also made sure that children and their parents knew that some of the facts that they heard about the tamandua were inaccurate. Families were provided with a fact sheet created by the museum's education team that contained accurate information about the tamandua.

RESULTS

Correctness Judgments

A 2 (age group, between subjects) × 3 (valence, within subjects) × 2 (informant status, within subjects) mixed ANOVA conducted on the correctness score revealed a main effect of valence, $F(2, 78) = 4.06$, $p = 0.02$, $\eta_p^2 = 0.095$. Children endorsed positive facts ($M = 3.29$, $SD = 1.12$) as correct over neutral facts ($M = 2.96$, $SD = 0.25$) which in turn were endorsed over negative facts ($M = 2.63$, $SD = 1.14$; all Bonferroni-corrected pairwise comparisons $ps < 0.01$; $ds = 0.29$, 0.30, and 0.31; see **Figure 2**). There were no main effects of informant status or age group and no significant interactions among these factors (all $ps > 0.30$).

Knowledge Boundary Judgments

The data from 10 participants were not included as they did not receive the option to select "both" informants due to experimenter error. The data for the remaining 70 participants (26 4- to 5-year-olds) were analyzed using a one-way ANOVA to compare the effect of age group on each of the generalization of knowledge scores (i.e., "zookeeper," "mother," and "both" knowledge areas).

For the "zookeeper" item set, there was a significant effect of age, $F(1, 68) = 13.84$, $p < 0.001$, $\eta_p^2 = 0.17$. Older children ($M = 3.11$, $SD = 1.03$) selected the zookeeper as knowledgeable more often than younger children ($M = 2.08$, $SD = 1.18$). To examine whether this effect indicated that only older children selected the zookeeper systematically, t-tests against chance (2 out of 4) were conducted. Older children selected the zookeeper at a rate significantly different from chance, $t(43) = 7.11$, $p < 0.001$, $d = 1.04$; younger children were unsystematic, $t(25) = 0.31$, $p = 0.76$.

For the "mother" item set, there was a significant effect of age, $F(1, 68) = 18.30$, $p < 0.001$, $\eta_p^2 = 0.21$. Older children ($M = 3.18$, $SD = 1.15$) selected the maternal figure as knowledgeable more often than younger children ($M = 1.77$, $SD = 1.53$). T-tests against chance (2 out of 4) revealed that older children selected the maternal figure at a rate significantly different from chance, $t(43) = 6.61$, $p < 0.001$, $d = 0.99$; younger children were unsystematic, $t(25) = -0.76$, $p = 0.46$.

Finally, for the "general" item set, there was a significant effect of age, $F(1, 68) = 4.24$, $p = 0.04$, $\eta_p^2 = 0.06$, such that younger children ($M = 3.77$, $SD = 2.95$) selected "both" informants as knowledgeable more often than older children ($M = 2.45$, $SD = 2.42$). T-tests against chance (3 out of 9) revealed that neither older nor younger children selected the expected answer of "both" at a rate significantly different from chance: older, $t(43) = -1.49$, $p = 0.14$; younger, $t(25) = 1.39$, $p = 0.18$. Additional t-tests against chance to examine whether children

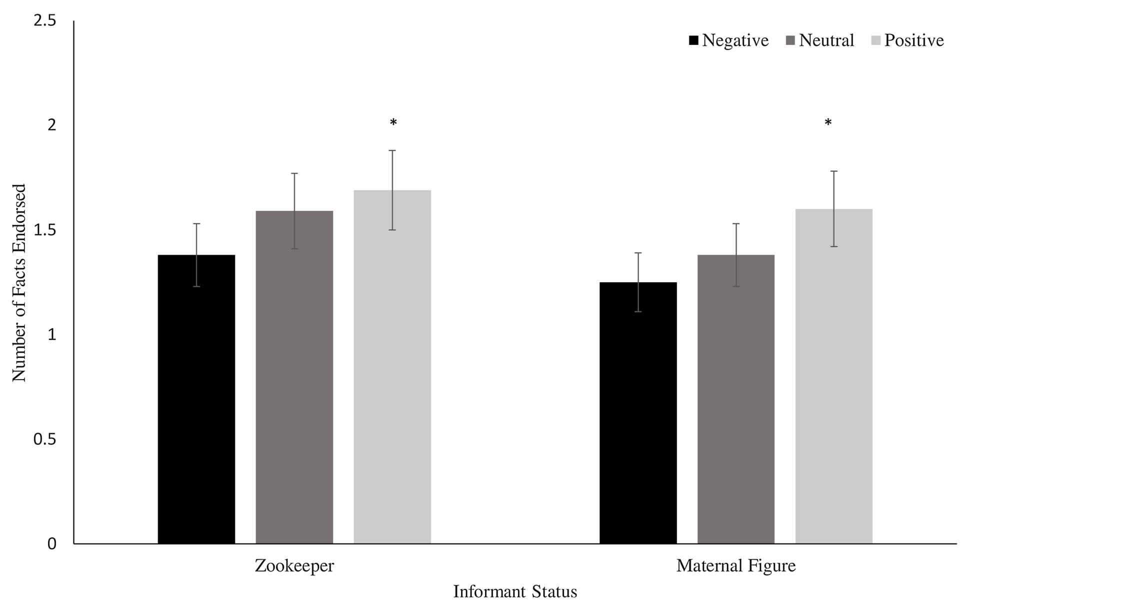

FIGURE 2 | Mean number of facts endorsed as correct by informant status and fact valence. *indicates significantly different from both negative and neutral facts, $p < 0.05$. Error bars reflect standard errors.

favored either informant revealed that older children selected the maternal figure systematically, $t(43) = 6.11$, $p < 0.001$, $d = 0.92$, and systematically refrained from selecting the zookeeper, $t(43) = -8.36$, $p < 0.001$, $d = 1.26$. Younger children also systematically refrained from selecting the zookeeper $t(25) = -3.92$, $p < 0.001$, $d = 0.77$, but younger children did not select the maternal figure at a rate significantly different from chance, $t(25) = 0.69$, $p = 0.50$. All of the older children and 20 out of 26 younger children (76.9%) endorsed the maternal informant for at least 5 of these 9 general knowledge items.

Memory Assessment

Preliminary analyses indicated that there was no significant effect of assessment order (i.e., memory assessment first vs. correctness judgments first) on children's recall of information about the tamandua, $F(1, 79) = 2.39$, $p = 0.126$. On average, children remembered approximately five facts about the tamandua ($M = 5.20$, $SD = 2.84$) out of 36 total facts. This average recall was not meaningfully increased when recall was summed across free and cued recall responses ($M = 5.19$). Therefore, the results reported below focus on cued recall only.

A 2 (age group, between subjects) × 3 (valence, within subjects) × 2 (informant status, within subjects) mixed ANOVA revealed a main effect of age, $F(1, 78) = 18.71$, $p < 0.001$, $\eta_p^2 = 0.193$, such that 6- to 8-year-olds ($M = 8.67$, $SD = 3.92$) remembered more information than 4- to 5-year-olds ($M = 4.87$, $SD = 3.66$).

There was also a main effect of valence, $F(2, 78) = 12.79$, $p < 0.001$, $\eta_p^2 = 0.141$. Children remembered more neutral information ($M = 3.14$, $SD = 2.29$) than positive information ($M = 1.83$, $SD = 1.61$) or negative information ($M = 2.26$, $SD = 1.73$; Bonferroni-corrected pairwise comparisons, $p < 0.001$, $d = 0.52$ and $p = 0.002$, $d = 0.36$); positive and negative information did not differ from one another (Bonferroni-corrected pairwise comparison $p = 0.052$). There were no significant interactions between valence, age, and informant status (all ps > 0.20); children remembered more neutral information irrespective of informant status or age (see **Figure 3**).

To investigate whether the main effect of age was due to the level of detail children remembered, a chi-square test of independence was conducted with the variables age group and level of detail (i.e., number of 1-point vs. 2-point responses). The relation between these variables was not significant, $\chi^2(1, 80) < 0.000$, $p = 1.0$. Descriptively, more children provided at least one 1-point response (90.32% of younger children and 93.88% of older children) relative to those who provided at least one 2-point response (67.74% of younger children and 91.84% of older children).

In addition to these analyses, children's recall of the subset of conflicting facts was examined separately. On average, children recalled between 2 and 3 of the 9 conflicting facts ($M = 2.76$, $SD = 1.74$). A 2 (age group, between subjects) × 3 (valence, within subjects) × 2 (informant status, within subjects) mixed ANOVA was conducted on children's conflicting fact cued recall score and revealed a similar pattern to children's cued recall score out of all 36 facts. The analysis revealed a main effect of age, $F(1, 78) = 8.99$, $p = 0.004$, $\eta_p^2 = 0.10$, such that 6- to 8-year-olds ($M = 3.20$, $SD = 1.71$) recalled more conflicting information than 4- to 5-year-olds ($M = 1.06$, $SD = 1.57$). There was also a main effect of valence, $F(1, 78) = 9.98$, $p < 0.001$, $\eta_p^2 = 0.11$. Children remembered more neutral conflicting information ($M = 1.34$, $SD = 1.11$) than positive conflicting ($M = 0.70$, $SD = 0.85$) or negative conflicting information ($M = 0.73$, $SD = 0.89$; Bonferroni-corrected pairwise comparisons both ps < 0.001, ds = 0.41 and 0.42); positive and negative conflicting information did not differ from one another (Bonferroni-corrected pairwise comparison $p = 1.0$).

Finally, separate two-tailed Pearson correlations were conducted to examine children's performance on the memory assessment in relation to their correctness judgments. Children's cued recall for positive, neutral, and negative information was not related to their endorsement of positive, neutral, or negative information from either informant on the correctness judgments (all ps > 0.10). This pattern held when children's cued recall for conflicting facts alone was examined separately by informant and when collapsed across informant (all ps > 0.10).

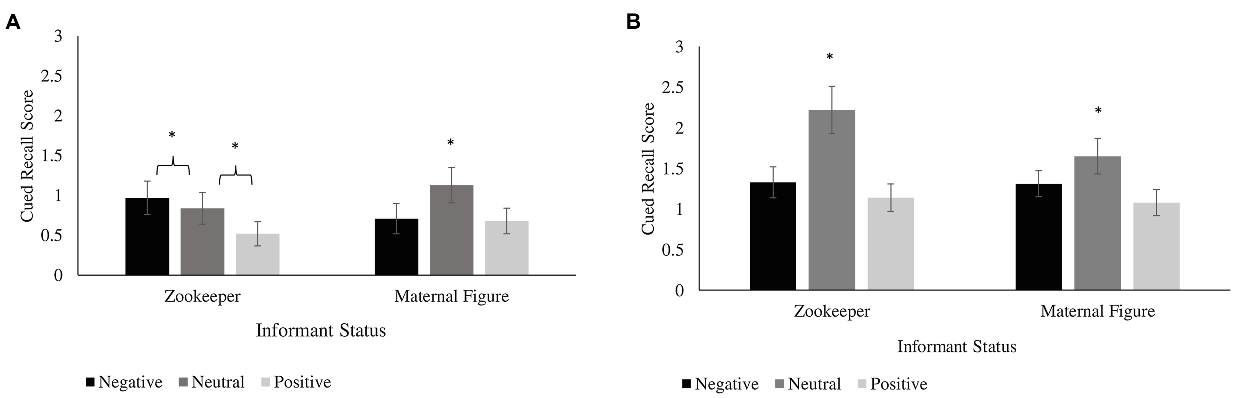

FIGURE 3 | Cued recall score by informant status and fact valence for **(A)** 4- to 5-year-olds and **(B)** 6- to 8-year-olds. *indicates significantly different from both negative and positive facts, $p < 0.05$. Error bars reflect standard errors.

DISCUSSION

As predicted, children judged positive information about an unfamiliar animal as more correct, regardless of the expertise of the informant providing that information. Despite this preference for positive information on the correctness judgments, older children recognized expertise and inferred knowledge more accurately than younger children on the knowledge boundary judgments, which did not involve valenced information. Overall, children's memory for the facts was relatively low, but our results were consistent with general age-related improvements: older children remembered more facts than younger children on the memory assessment. In contrast to children's correctness judgments of conflicting testimony, when children recalled facts from the exhibit interaction, their memory was best for neutral facts. Taken together with older children's performance on the knowledge boundary judgments, the findings from the memory assessment suggest that age-related improvements in children's ability to identify who is a qualified source of information may not align with what children remember. We discuss the theoretical implications of this dissociation, along with the implications for children's science center learning outcomes.

A central aim of this study was to examine the relation between children's preference for positivity when they evaluate informants (e.g., correctness judgments) and what children remember in a naturalistic setting (e.g., memory assessment). In general, children's recall of exhibit facts was low relative to the total amount of possible information that they could recall, and recall was not scaffolded by the presence of source expertise or valence. Children's recall was unrelated to their judgments about which informant was correct (i.e., whichever informant presented positive facts). In contrast, when children remembered information about the tamandua, it was neutral rather than positive or negative information. In general, positive and negative information tend to be salient when children recall personal experiences (e.g., Fivush, 1998) or other narrative material (e.g., Potts et al., 1986), and this valenced information is often reported in children's qualitative accounts of museum field trips (e.g., Wolins et al., 1992). It is surprising that the physical presence of the tamandua in this study did not heighten the salience of valenced content regarding its behavior (e.g., is this animal "friendly" or potentially aggressive?). Instead, children's better recall of neutral relative to valenced information may indicate that neutral information was easier for children to process and remember considering potential distractions in a science center environment (e.g., other visitors and noise). However, we interpret children's recall of neutral information with caution given the relatively small practical differences in recall across valence.

Somewhat surprisingly, children did not draw on source expertise to scaffold recall on the memory assessment. Older children could have used source expertise as a cue to recall accurate information given older children's sensitivity to qualitative differences in the types of knowledge that others possess (e.g., Raviv et al., 1990; Danovitch and Keil, 2007). Specifically, it would be feasible for older children to demonstrate sensitivity to expertise during recall even if they demonstrated a preference for positivity when they evaluate the accuracy of sources for correctness judgments. However, source expertise may not have been salient enough in this study to elicit additional processing. Although the informants offered conflicting facts about the tamandua, each discussed the same aspects of the tamandua overall (e.g., habitat, behavior, and eating habits). In this way, the two informants may have presented an overall similarity to one another (e.g., Thierry and Pipe, 2009). If cognitive demands were high due to the number of potential cues and the amount of information presented, children may have been unable to use source expertise to scaffold recall.

Children also did not use expertise information to make correctness judgments about which informant they thought provided accurate information about the tamandua, but rather preferred positive statements. Despite children's sensitivity to expertise across a variety of laboratory-based studies (e.g., Lane and Harris, 2015; Toyama, 2017), this prioritization of positive information is consistent with a sizable literature in which children's correctness judgments or evaluation of expertise is influenced by valenced information (see Marble and Boseovski, 2020). This consistency with laboratory-based research suggests that the physical learning environment may not play a major role in children's informant judgments. Instead, the ecological validity of laboratory-based selective trust studies might be strengthened by incorporating multiple or conflicting cues to knowledge. Theoretically, this correctness judgment finding suggests that children's preference for positivity may be a motivation or belief-based bias, distinct from memory-related biases. Older children's use of expertise information in the knowledge boundary judgments, in which the valence of information was not manipulated, supports this view. Older children demonstrated a nuanced ability to infer knowledge for the zookeeper informant and the maternal figure for the "zookeeper" and "mother" sets of this knowledge boundary task, respectively. This knowledge boundary judgment performance suggests that in the absence of valence information, older children may capitalize on other cues to evaluate testimony, including expertise (see Marble and Boseovski, 2020). If positive information is inaccurate, children may need assistance to avoid inappropriate endorsement of incorrect information. Although this information may not reflect what they remember later, this initial endorsement could prompt repeated retrieval of inaccurate information, resulting in an illusion of truth (Dechêne et al., 2010).

Despite older children's success on two sets of the knowledge boundary judgments, children across ages struggled to infer that both the zookeeper informant and the maternal figure could share general knowledge. Most children selected the maternal figure on more than half of the trials. One possible explanation for this pattern is that children were primed to think about the zookeeper informant and the maternal figure as members of distinct categories in a science center context. Children may have viewed "mothers" to be a broader category akin to "adults" but were not able to reflect that "zookeepers" could also be members of other categories. Accordingly, children did not generally endorse shared knowledge (i.e., an overlap in roles or identities) among these individuals. Indeed, even 6- to 8-year-olds treated "mothers" as more globally knowledgeable despite the option to select an answer choice of "both" on this assessment. This perception of maternal informants has implications for who children attend to during science center visits.

In general, it is somewhat surprising that a science center context did not prime children to prioritize information from the expert, zookeeper source. However, it is possible that children do not view their experiences at these locations as explicitly educational. Indeed, parents are sometimes less aware of the educational value of museum exhibits relative to the educators who organize these opportunities (e.g., Downey et al., 2010; but see Falk et al., 1998). If the entertainment value of science center experiences is emphasized (Rennie and McClafferty, 1995), children may be less likely to prioritize educational goals and pay attention to experts. Although science centers may face the unique challenge of increasing parent perceptions of experts as good sources of information (Luke et al., 2019), the findings from this study suggest that increasing the salience of expertise *via* clear labels or identification by a parent may promote children's learning from these reliable sources (Gelman et al., 1998).

Indeed, this parental scaffolding may support learning when children miss cues to expertise or if speakers are prone to human fallibilities (e.g., poor explanations, Clegg et al., 2019; under-informativeness, Gweon et al., 2014). Elaborative conversations directed by caregivers have been an effective strategy to support the memory of younger children (Cleveland and Reese, 2005). Recent research suggests that parent-child conversations (e.g., Benjamin et al., 2010; Jant et al., 2014) and other memory developments (e.g., Pathman et al., 2011) figure prominently in what children remember from these autobiographical experiences, but these phenomena were not the focus of the present study. Parent-child conversations can also promote continued learning outside of museum settings and support children's transfer of information from museum to home settings (e.g., Benjamin et al., 2010; Mills and Sands, 2020). The memory assessment in this study took place without the benefit of this scaffolding, which may partially explain why children only remembered a few facts. The memory assessment performance in this study suggests that in a naturalistic setting, children may benefit from a small amount of key information, which may also be advantageous for programming. For example, formal expert talks can be kept short to allow more informal engagement with visitors or more interactive opportunities for children, which in turn might also contribute to the richness of the information that children remember (e.g., Imuta et al., 2018). Specifically, it is possible that the surrounding environment (e.g., other visitor conversations, noises, and sights) affects children's ability to focus explicitly on the target exhibit. Indeed, children's ability to control their attention and ignore distractions improves across early and middle childhood (Best and Miller, 2010).

Limitations and Future Directions

Some aspects of the method used in the current study may have limited children's ability to remember information about the tamandua and highlight important considerations for comparisons between laboratory-based and naturalistic research. For example, the presentation method of information about the tamandua prioritized experimental control but as a result might not have followed a truly narrative format. Given that children's recall is enhanced when an event follows a narrative structure (see Nelson and Fivush, 2004, for review), it is possible that children in this study would have benefitted from a more story-like presentation of facts. Another possibility is that recall would benefit from an exhibit that involved "hands-on" interaction (e.g., Imuta et al., 2018). In addition, the on-location memory assessment provided a compelling snapshot of children's judgments and memory, but this procedure does not inform our understanding of children's long-term memory for exhibit information. Nonetheless, a dissociation between what children endorsed as correct and what they remembered emerged, which presents compelling avenues for future research regarding children's informal learning. Future research might also consider the inclusion of a source memory task to address questions regarding children's encoding of information and should generally address how children's priorities when they evaluate information map onto learning outcomes across a variety of contexts. It is likely that a combination of motivational biases in the moment and memory-specific effects play a role in these outcomes.

Another limitation of the current study could involve the differences between an experimental paradigm and expert behavior in naturalistic settings. Based on both formal and informal observations by the research team at this same science center, it appeared that the true experts engaged variably with both large groups and individual visitors, whereas real parents tended to address their individual children in conversation. In contrast, we sought experimental control for the possible effect of consensus or group effects and decided to retain the one-on-one element of the paradigm adapted from Boseovski and Thurman (2014), particularly because the "group" was composed of non-participating museum visitors. Future research might address the consensus element of naturalistic settings as well as the possibility that an expert and parent would engage in conversation with one another rather than taking individual turns to relay information.

Conclusion

Taken together, the results from this study shed light on an important distinction between children's acceptance of information during exhibit experiences and what they remember from these interactions. These findings demonstrate the strength of considering children's developmental trajectories across multiple literatures to better understand children's everyday learning in these prevalent naturalistic settings. These findings also highlight the need to extend research on children's judgments of everyday expert and non-expert sources in naturalistic settings. Children's sensitivity (or lack thereof) to who shares information and what those individuals say may enhance or hinder children's learning outcomes at these important naturalistic locations.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Office of Research Integrity at the University of North Carolina at Greensboro. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JB and TP conceptualized the design of this study. JB, TP, and SM supervised this project and provided guidance on data analyses and contributed to the writing and editing of this manuscript. KM, MS, JC, and KB collected the data or participated as the informants for this study. KM wrote the manuscript with contributions to the writing and feedback from JC and KB. All authors contributed to the article and approved the submitted version.

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Brief Interventions Influence the Quantity and Quality of Caregiver-Child Conversations in an Everyday Context

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Reading and arithmetic are difficult cognitive feats for children to master and youth from low-income communities are often less "school ready" in terms of letter and number recognition skills (Lee and Burkam, 2002). One way to prepare children for school is by encouraging caregivers to engage children in conversations about academically-relevant concepts by using numbers, recognizing shapes, and naming colors (Levine et al., 2010; Fisher et al., 2013). Previous research shows that caregiver-child conversations about these topics rarely take place in everyday contexts (Hassinger-Das et al., 2018), but interventions designed to encourage such conversations, like displaying signs in a grocery store, have resulted in significant increases in caregiver-child conversations (Ridge et al., 2015; Hanner et al., 2019). We investigated whether a similar brief intervention could change caregiver-child conversations in an everyday context. We observed 212 families in a volunteer-run facility where people who are food-insecure can select food from available donations. Volunteers greet all the clients as they pass through the aisles, offer food, and restock the shelves as needed. About 25% of the clients have children with them and our data consist of observations of the caregiver-child conversations with 2- to 10-year-old children. Half of the observation days consisted of a baseline condition in which the quantity and quality of caregiver-child conversation was observed as the client went through aisles where no signs were displayed, and volunteers merely greeted the clients. The other half of the observation days consisted of a brief intervention where signs were displayed (signs-up condition), where, volunteers greeted the clients and pointed out that there were signs displayed to entertain the children if they were interested. In addition, there was a within-subject manipulation for the intervention condition where each family interacted with two different categories of signs. Half of the signs had academically-relevant content and the other half had non-academically-relevant content. The results demonstrate that the brief intervention used in the signs-up condition increases the *quantity* of conversation between a caregiver and child. In addition, signs with academically-relevant content increases the *quality* of the conversation. These findings provide further evidence that brief interventions in an everyday context can change the caregiver-child conversation. Specifically, signs with academically-relevant content may promote school readiness.

Keywords: cognitive development, informal learning, brief interventions, food pantry, caregiver-child conversations

INTRODUCTION

Reading and arithmetic are uniquely human abilities that typically take several years of formal training in school to acquire (Duncan et al., 2007). Children who practice academic skills before the start of formal education have an advantage that is evident at the start of kindergarten, and this advantage continues to grow throughout elementary school (Lee and Burkam, 2002; Gibson et al., 2020; Susperreguy et al., 2020). One of the ways children learn how to read and do math outside of formal schooling is by being active learners and engaging with their environment, particularly within a social context (Piaget, 1954; Vygotsky, 1962, 1978; Tomasello et al., 2005). School-aged children spend less than 20% of their waking hours in formal educational settings (LIFE Center, 2005). As a result, children can develop academic skills through conversations with caregivers who may be particularly well-suited to tailor the conversational content to the individual child and their current context. Caregivers who produce higher amounts of child-directed speech tend to have children with stronger oral language skills (Huttenlocher et al., 1991; Hart and Risley, 1995; Hoff, 2003). Consequently, our first goal in this paper was to create situations in everyday contexts that could increase the *quantity* of conversations between a caregiver and child.

Children who discuss literacy and mathematics with their caregivers tend to have better academic and cognitive outcomes (Gunderson and Levine, 2011; Pruden et al., 2011; Sheridan et al., 2011; Susperreguy et al., 2020). Learning about academically-relevant concepts can be promoted in the home environment. Research indicates that an increase in caregiver-child early math talk is associated with better outcomes on children's future math skills (Lombardi and Dearing, 2020; Son and Hur, 2020). Specifically, Gunderson and Levine (2011) found that children's future understanding of cardinality (the number of items in a set) was best predicted by parent number talk using objects that were physically present in their immediate environment. Similarly, early spatial language such as naming shapes and colors also predicts the amount of spatial language that children produce. Shape and color talk in the home is indicative of later performance on spatial cognition tasks (Pruden et al., 2011), which has been linked to early mathematics performance (Mix and Cheng, 2012), STEM success (Wai et al., 2010), and school readiness (Verdine et al., 2014a). However, a recent meta-analysis by Anderson et al. (2021) reveals that definitions of conversational quality vary from study to study. In this paper, we define *quality* of conversation as variation in the different topics discussed with respect to number, color and shape talk. Our second goal was to test whether specific categories of questions were more effective than others in encouraging caregivers to engage in conversations about academically-relevant concepts like numbers, colors, and shapes in contrast to a more general language condition that consisted of non-academically-relevant content like questions that required one-word answers (e.g., how old are you?) or pronouncements (e.g., Everywhere you go, talk about what you see!). More broadly, our goal was to measure the *quality* of caregiver-child conversations in an everyday environment.

Despite the importance of integrating number, color and shape talk into conversations with children, there is wide variation in how much of the conversation between caregivers and children consist of these crucial topics (Levine et al., 2010; Gunderson and Levine, 2011; Pruden et al., 2011; Fisher et al., 2013; Resnick et al., 2016). There is growing evidence that children from lower-income families lag behind their peers from mid- and high-socioeconomic status (SES) families in terms of mathematical knowledge and that there is wide variability in the amount of caregiver-child math talk in their informal learning environments (Starkey et al., 2004; Ramani et al., 2015; Son and Hur, 2020). Similar differences are also found in the domain of color and shape talk, where lower-income families use significantly fewer spatial words during conversations compared to their higher-income peers (Bower et al., 2020; Verdine et al., 2014b). However, several studies have demonstrated that brief interventions can improve conversations between caregivers and children from lower-income families, particularly within informal learning environments such as grocery stores, libraries, bus stops, or at home (Starkey and Klein, 2000; Siegler and Ramani, 2008; Ridge et al., 2015; Hassinger-Das et al., 2020b). Our third goal was to test this kind of short-term intervention, to determine whether there is flexibility in how a family responds to these interventions based on the contents of the signage. Specifically, are individual families equally likely to engage in academically-relevant as well as non-academically-relevant conversations? We predict they will be.

Previous work provides evidence that a brief intervention of displaying signage in an everyday context of a grocery store can change the conversation between caregivers and children (Ridge et al., 2015; Hanner et al., 2019). Ridge et al. (2015) displayed signs in grocery stores located in low- and middle-SES neighborhoods and observed families' conversations. These signs had questions like "Where does milk come from?" and "What is your favorite vegetable?" The authors found that for the grocery store in the low-SES neighborhood, the signs increased both *quantity* and *quality* of caregiver-child conversation compared to a baseline when there were no signs displayed. However, in the mid-SES neighborhood, there were no differences in conversations across the two conditions, likely because the interaction between caregivers and children was already high.

Hanner et al. (2019) replicated and extended Ridge et al.'s (2015) findings by focusing on math talk. They tested three conditions: math signs, general language signs, and a baseline with no signs. The math-sign condition encouraged caregivers to ask their children questions about numbers and math, such as "How many glasses of milk do you drink in a day/week?" The general language signs condition served as a control to ensure that any observed differences in math talk were a result of math-related prompts and not merely a result of posting signs. This condition had questions that were similar to those from Ridge et al. (2015) such as "Where does milk come from?" or "Why is milk good to drink?" The results demonstrated that the math signs were associated with significantly more math talk than the other two conditions. These math signs elicited more questions and conversations about principles of cardinality, counting, and calculation from caregivers and children compared to the general language and baseline conditions. Taken together, Ridge et al. (2015) and Hanner et al. (2019) show that brief interventions in an everyday context can change caregiver-child conversations in ways that may promote school readiness.

The current study aims to build upon these two successful studies. First, we will describe our study and then highlight the ways in which it is distinct from the previous studies. We examined whether displaying signs in an everyday environment could increase the *quantity* and *quality* of caregiver-child conversation and whether there was flexibility in the content of the conversation based on the questions on the signs. We observed families in a food pantry, a volunteer-run facility where people who are food-insecure can select food from available donations. This particular food pantry has two or three volunteers stationed in each aisle to greet the clients and restock the shelves as needed. Each client takes a shopping cart at the entrance and they push the cart through the aisles in a single-file line that winds through all aisles of the pantry. Approximately 25% of the clients have children with them when they visit the food pantry. The observers worked as volunteers in the aisles. Each family was observed up to four times across different aisles in the food pantry. In the baseline condition where no signs were displayed, the observer would greet the client and, if they had a child in the target age range, they would observe the caregiver-child conversation while the family passed through the aisle. After the family left the aisle, the observer would record notes about the characteristics of the conversation. In the condition where signs were displayed, the only difference was that the observer would greet the client and point out that there were signs for children. For examples of the sign content, see **Figure 1**.

Our study is different from Ridge et al. (2015) and Hanner et al. (2019) in terms of the setting, the use of prompting, the sample, and the design. First, the setting is different in that we examined whether the phenomenon would generalize to a new everyday environment, in this case, a food pantry. The context of this food pantry is different from a grocery store in that every client was greeted as they entered an aisle and they were offered various food options by volunteers. In addition, this context allowed us to prompt attention to the signs in a naturalistic manner. The rationale for this came from studies that discuss the positive effects of providing caregivers specific prompts that result in children's learning. Previous research has demonstrated that short interventions using prompts can provide caregivers with the necessary scaffolding to incorporate critical number, color and shape language into their conversations with children. In addition, these prompts can help caregivers tailor their conversations to their children's interests and preferences in informal learning contexts such as homes and museums (Vandermaas-Peeler et al., 2012a,b; Haden et al., 2014; Jant et al., 2014; Polinsky et al., 2017; Braham et al., 2018). Second, the sample in our study is different because we used a comprehensive sample instead of a convenience sample. Every family with a child that passed through the aisles of the food pantry on those particular days was observed at least once. Lastly, our design was different because we were able to observe each family multiple times. In the baseline condition with no signs, we primarily observed the *quantity* of the caregiver-child conversation in four different aisles. In the signs-up condition, we observed the *quantity* of caregiver-child conversation. Additionally, we had two different categories of signs within the signs-up condition: academically-relevant and non-academically-relevant. The academically-relevant signs were similar to Hanner et al.'s (2019) prompts about math, although we added questions about colors and shapes, too. The non-academically-relevant signs served as a control to ensure that any observed differences in the number, color or shape talk were a result of the academically-relevant prompts and not merely a result of posting signs. Within the signs-up condition, the number, color and shape talk between caregivers and children was observed for both academically-relevant and non-academically-relevant signs to indicate the *quality* of the conversation.

To clarify the difference between our two categories, examples of the academically-relevant category include: "How many bananas are in a bunch? How many bananas are in two bunches?" or "Can you find a triangle? Can you find something green?" The questions on these signs were adapted from the literature on the strong positive association between math and spatial talk and children's academic outcomes (Levine et al., 2010; Gunderson and Levine, 2011; Fisher et al., 2013; Verdine et al., 2014a; Resnick et al., 2016). The second category of signs, non-academically-relevant signs, asked simple factual questions with one-word answers, or consisted of pronouncements which are broad statements that informed caregivers about the benefits of talking to their children. A few examples include: "How old are you? What year is it?" or "Everywhere you go, talk about what you see!"

We had three predictions: first, there will be a higher *quantity* of conversation between caregivers and children who are exposed to the condition with signs compared to the baseline condition with no signs; second, there will be a higher *quality* of conversational content when caregivers and children are exposed to the academically-relevant signs compared to the non-academically-relevant signs; third, caregivers will be flexible in tailoring the content of their conversation, in that they would

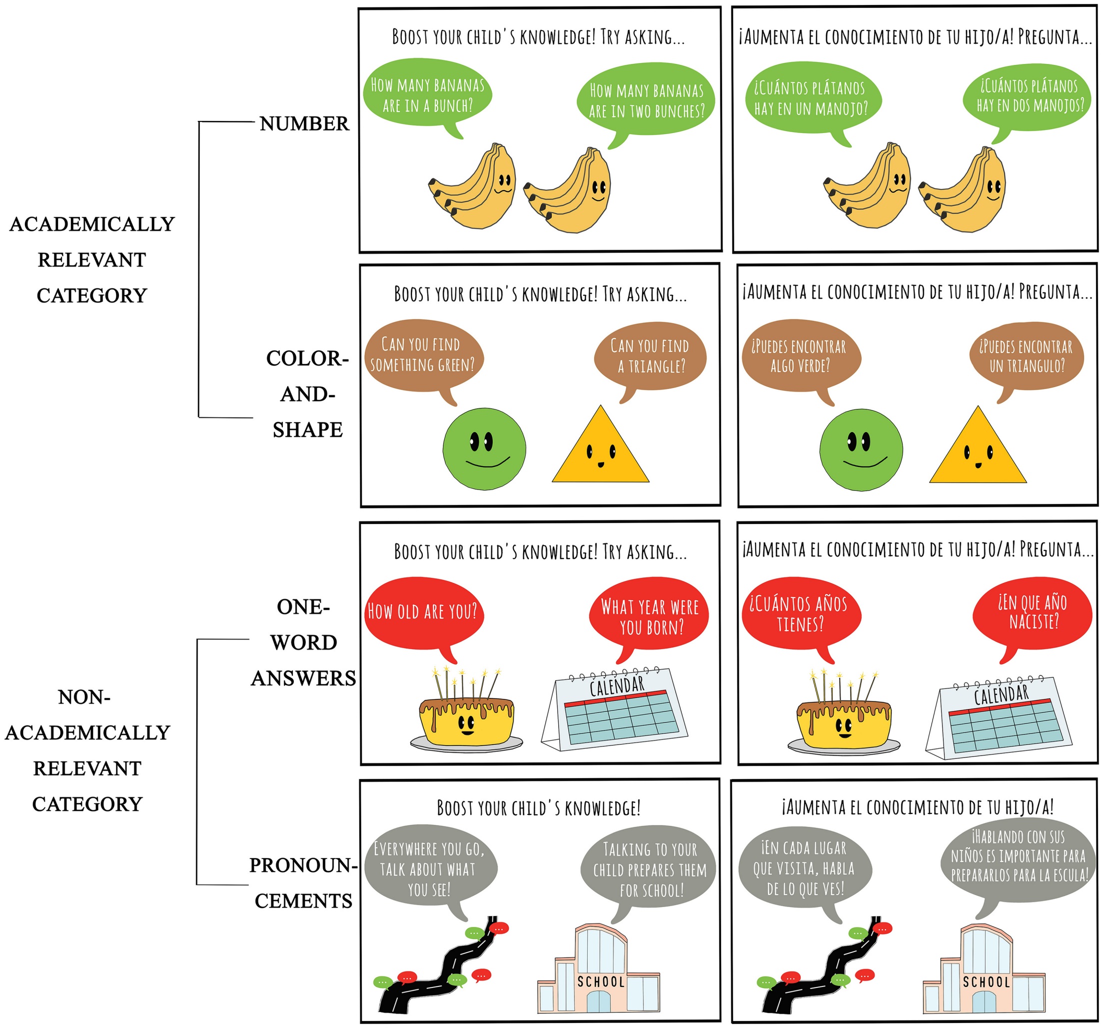

FIGURE 1 | Samples of the academically-relevant (top two rows) and non-academically-relevant (bottom two rows) signs. The remaining two sets of signs used in the study can be found in the **Supplementary Material**.

be equally likely to engage in conversations about academically-relevant, as well as non-academically-relevant signs.

MATERIALS AND METHODS

Participants

We observed a total of 212 families. In this context, we define a family as consisting of at least one adult and one child estimated to be between 2 to 10 years of age. A total of 132 families were observed during the signs-up condition and 80 families were observed during the baseline condition with no signs. Approximately half of the families we observed had a child who appeared to be between the ages of 2 to 5 (n = 107) and the rest appeared to be between the ages of 6 to 10 years (n = 93). The ages of children in the remaining 12 families were not recorded. The vast majority of target adults were female (89%). The target children were 55% female, 43% male and the remaining 2% were not recorded. Demographic information for our sample is included in the **Supplementary Material**. This information is approximate because it was based on visual appearance and summarized according to the most common assessment made by all the observers.

In our sample, we observed that approximately 56% of families spoke only English, 30% spoke only Spanish, another 8% spoke both Spanish and English. The language(s) spoken by the remaining 6% of families was not recorded. Data were originally collected from 221 families, however, seven families were excluded for the following reasons: Two families (less than 1%) spoke a language other than English or Spanish and were eliminated from the final sample because the coders could not accurately record the characteristics of the conversation. Two families were excluded because the observers independently recorded the valence of the target child's conversation as negative or very negative (i.e., crying, screaming behaviors) across multiple aisles, rendering engagement with the signs and conversational coding impossible. Five additional families were also excluded because the observers recorded the target child's age to be 1 year and might have been potentially too young to benefit from the intervention.

The study was exempt from IRB review under category 2 because we observed public behavior. All families were identified by the number on the cart that they pushed through the food pantry. The demographic information was observational in nature and the data do not contain any identifiable variables. Consequently, we were not required to collect informed consent or debrief participants. We obtained written permission by the administration of the food pantry to conduct our study on their premises.

A minimum stopping rule of n = 180 was chosen based on similar prior research studies conducted in a grocery store (Ridge et al., 2015; Hanner et al., 2019). However, since the study design of these previous studies was significantly different from our study design, we ran a sensitivity analysis on our between-subjects variable (no-signs vs. signs-up) using GPower 3.1.9.6 (Faul et al., 2007). This sensitivity analysis computed the required effect size and was based on a chi-squared goodness-of-fit test, with an $\alpha = 0.05$, power $(1-\beta) = 0.95$, total sample size (N) of 212, and $df = 2$. We obtained a resulting critical χ^2 value of 5.99 and an effect size (w) of 0.27 (the smallest effect that could be reliably detected given the α, power, total sample size, degrees of freedom, and design/assumptions of the study). These resulting values are similar to sensitivity analyses conducted on the results of Hanner et al. (2019) [critical χ^2 value of 5.99 and an effect size (w) of 0.29 obtained by using an $\alpha = 0.05$, power $(1-\beta) = 0.95$, total sample size (N) of 179, and $df = 2$]. In addition, a sensitivity analysis was conducted on our within-subjects variable (academically-relevant vs. non-academically-relevant signs) using GPower. The sensitivity analysis was based on a Poisson regression with $\alpha = 0.05$, power $(1-\beta) = 0.95$, total sample size (N) of 132, base rate (β_0) of 0.01, and a binomial distribution of the predictor. We obtained a critical z value of 1.64 with a $\text{Exp}(\beta_1)$ value of 4.76 indicating the smallest effect that could be reliably detected given the above parameters.

Procedure

All observations were conducted during the weekly distribution hours that occurred on Mondays and Thursdays between 9:30 am and 2 pm at a food pantry located in a suburb of a major metropolitan city in the United States. The data were collected over the course of five consecutive distribution days. The first and the fourth days consisted of the baseline condition with no signs and the remaining 3 days of observations comprised the signs-up condition when signs were displayed. A total of 80 families were observed during the baseline condition (45 and 35 families observed on each day, respectively). A total of 132 families were observed across the 3 days of the signs-up condition (44, 46, and 42 families observed on each day, respectively). Families visited the food pantry as often as once a week, but typically came only once a month, making it highly likely that data collected on different days was entirely between-subjects. Due to the observational nature of the study, we were unable to record the number of times a specific family visited the food pantry during our observation period. However, one benefit of our study design was that the signs were different on each day that we collected data. On the remote chance that a family was observed twice across observation days during our study, they did not see the same signs.

As mentioned above, this particular food pantry functions by taking food donations from local businesses and distributing them to people in need during specific hours twice a week. The distribution days are staffed by local volunteers who greet the clients in each aisle, offer specified quantities of each product, and restock the shelves as needed. There are usually two or three volunteers stationed in each aisle. The context of this food pantry was one where small talk among the volunteers and the families was the norm. Families answer many questions posed by the volunteers. For instance, volunteers often asked the adults questions like "Do you want a bag of lentils?", "Would you like a box of this cereal or that one?", or "We have pancake mix today too! Would you like a box?". Volunteers regularly engaged with all the children passing through the aisles by asking for high-fives, checking in on their schooling, telling them that they were wearing cool shirts, and making such small-talk. Therefore, drawing the family's attention to the signs (when displayed) with a statement like "there are signs to look at today!" was not out of the ordinary. Our observers worked primarily as volunteers because only about a quarter of the clients had children with them when they came through the food pantry.

Each client is given a shopping cart at the entrance to the food pantry. They move through all the aisles in a single-file line at a slow but steady pace. In both conditions, when a client entered the aisle, the observer would greet them, offer the contents on the shelf, and engage in small talk as the line progressed through the aisle, as is standard for volunteers in this food pantry. In the baseline condition, if the client had a child with them, the observer would observe the conversation between the caregiver and child in addition to greeting them and offering food. After the family left the aisle, the observer would write down the details of the conversation on a coding sheet. In the signs-up condition, the only difference was that, if the client that had a child with them, the observer would also tell the caregiver that there were signs up to entertain the children.

In both the baseline condition with no signs and the signs-up conditions, the observers were located in four different aisles—dry goods, freezer, bread, and produce. This means that a single family was observed four times during their time at the food pantry. Due to the observational nature of the study, it was not possible for the observers to be unaware of the contents of the sign in their aisle. However, our critical comparisons depend on codes made by independent observers who were unaware of the caregiver-child conversation in the other aisles. Across the five observation days, the observers varied across sign conditions (baseline and signs-up) and aisle locations. All observers were trained for approximately 6 hours in observation coding techniques prior to data collection. All observers were fluent in English and half of the observers who were also fluent in Spanish coded conversations of families that spoke Spanish. At least one or two observers (out of four observers) present on each observation day were fluent in Spanish.

The study consisted of a mixed design with the between-subjects factor of signs condition (baseline with no signs or signs-up) and the within-subjects factor of sign type (academically-relevant and non-academically-relevant). Within the academically-relevant signs, there were two levels: number and color/shape. Within the non-academically-relevant signs, there were two levels: one-word answers and pronouncements. Finally, there were three sets of signs so that we could counterbalance the location and type of each sign. For example, the number questions might be in the freezer aisle on day one ("How many eggs are in a dozen?), in the bread section on day two ("How many slices of bread are in a sandwich?"), and the produce aisle on day three ("How many bananas are in a bunch?"). The **Supplementary Material** contains a table with the complete list of prompts used in each aisle on the three signs-up days. The counterbalancing across days/aisles ensured that no particular question was responsible for the differences in our within-subject factors.

When families had more than one child in the target age range, the observer chose a single child as the target child based on the following predetermined rule: All the shopping carts in the food pantry were numbered. If the cart was an odd number, the target child was the older child (or the oldest in the rare case of three or more children). If the cart was an even number, the target child was the younger child (or youngest in the rare case of three or more children). This rule allowed multiple observers across different aisles to observe the same child unobtrusively.

Two observers simultaneously observed and double-coded 28 of the 219 families to establish reliability. These double-coded observations were evenly distributed across baseline and signs-up conditions, as well as across the four aisles of the food pantry. The observers had 87% inter-rater joint probability agreement on double-coded variables related to the *quantity* and *quality* of caregiver-child conversations.

Coding

Our coding scheme was modeled after the methods of Hanner et al. (2019). We coded for the following variables: the valence of the overall caregiver-child interaction, the number of conversational turns, whether specific number, color, and shape talk was discussed, and observed demographics. Coding of these conversations was done in the moment and not transcribed.

Quantity of conversation is indicated by the number of conversational turns within a family. Conversational turns were defined as the number of times the adults and children in a group took turns to speak to the target child, or the target child spoke to one of the family members. A turn consisted of a single word, sentence, or a few sentences that were not interrupted or broken by another speaker. It included verbal comments and non-verbal gestures, like responsive head nods or pointing, that was directed toward or originated from the target child. We did not include conversational turns in situations where the adults in the group or children outside the targeted age range were conversing among themselves and were not engaging the target child. The number of conversational turns was coded in the following ranges: 0, 1, 2, 3–5, 6–9, 10–15, 16–20, and 20+. These ranges were collapsed into the following three bins during analyses: 0–5, 6–15, and 16+. Since chi-squared analyses with either set of bins were significant, we chose to collapse conversational turns into three bins for simplicity and alignment with Ridge et al. (2015) who also used three bins.

Quality of conversation is operationalized by whether the families incorporated academically-relevant content such as numbers, colors, and shapes into their conversation during the observation period. To measure this variable, the observers marked the sheet when the family engaged in conversations related to the following six domains: used numbers, elicited numbers, counted numbers, pointed to colors or shapes, used color or shape words, and elicited color or shape words. These domains were binary coded (present vs. absent) when the target child or any adult(s) within the family engaged in any of these behaviors at least once. A behavior was coded with a score of 1 if it was present and 0 if it was absent. This score ranged from 0 to 6. For example, if a child saw the sign: "How many bananas are in a bunch? How many bananas are in two bunches?," counted and answered that there were five bananas in a bunch and 10 bananas in two bunches, this would result in a score of 2, with 1 point for using numbers and 1 point for counting. In contrast, a child who saw the sign: "Everywhere you go talk about what you see" may have talked about products in the aisle like the cereal box. In our coding scheme, this would be scored as zero unless the child or caregiver mentioned the cereal box was yellow or the shape of the cereal box was rectangular.

Analysis Plan

To assess whether the presence of signs increased the *quantity* of conversation between caregivers and children, we performed a chi-squared analysis on the number of conversational turns across the between-subjects variable of signs condition (baseline with no-signs vs. signs-up). Next, to analyze whether there was a difference in the *quality* of caregiver-child conversation, we conducted a mixed-effects Poisson regression. This type of analysis was used because our dependent variable was a count variable of the amount of number, color and shape talk discussed by each family during the length of the observation and it followed a Poisson distribution. Finally, we examined whether the effect was carried by a specific type of sign. We conducted mixed-effects Poisson regressions to measure differences in the number, color and shape talk produced by families across the four different types of signs. To account for other variables that might have influenced the number, color and shape talk discussed by caregivers and children, we included the target child's gender and age as fixed effects and random intercepts by family unit in all the Poisson regression models. All categorical variables were coded as indicator variables during analysis and missing observations were omitted by the mixed-effects Poisson regression models. All the analyses and visualizations were performed in R Studio (R Core Team, 2020) using the "stats" and "ggplot2" packages from RStudio, and the "lme4" package (Bates et al., 2014). A fully reproducible repository hosting the coding sheet, data, and analyses can be found at: https://github.com/apoorvashivaram/foodpantry.

RESULTS

As show in **Figure 2**, there was a significantly higher number of conversational turns in the signs-up compared to the baseline condition with no signs, as indicated by a Pearson's chi-squared test, $\chi^2(2) = 44.13$, $p < 0.001$. For the baseline condition, the majority of families (63%) had fewer than five conversational turns, 31% had 6–15 turns, and only 6% had 16 + turns. This pattern was reversed for the signs-up condition with the majority of families in the latter two bins—36% of families had conversations with 0–5 turns, 45% had 6–15 turns and 19% had 16 + turns.

Our next analysis revealed that there was a significant difference in conversational content based on the category of sign. The academically-relevant signs had an average of 1.23 target domains discussed (*SD* = 1.14; Range: 0–4) compared to the non-academically-relevant signs that had an average of 0.16 (*SD* = 0.44; Range: 0–2) (see **Figure 3**).

The number, color and shape talk based on the type of signs (academically-relevant or non-academically-relevant; with non-academically-relevant as the reference group) was also predicted by a mixed-effects Poisson regression with child's gender and age as fixed effects and random intercepts by family unit. Particularly notable is that the number, color and shape talk increased by a factor of 6.72 compared to non-academically-relevant signs, when accounting for child's gender and age as fixed effects (see **Table 1**). This value of 6.72 was obtained by exponentiating the estimate for academically-relevant signs ($\beta = 1.905$) since every unit increase in the predictor variable "type of signs" (that is, from non-academically-relevant to academically-relevant signs) has a multiplicative effect of $exp(\beta)$ on the mean of the dependent variable (here, number, color and shape talk). Approximately 63% of families observed near the academically-relevant signs discussed number, color, or shape talk compared to only 14% near the non-academically-relevant signs. Taken together, these results indicate that, after attention was directed to both categories of signs, the academically-relevant signs led to more number, color and shape talk.

Finally, our results indicate that the differences between the academically-relevant and non-academically-relevant categories are not carried by any particular type of sign within the academically-relevant category (Number: $M = 1.14$, $SD = 1.06$, Range: 0–4; Color/shape: $M = 1.31$, $SD = 1.20$, Range: 0–4). However, there were differences within the non-academically-relevant category. The one-word mean was significantly higher ($M = 0.32$, $SD = 0.58$, Range: 0–2) than pronouncements ($M = 0.01$, $SD = 0.10$, Range: 0–1); however, both means were low and the variance for pronouncements was small (see **Figure 4**).

To examine differences in type of talk produced within families across the four types of signs, three mixed-effects Poisson regressions were conducted while controlling for the type of sign, with child's gender and age as fixed effects and with random intercepts by family unit. There was no significant difference in number, color and shape talk between the number and color/shape signs ($\beta = 0.26$, $SE = 0.16$, $p = 0.10$). However, number signs prompted significantly higher talk about the target domains than one-word answers signs ($\beta = -1.10$, $SE = 0.24$, $p < 0.001$) and pronouncements signs ($\beta = -4.29$, $SE = 1.01$, $p < 0.001$). Color/shape signs prompted significantly higher talk about the target domains than both one-word answers ($\beta = -1.36$, $SE = 0.23$, $p < 0.001$) and pronouncements signs ($\beta = -4.55$, $SE = 1.01$, $p < 0.001$). Finally, one-word answers signs prompted significantly higher talk about the target domains than pronouncements ($\beta = -3.18$, $SE = 1.02$, $p = 0.002$) (see **Supplementary Material** for the regression tables).

DISCUSSION

The main goal of this study was to examine whether a brief intervention could change the conversation between caregivers and their children. We found that there were significantly

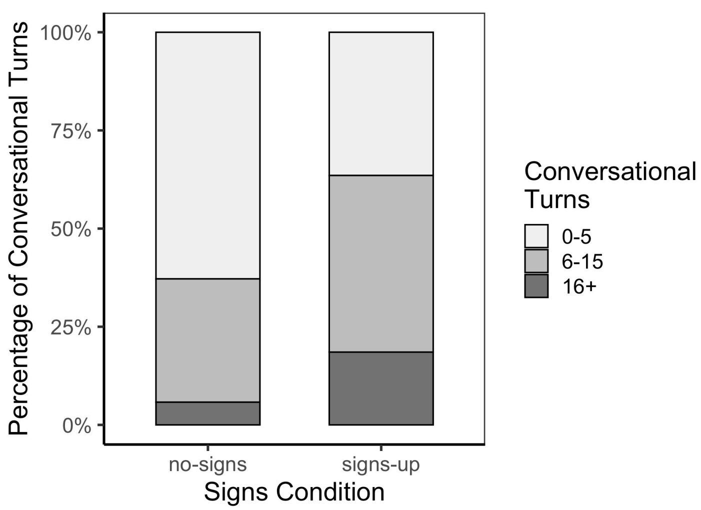

FIGURE 2 | Percentage of conversational turns across the baseline with no-signs versus the signs-up conditions.

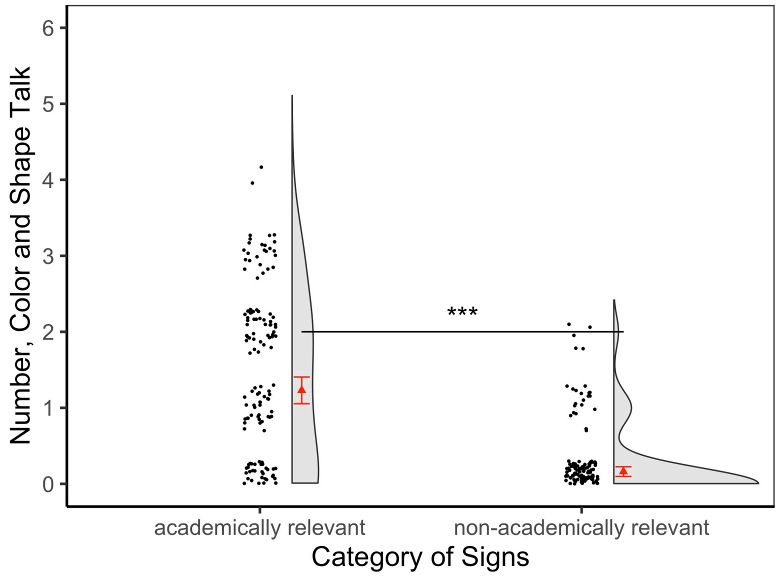

FIGURE 3 | Number, color, and shape talk produced by families across the academically-relevant and non-academically-relevant sign categories. This score ranged from 0 to 6. The red triangle represents the mean and the red whiskers are standard error bars. The black dots represent the individual data points in the distribution and the half-violin plot represents the density of the distribution at different levels of the dependent variable. *** $p < 0.001$.

more conversational turns between caregivers and children when their attention was prompted to the signs during the signs-up condition compared to the baseline condition with no-signs. We interpret these findings as evidence that a brief intervention and prompting families' attention to the signs can change the *quantity* of conversations in an everyday environment of getting food at a food pantry. Our second goal was to investigate whether the *quality* of conversations was influenced by the contents of the sign. We found that academically-relevant signs encouraged number, color and shape talk compared to non-academically-relevant signs, despite the fact that families were prompted to attend to both categories of signs equally. Our third goal was to investigate whether caregivers were able to tailor the content of their conversation according to the type of sign displayed. By observing caregivers at several different time points, we found that they were equally adept at fostering different types of conversations. Moreover, these results are not due to specific types of questions since both number and color/shape questions on the signs were equally effective in prompting higher *quality* conversations, while one-word answers and pronouncements signs yielded significantly less number and color/shape talk. Together, this brief intervention of displaying signs and prompting families' attention toward them increases the *quantity* and *quality* of caregiver-child conversations.

TABLE 1 | Results of the fixed-effects factors of the Poisson regression predicting the number, color and shape talk across the two signs-up categories.

Predictor	Number, shape and color talk
Intercept	−2.184*** (0.310)
Academically-relevant signs	1.905*** (0.219)
Child's gender—Male	−0.173 (0.160)
Target child's age	0.086* (0.035)
N	275
logLik	−274.614
AIC	559.229

*The reference group for this analysis is the non-academically-relevant signs, with a target child who was a 2-year-old female. Values in each cell are estimates and their standard errors. * indicates p < 0.05 and *** indicates p < 0.001.*

These results provide a conceptual replication of previous findings by Ridge et al. (2015) and Hanner et al. (2019) since the setting and procedure for our study was quite different from the previous work. Ridge et al. (2015) and Hanner et al. (2019) conducted their observations in grocery stores and it was left up to chance whether the families saw or read the signs. In contrast, we collected data in a food pantry where families who are food-insecure visit to receive donations. In this food pantry, all clients entered the aisles in a single-file line, were greeted, and families were also informed that the signs were for entertaining the children. Another difference was that Ridge et al. (2015) and Hanner et al. (2019) employed a convenience sampling technique whereas our sample included nearly all the families who visited the food pantry on the distribution days when the observations took place. Our findings align with previous research showing that brief interventions that promote math and spatial talk can encourage caregivers to engage their children in conversations (Siegler and Ramani, 2008; Hassinger-Das et al., 2020a). Additionally, Haden et al. (2014) have demonstrated that families who received prompts during a museum visit were significantly more likely to ask relevant questions and promote STEM-related conversations. Similarly, Braham et al. (2018) provide evidence that when parents talk to children in a grocery store, children's spontaneous focus on number

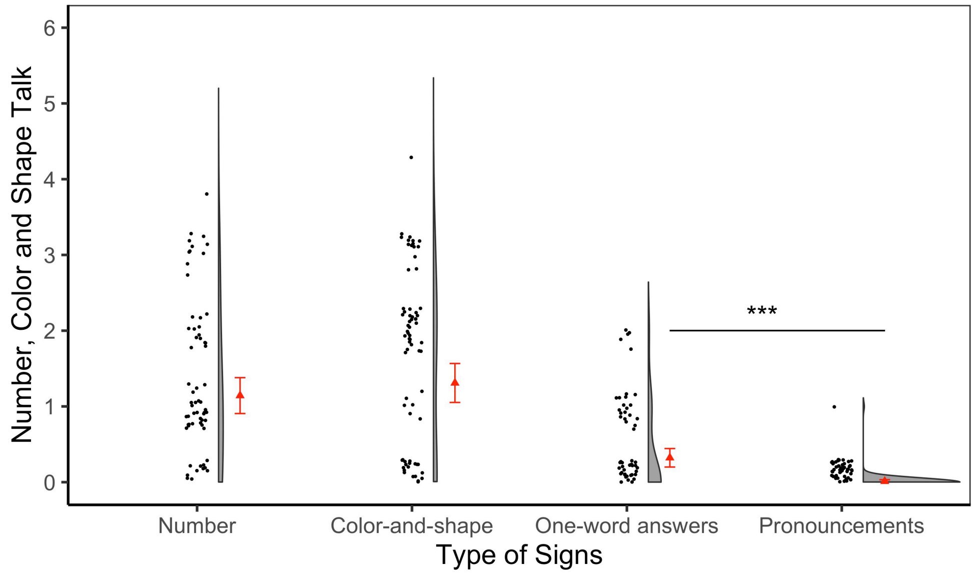

FIGURE 4 | Number, color, and shape talk across the four types of signs. This score ranged from 0 to 6. The red triangle represents the mean and the red whiskers are standard error bars. The black dots represent the individual data points in the distribution and the half-violin plot represents the density of the distribution at different levels of the dependent variable. *** $p < 0.001$.

was significantly greater compared to when families discussed healthy eating concepts. Although there was no direct correlation between amount of math talk and children's increases in their spontaneous focus on number, the study by Braham et al. (2018) provides sufficient causal evidence for a link between parent-child conversations and children's increases in their spontaneous focus on number.

This study is a successful example of conducting ecologically valid research in an everyday environment. An important implication that can be drawn from these results is that stakeholders who are implementing future interventions in everyday contexts might benefit from specifically addressing the target outcomes they are interested in (e.g., conversations about academically-relevant content; increasing the *quantity* of conversation; entertainment). The best possible outcome is to design everyday environments by seeking input from those who frequent these everyday locations and to incorporate stakeholders who are educators or developmental scientists who could help design successful learning opportunities.

Yet, there are a few limitations to be considered in regards to the research design and context of this study. First, it is unclear whether short conversations about a variety of academically-relevant concepts or more in-depth conversation about one concept is the critical factor in promoting school readiness through conversations between caregivers and children. Most prior research has examined the effects of the amount of math or shape talk as given by the frequency of occurrence, but there are a few studies that have assessed the variability in the types of words being used in conversation (e.g., Eason and Ramani, 2020). The coding scheme for this study was designed to measure conversations about multiple academically-relevant concepts such as numbers, colors, and shapes. Future research can build on this coding scheme by distinctly coding for both breadth and depth of relevant topics and analyze whether one concept is more important than the other in promoting school readiness.

Second, a result of the naturalistic observational study design was that the observers were not blind to the conditions. All caregiver-child conversations were coded in the moment, not transcribed, and thus, were also limited in the amount of detailed coding information the observers could obtain during the brief observations. To reduce the amount of bias introduced into the coding, we had independent observers positioned in four aisles and the individual observers differed by days. Future studies could design double-blind data collection processes by training independent volunteers to observe the conversations.

More broadly, this study raises possible avenues for future research. One question pertains to the optimal dosage: how much exposure to signage with academically-relevant goals is necessary before the conversational benefits generalize to other contexts? Would the context of the food pantry serve as a sufficient prime to prompt conversations about academically-relevant concepts the next time the families visit the food pantry? Or do the signs have to be displayed for several weeks to result in long-term benefits? Additionally, in the current study, we were unable to determine whether these conversations influenced children's learning since our data are limited to the immediate context of the food pantry. To better understand the scope and generalization of these studies to other context, future research could send follow-up surveys to caregivers shortly after these brief interventions to track whether these effects extended to other everyday contexts and whether there is an increased awareness among family members about the importance of early learning.

In conclusion, our findings demonstrate that the presence of signs is associated with a greater number of conversational turns between caregivers and children and that the type of signs (specifically, academically-relevant signs) prompted conversations about number, color and shape talk. Together, these findings suggest that it is possible to implement brief interventions that can influence the *quantity* and *quality* of caregiver-child conversations in everyday contexts that can potentially promote academic achievement and school readiness.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are publicly available. This data can be found here: https://github.com/apoorvashivaram/foodpantry.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AS contributed to the conceptualization, study design, data collection, data analysis, visualization and interpretation, and writing, editing, and revising the manuscript. YC, EA, AF, RJ, LE, and SP were contributed to the study design, data collection, and review of the manuscript. ML contributed to the conceptualization, study design, and review of the manuscript. SH contributed to the conceptualization, study design, data collection and interpretation, and writing, editing, and revising the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.645788/full#supplementary-material

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Tinkering With Testing: Understanding How Museum Program Design Advances Engineering Learning Opportunities for Children

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Using a design-based research approach, we studied ways to advance opportunities for children and families to engage in engineering design practices in an informal educational setting. 213 families with 5–11-year-old children were observed as they visited a tinkering exhibit at a children's museum during one of three iterations of a program posing an engineering design challenge. Children's narrative reflections about their experience were recorded immediately after tinkering. Across iterations of the program, changes to the exhibit design and facilitation provided by museum staff corresponded to increased families' engagement in key engineering practices. In the latter two cycles of the program, families engaged in the most testing, and in turn, redesigning. Further, in the latter cycles, the more children engaged in testing and retesting during tinkering, the more their narratives contained engineering-related content. The results advance understanding and the evidence base for educational practices that can promote engineering learning opportunities for children.

Keywords: parent-child interactions, engineering practices, reflection, learning, museums, informal education

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TINKERING WITH TESTING: UNDERSTANDING HOW MUSEUM PROGRAM DESIGN ADVANCES ENGINEERING LEARNING OPPORTUNITIES FOR CHILDREN

Advancing engineering learning opportunities for children is a national priority in the United States as part of an effort to increase the quantity, quality, and diversity of the pool of future engineers and other STEM professionals (National Academy of Engineering [NAE], and National Research Council [NRC], 2009). The *Framework for K-12 Science Education* (National Research Council [NRC], 2012), *Next Generation Science Standards* (NGSS Lead States, 2013), and policy reports on the topic (e.g., National Research Council [NRC], 2009; National Science Board [NSB], 2010; National Academies of Sciences, Engineering, and Medicine [NAS], 2018) emphasize the potential for STEM-related experiences in early childhood to pay big dividends in terms of advancing skills that prepare pathways to future STEM educational opportunities and careers. For example, children who spend time in STEM-related museum exhibits tend to show more interest in STEM, do better in STEM-related classes, show better scientific reasoning abilities, and express more interest in STEM subjects and careers (National Research Council [NRC], 2009, 2012, 2015). Studies of autobiographical memory stories of career scientists also support the notion that informal learning experiences in early childhood advance skills that can open doors to future science and engineering pursuits (e.g., Maltese and Tai, 2010; Jones et al., 2011; Crowley et al., 2015). Nevertheless, to realize these potential benefits of early STEM experiences, we need to understand how to design and facilitate experiences in early childhood that can deepen engagement in disciplinary practices of science and engineering. Our work aims to grow the empirical base for educational practices that support young children's engagement in engineering design during informal learning experiences in museums.

Our work focuses on *tinkering*—a form of playful, open-ended problem-solving involving real tools and materials (Vossoughi and Bevan, 2014). Museums and other informal learning institutions have increasingly integrated design-make-play experiences such as tinkering into STEM-relevant offerings for children and families. With this move, however, has come the realization among educators and researchers (e.g., Honey and Kanter, 2013; Bevan, 2017; Pagano et al., 2020) that not all tinkering activities engender children's engagement in engineering design practices as outlined in the *Next Generation Science Standards* (NGSS Lead States, 2013) and the *Framework for K-12 Science Education* (National Research Council [NRC], 2012). In particular, NGSS and the *Framework* break the engineering design process into three stages: (1) defining an engineering problem, (2) creating and testing possible solutions, and (3) improving the design solution. Whereas the expectations around these big ideas become more complex across K-12, even for the youngest learners, the NGSS and *Framework* place strong emphasis on the development and testing of solutions and iterative refinement. Although tinkering and engineering are not identical (Martinez and Stager, 2013), when young children playfully explore a problem space and test and iteratively adjust their creations during tinkering, this engagement in disciplinary practices may especially benefit learning about engineering (e.g., Berland et al., 2013; Petrich et al., 2013; Vossoughi and Bevan, 2014).

Approach

As we see it, tinkering is nearly an ideal context for exploring ways to support informal engineering learning opportunities. Our approach marries constructivist ideas about the importance of learning through direct experiences interacting with objects (e.g., Piaget, 1970) with sociocultural theories emphasizing that learning is co-constructed through socially shared and scaffolded (guided) activities with others (e.g., Vygotsky, 1978; Hirsh-Pasek et al., 2003; Rogoff, 2003; Gaskins, 2008). The emphasis in museums on hands-on activities with objects to promote learning reflects Piaget's (1970) view that representations of knowledge emerge from and are tied to actions on objects (see also Bruner, 1996). More recently, work on embodied cognition underscores the importance of physical actions for learning (Martin and Schwartz, 2005; Martin, 2009; Macedonia, 2014; Pouw et al., 2014). Nonetheless, children's engagement in museum exhibits and programs is frequently social, and consistent with sociocultural theories that the social milieu can provide critical mechanisms for learning from hands-on activities. Children's work with objects often becomes the focus of social-communicative exchanges between children and caregivers that can support understanding of underlying ideas and learning for a number of reasons (e.g., Narayanan and Hegarty, 2000; Jant et al., 2014). For example, parent-child interactions during tinkering can provide mechanisms for making physical engagement with objects a focus of explicit learning. Moreover, parent-child social-communicative exchanges can also facilitate the process of what Sigel (1993) called *distancing* and what Goldstone and Sakamoto (2003) called concreteness fading—learning to focus less on the objects and more on the concepts and knowledge that can be gained from object manipulation.

To contribute to both theoretical and practical understandings of ways to support engineering learning we employ design-based research (DBR), a form of use-inspired basic research (e.g., Barab and Squire, 2004; Joseph, 2004; Sandoval and Bell, 2004). In visitor studies, educational psychology, and other applied fields, it is often unclear how to integrate results gained through basic experimental research methods into practice (and vice versa). DBR seeks to bridge this gap between basic research and application. In Stokes' (1997) four quadrants of scientific research addressing understanding (yes/no) and use (yes/no), DBR falls in Pasteur's quadrant (yes/yes), named for the scientist whose renowned scientific discoveries had immediate use in stopping bacterial contamination (pasteurization) and preventing diseases (vaccines). DBR aims to advance both theoretical understandings and practical applications. Importantly, to meet the challenges of DBR, our university researcher-children's museum practitioner partnership is fully collaborative (Allen and Gutwill, 2016; Haden et al., 2016). The decision-making power is shared in all aspects of the work, from the identification of a problem that could advance theory and practice, to the design of tinkering programs, iteration of practices, and ways of assessing learning (Haden, 2020).

DBR involves multiple phases—cycles—within one study. A cycle begins with the theory-driven design of practices, and encompasses analysis of the impacts of those practices, with the outcomes of each cycle serving as inputs to the redesign of practices and theory refinements in the next cycle. Through successive iterations, and improvements in theoretical and design ideas, one should expect that educational practices improve in terms of advancing learning (Joseph, 2004). Our DBR focused on a specific problem of practice: whereas open-ended, tool-focused programs in a tinkering exhibit in a children's museum (e.g., Woodshop Plus) engendered tool use and joint engagement by parents and children, there was little evidence of deep engagement in engineering (Pagano et al., 2020). We advanced the idea that tinkering programs offering a function-focused problem-solving goal—in this case, to make something that rolls—would increase engagement in engineering practices, and in particular, children's testing of their creations. Given that testing is a key aspect of the engineering design process

(NGSS Lead States, 2013), we thought that if we could encourage testing, it would foster children's engagement with and learning about engineering practices.

Tinkering With Testing

Research shows that young children are eminently capable of engaging in nascent engineering and science practices once thought beyond their years (e.g., Gelman and Brenneman, 2004; National Research Council [NRC], 2009; Lachapelle and Cunningham, 2014; Lucas and Hanson, 2014; English and Moore, 2018). Moreover, tinkering activities can provide an important entry point for participation in specific disciplinary practices of engineering emphasized in engineering education (National Research Council [NRC], 2009, 2012; NGSS Lead States, 2013). Nonetheless, to bring engineering learning to fruition through tinkering, children need to not only make something through exploration of tools and materials, but also participate in the *engineering design process* of creating, testing, and enhancing and improving their solutions to problems. We studied iterative cycles of a program that posed an engineering design problem: make something that rolls. Engineering design problems are characterized by *criteria* and *constraints*. In the Make it Roll program, the criteria for success were specified—the creation needed to roll, not slide. The constraints included the materials that were available in the exhibit that could be used to make wheels and axles, e.g., plastic bottle caps, drinking straws. Wheels and axles (used to reduce friction) are one of six types of simple machines that engineers use on a daily basis to solve problems. Determining whether and how to make the wheels or axles spin was a primary focus of the testing and redesigning we aimed to observe among families.

Our approach to supporting engagement in the engineering design process was twofold, involving exhibit design and facilitation strategies. In the first DBR cycle in this study—Make it Roll I—we created exhibit spaces for testing, including small ramps at the worktables and a large ramp. The design challenge "Make Something that Rolls" was written on the chalkboard, and facilitation staff stated the challenge verbally when they greeted visitors entering Tinkering Lab exhibit. In the subsequent two cycles, Make it Roll II and Make it Roll III, the design iterations and facilitation strategies changed to increase children's engagement in testing their tinkering creations. There were alterations to the location and design of the large ramp (**Figure 2**), as well as iterations of a *facilitated orientation* for visitors as they entered the exhibit (**Figure 3**). During the orientation, museum staff introduced key engineering information about wheels and axles (e.g., "For your car to roll, either the axle needs to spin or the wheels need to spin freely.") and encouraged testing of different model cars (e.g., "Go ahead and test the car on the ramp to see if it rolls.").

The decision to introduce the facilitated orientations in the second cycle was guided by prior work showing that when families were offered engineering related information at the outset of their museum experience, it benefits children's engagement in an engineering activity, and their recall of science and engineering information weeks later (Benjamin et al., 2010; Haden et al., 2014). However, whereas in prior work researchers primed families with exhibit-related information (van Schijndel et al., 2010; Jant et al., 2014; Eberbach and Crowley, 2017; Willard et al., 2019), these interventions rarely simulated the kinds of interactions families might have with museum staff. We were interested in how opportunities to engage with practices of engineering through exhibit design and staff facilitation might affect children's engagement in testing during tinkering and engineering learning.

Children's Narrative Reflections About Learning

We also assessed what children may have learned from their tinkering experiences in a way that would be organic to the museum setting (Callanan, 2012; Acosta et al., 2021). After children finished tinkering, we invited them to respond to a series of open-ended prompts to tell a short narrative about their tinkering project. Most of the prior work on using narratives as a measure of children's learning from exhibit experiences has involved parent-child reminiscing (Benjamin et al., 2010; Haden et al., 2014; Jant et al., 2014; Pagano et al., 2019, 2020). Nevertheless, by the age of five, children are able to tell reasonably coherent stories about recently experienced events in response to fairly open-ended prompts (Fivush et al., 1995; Reese et al., 2011). Moreover, although there has been more attention given to family conversations during exhibit experiences as mechanisms for scaffolding STEM learning in museums (e.g., Crowley et al., 2001a,b; Leinhardt et al., 2002; National Research Council [NRC], 2009; Sobel and Jipson, 2016; Callanan et al., 2020), what children say about their experiences shortly afterward can be viewed both as an extension of the learning process and an outcome of learning (Acosta et al., 2021). With respect to children's narrative reflections as an assessment of learning outcomes, the content of children's reflections can offer insights into what children understood about their experiences. Further, in the context of our work, analysis of the content of children's reflections can address whether and to what extent our tinkering interventions support children's engineering learning through tinkering.

Hypotheses

Across three DBR cycles, we observed parent-child pairs who visited the Tinkering Lab exhibit at a children's museum during one of the three programs. Children's narrative reflections were elicited immediately after tinkering. We advanced the following hypotheses:

1. If our efforts to iterate the Make it Roll program were successful at increasing engagement in engineering practices, families in the later cycles of our DBR would engage in more testing and redesigning than those in the initial cycle.
2. Families' engagement in testing would be positively related to children's talk about engineering in their narrative reflections immediately after tinkering. We also predicted that the more children and parents engaged in testing, the less children would talk about tools and materials in their post-tinkering narrative reflections.

METHODS

Participants

The sample consisted of 213 families with 5–11-year-old children. We recruited families as they entered the *Tinkering Lab* exhibit at the Chicago Children's Museum. Sixty-four families visited during the first cycle of the Make it Roll program in Summer 2016; 83 families visited during the second cycle of the Make it Roll program in Summer 2017; and 66 families visited during the third cycle of the Make it Roll program in Summer 2019. The analytic sample reflects only the families who made something that rolled during their visit to *Tinkering Lab*, 59, 80, and 66 families, in cycles 1, 2, and 3, respectively. **Table 1** provides demographic information by DBR cycle.

Procedure

The study procedures were approved under Loyola University Chicago IRB protocol #1776, *Advancing Early STEM Learning Opportunities through Tinkering and Reflection.* The study took place in the *Tinkering Lab* exhibit at Chicago Children's Museum. *Tinkering Lab* is a workshop space that is equipped with a range of tools and repurposed materials, which during the Make it Roll cycles included tools (e.g., hole punchers, scissors, tape, and glue) and materials (straws, sticks, CD disks, spools, bottle caps, cardboard, wood dowels, skewers, paper food trays, and other recyclables) that could be used to make something that rolls. With written informed consent from parents and children's assent, we audio and video recorded individual families as they tinkered. Families picked which one adult and one child in the family group would wear the microphones and would be the targets for the observation. Families were encouraged to interact as they normally would and could stay in the exhibit for as long as they wanted.

TABLE 1 | Demographic information for families in the three cycles of the Make it Roll program.

	Make it Roll		
	Cycle 1 *N* = 59	**Cycle 2** *N* = 80	**Cycle 3** *N* = 66
Age of target child in years [Mean(SD)]	7.45 (0.82)	7.09 (0.83)	7.18 (1.01)
Sex of target child (#)			
Female	30	33	34
Male	29	46	32
Not reported	0	1	0
Race/Ethnicity of target child (%)			
White	67.8	42.5	57.6
African American/Black	3.4	6.3	9.1
Asian	3.4	6.3	6.1
Hispanic/Latino	22.0	16.3	13.6
American Indian/Alaska Native/Native Americans	0	0	1.5
Mixed	3.4	15.0	4.5
Other	0	1.3	1.5
Not reported	0	12.5	6.1
Education of target parent (%)			
Completed some high school	1.7	1.3	1.5
High school graduate	5.1	6.3	1.5
Associate degree	17.0	13.8	16.7
Bachelor's degree	27.1	25.0	30.3
Completed some postgraduate	3.4	6.3	3.0
Master's degree	23.7	33.8	33.3
Ph.D., Law, Medical Degree	10.2	11.3	6.1
Not reported	11.9	2.5	7.6

Design-Based Cycles

Families who participated in this study came to *Tinkering Lab* during one of three cycles of our design-based research (DBR) focused on the Make it Roll program. The cycles varied regarding the design of the exhibit and the information that was provided to families by facilitation staff members:

Cycle 1

During the first cycle of the Make it Roll program, museum staff greeted families as they entered the exhibit, invited them to make something that rolls, and pointed out the available tools and materials. They also assisted with tool use (e.g., hot glue gun, saw) and answered any questions visitors had. As illustrated in **Figure 1**, on each of the tables in the large workshop area, there were small tabletop ramps with fun encouragements written on the top (e.g., "Rock and Roll It"). In the far corner of the exhibit there was a large six foot wooden ramp.

Cycle 2

During the second cycle of the Make it Roll program, museum staff offered families a brief *facilitated orientation* as they entered the workshop through a smaller programming space. As shown in **Figure 2**, the programming space was set up with one station featuring a tabletop ramp and various model vehicles, some with rotating wheels and axles, and some with stationary wheels. The models were made of materials that were not available in the large workshop space where the families would make their own creations. Using the ramp and models, museum staff provided information about wheels and axles ("If something is to roll, either the wheels move by themselves or the wheels move with the axle."), encouraged testing (e.g., "Go ahead and test the car on the ramp to see if it rolls."), and identified differences between sliding and rolling (e.g., "Why did this car slide and that one roll?"). These orientations were unscripted, and staff were encouraged to use their natural speaking style, although they received training on the information that should be included in the orientation about wheels and axles, testing, and sliding vs. rolling. As in Cycle 1, staff provided support for tool use as families tinkered.

The design of the workshop space was also iterated. Some materials to make wheels in the first cycle (CD disks) were removed because they proved to make poor wheels, and others were made more available, specifically a greater variety of plastic caps of various sizes. As shown in **Figure 2**, the tabletop ramps were redesigned to look like a roadway, and the large ramp was placed in the center of the room. The large 6-foot ramp was also made more colorful, and the incline less steep, to make it more

FIGURE 1 | Tinkering Lab exhibit during the first cycle of the Make it Roll program.

difficult for contraptions to slide instead of roll down the ramp. There was also a six foot straightaway added to the end of the ramp, along which a measuring tape that offered information about distance traveled from the bottom of the ramp toward a catch bin at the end (see **Figure 2**).

Cycle 3

During the third cycle of the Make it Roll program, museum staff continued to provide facilitated orientations to families before they entered the exhibit, but we iterated the presentation from what was offered in Cycle 2. As shown in **Figure 3**, families were presented with the challenge to make something that rolls and then invited to explore three stations, each containing a small ramp and various models. At the first station, one model did not include an axle and had the wheels glued on the sides, while the second model had an axle that spun freely to rotate the wheels. At the second station, one model had different sized pairs of wheels, whereas the second model had wheels that were the same size on the front and back. At the third station, one model had wheels positioned too high on the body of the vehicle so they could not touch the ground, and the other had wheels that touched the ground. Facilitators encouraged parents and children to compare and test each pair of models to determine how they were different and which one rolled. Again, facilitators received training, but did not have a set script. Regarding the design of the large workshop space, there were no changes from Cycle 2; the tabletop ramps and the large ramp were the same and their positions were the same in the space. Immediately after the facilitated orientation, families were invited to enter the exhibit and make something that rolls.

Children's Narrative Reflections

Immediately after tinkering, 50 children in cycle 1, 30 children in cycle 2, and 63 children in cycle 3 were engaged in a narrative reflection task by a researcher. The reduced sample sizes in cycles 1 and 3 are due to either children electing not to complete the narrative reflection, the family needing to leave after tinkering, or technical difficulties. In cycle 2, as part of our larger project, our data collection split the sample to collect either parent-child reminiscing data (see Pagano et al., 2020) or children's narrative reflections immediately after tinkering.

The narrative reflection began by inviting the children to place their creation on a ramp against a colorful backdrop and then use a tablet computer to take a picture of their creation (see **Figure 4**). The researcher then elicited the children's reflections using the following open-ended prompts: (1) What did you do in Tinkering Lab today? (2) How did you do it? (3) What did you learn today? Given our design-based approach, we also iterated these post-tinkering reflections. Specifically, we added the following questions in cycle 2: "Did somebody help you? Tell me how you worked together." "Did you test your creation? Did it roll?" In cycle 3, we began the interview with questions about the orientation: (1) "When you entered the Tinkering Lab, did you explore the test tracks in the small workshop? What did you do there?" (2) "Was it helpful? How was it helpful?" (3) "Did you learn anything from comparing the creations? Tell me all about it." We then asked the children about their tinkering experiences. Although these questions were worded slightly differently than in the previous iterations, they were covering the same topics. (4) What did you do in the large workshop in Tinkering Lab? (5) How did you make it? Tell me all about making it. (6) Did you

FIGURE 2 | Programming space and Tinkering Lab exhibit during the second cycle of the Make it Roll program.

try it out, did you test it? What happened when you tried it out? (7) Did you have to fix your creation? Why did you have to fix it? How did you fix it? Tell me all about it. (8) Did somebody help you? Tell me how you worked together. (9) What did you learn today? (10) Anything else you would like to tell me about making your creation roll? All of the questions were also followed with general prompts (e.g., "Anything else you would like to share?" "Tell me more.") to elicit more information from the children. These reflections were video and audio recorded.

Coding

The interactions during tinkering were scored directly from the video records. Children's post-tinkering reflections were coded from verbatim transcripts. The procedures for establishing inter-rater reliability were the same for all coding systems. Specifically, two researchers independently coded 20% of the records and compared their results. Once reliability was established, no single reliability estimate in any cycle was below Cohen's kappa (κ) 0.70.

FIGURE 3 | Programming space during the third cycle of the Make it Roll program.

Engagement in Engineering Design Practices

To capture engagement in engineering practices, we focused on those instances when either the child or the parent physically tested to see if their creations or parts of their creations rolled. A *test* was scored when the child or parent attempted to spin the wheels or axles of their creation on a ramp, or while holding it on or above the worktable. We distinguished tests from test repetitions. A *test repetition* was scored when the child or parent tested the creation without making any changes to the creation between tests. Kappas averaged 0.85 for children and 0.90 for parents. We further coded what happened after each test or test repetition performed by the child or the parent as either: (1) redesigning –making changes to the creation (e.g., repositioned a wheel to make it spin or touch the ground, swapped the drinking straw for a wooden stick to serve as an axle), (2) decorating—adding non-functional parts to the body of the creation (e.g., added a flag, wrote their name on the creation), or (3) testing was taken over by the partner—after the test by the parent or the child the other partner took the creation and conducted a test (e.g., the child was testing the creation and the parent took the creation and conducted another test without doing anything to the creation in between these tests), (4) other/undefined. Kappas for these subcodes averaged 0.83 for children, and 0.86 for parents.

Children's Narrative Reflections

The transcripts of the children's narrative reflections were coded using a system developed by Acosta et al. (2021). The coding unit was *instance of occurrence*; any word or group of words that fit the coding category were coded, except repetitions. The content of the children's talk during the narrative reflections was coded when it involved (1) naming or describing *tools and materials* (e.g., "We used the tape so the wheel could stick on." "I used the black straws."), and (2) *engineering-related talk*, including talk about testing, redesigning, and how the wheels and axles help make something roll (e.g., "We tested on the ramp." "I learned that my wheels need to

FIGURE 4 | Narrative reflection station.

spin for my car to roll"), predictions and explanations (e.g., "Well it's not very good at racing because it goes sideways."), and mathematics reflecting progress toward the engineering goal (e.g., "My car rolled to the two foot measure."). The kappas averaged 0.89.

RESULTS

Preliminary Analyses

Initial analyses addressed whether children in the three DBR cycles were equivalent in terms of child age and gender. As shown in **Table 1**, there were no significant age differences, [$F_{(2,204)} = 2.86$, $p = 0.059$, $\eta^2 = 0.03$], nor significant gender differences across the three cycles, $\chi^2(2, N = 204) = 1.52$, $p = 0.47$, Cramer's $V = 0.09$.

Engagement in Engineering Design Practices During Tinkering by DBR Cycle

When looking across DBR cycles, 93% of the children tested their creation at least once, and the percentage of children who tested their creation at least once did not vary by cycle, $\chi^2(2, N = 205) = 4.84$, $p = 0.089$, Cramer's $V = 0.15$ (Cycle 1: 88.1%; Cycle 2: 97.5%; Cycle 3: 90.9%). Children worked on their creations with a parent, and 81.5% of the parents tested the creation at least once. In the later cycles (Cycle 2: 81%; Cycle 3: 91%), a higher percentage of parents tested the creation compared to the initial cycle (71%), $\chi^2(2, N = 205) = 8.03$, $p = 0.018$, Cramer's $V = 0.20$. In more than half of the families, the first test was conducted by the child, with no difference across cycles in the percentage of families where this was the case (Cycle 1: 61.1%; Cycle 2: 61.3%; Cycle 3: 51.6%), $\chi^2(2, N = 196) = 1.60$, $p = 0.449$, Cramer's $V = 0.09$. When examining what happened after children's first test, we also found no differences across cycles in the percentage of children who continued to work on their creation to improve or redesign it (Cycle 1: 56%; Cycle 2: 54%; Cycle 3: 65%), $\chi^2(12, N = 192) = 16.23$, $p = 0.181$, Cramer's $V = 0.21$.

We hypothesized that families in the later cycles of the program would engage in more testing and redesigning than families in the initial cycle. Therefore, we examined whether families' engagement in testing varied based on the DBR cycle (Make it Roll 1, 2, or 3) they participated in. As shown in **Table 2**, compared to children in the first cycle, children in the second and third cycles conducted significantly more tests [$F_{(2,204)} = 8.83$, $p < 0.001$, $\eta^2 = 0.08$], and test repetitions [$F_{(2,205)} = 6.88$, $p < 0.01$, $\eta^2 = 0.06$]. Likewise for parents, those in the second and third cycles conducted significantly more tests than parents in the first cycle [$F_{(2,204)} = 10.17$, $p < 0.001$, $\eta^2 = 0.09$]. Parents did not perform many test repetitions, but there were more test repetitions by parents who participated in Cycle 2 than Cycle 1 [$F_{(2,204)} = 6.57$, $p < 0.01$, $\eta^2 = 0.06$].

Next we considered what happened after children and their parents performed a test or test repetition. **Table 3** shows the proportion of tests or test repetitions that were followed by redesigning, retesting, decorating, or the partner taking over. As shown in **Table 3**, most tests or test repetitions were followed by redesigning. However, contrary to our hypothesis, we did not find that redesigning increased across DBR cycles, for children [$F_{(2,189)} = 0.41$, $p = 0.66$, $\eta^2 = 0.00$], or parents [$F_{(2,166)} = 1.81$, $p = 0.166$, $\eta^2 = 0.02$]. Essentially, the iterative improvements in the program increased testing, which in turn engendered further engagement in the engineering process during tinkering. There were fewer tests followed by decorating in Cycles 2 and 3 compared with Cycle 1 for children [$F_{(2,189)} = 7.34$,

TABLE 2 | Families' engagement in testing by DBR cycle.

	Make it Roll					
	Cycle 1		Cycle 2		Cycle 3	
	M	*SD*	*M*	*SD*	*M*	*SD*
Children						
Tests	4.49_a	4.48	7.15_b	5.57	8.89_b	7.18
Test repetitions	0.81_a	1.71	4.20_b	6.56	4.63_b	8.28
Parents						
Tests	2.58_a	2.85	5.55_b	6.79	7.29_b	6.64
Test repetitions	0.10_a	0.48	0.94_b	1.85	0.62	1.12

Across individual rows, means with subscript a differ from means with subscript b at p < 0.05 in pairwise tests with Bonferroni adjustment for multiple comparisons.

TABLE 3 | Proportion of tests followed by redesigning, decoration, and partner taking over.

	Make it Roll					
	Cycle 1		Cycle 2		Cycle 3	
	M	*SD*	*M*	*SD*	*M*	*SD*
Children						
Redesigning	0.36	0.36	0.37	0.25	0.41	0.28
Decoration	0.11_a	0.22	0.02_b	0.07	0.04_b	0.11
Parent takes over	0.05	0.12	0.05	0.10	0.08	0.13
Parents						
Redesigning	0.60	0.35	0.58	0.30	0.49	0.29
Decoration	0.13_a	0.30	0.01_b	0.04	0.05	0.17
Child takes over	0.10	0.17	0.18	0.27	0.21	0.23

Across individual rows, means with subscript a differ from means with subscript b at $p < 0.05$ in pairwise tests with Bonferroni adjustment for multiple comparisons. The proportions do not add up to 1, because of other/unclassifiable behaviors that occurred infrequently after a test.

$p < 0.01$, $\eta^2 = 0.07$], and parents [$F_{(2,166)} = 5.29$, $p < 0.01$, $\eta^2 = 0.06$].

Linking Engineering Engagement During Tinkering and Children's Narrative Reflections

We hypothesized that the more families tested during tinkering the more their children would talk about engineering in the post-tinkering narrative reflections. Further, we thought that the more testing the parents and children engaged in during tinkering the less the children would talk about tools and materials in their narrative reflections. Recall that we iterated these post-tinkering reflections and the number of questions asked varied across cycles. Therefore, we calculated the proportion of children's talk about materials and tools and about engineering-related talk, dividing the frequency of each of these codes by the total number of questions asked. As shown in **Table 4**, overall, children's tests during tinkering were positively associated with their talk about engineering in the post-tinkering narrative reflections. As also predicted, parents' test and tests repetitions during tinkering negatively correlated with children's talk about tools and materials in their reflections. In other words, the more engineering was the focus of the tinkering activity the less "tool talk" in the children's reflections. What is more, when we looked at the correlations by DBR cycle, in Cycles 2 and 3, we saw significant positive correlations between children's tests during tinkering and their engineering talk in the reflections, and in Cycle 3, positive correlations between children's test repetitions during tinkering and engineering talk in the reflections. For parents, the negative associations between test repetitions during tinkering and children's talk about tools and materials in the reflections were only statistically significant for Cycle 2. Overall, this pattern of results suggests that when testing by children and their parents during tinkering is more frequent, as was the case in Cycles 2 and 3, children's reflections included more talk about engineering, and less talk about tools and materials.

DISCUSSION

Using a design-based research approach, we studied ways of enhancing engineering learning opportunities for children in an informal educational setting. Taken together, the results suggest exhibit design and facilitation strategies that can promote children's engagement with authentic practices of engineering during tinkering, specifically, testing and redesigning. The work also illustrates how design-based research methods can help us understand and support learning in real-world contexts.

Engagement in Engineering Design Practices

Our results demonstrate that children can and do participate in the engineering design process during tinkering by creating, testing, and re-designing. This was true in all three cycles of our "function-focused" tinkering program that posed a specific engineering challenge to make something that rolled, and included exhibit design features to support testing and iterating toward a functional goal. Prior work suggests that parents and children talk more about engineering during such function-focused tinkering programs than tool-focused programs (Pagano et al., 2020), and here we show too that hands-on engagement during the Make it Roll program was engineering-rich. The majority of the children we observed tested to see if their creation did indeed roll. After testing their creation, more than half of the children continued to work on their creation to redesign or improve it. Although relatively speaking the proportion of tests that were followed by redesigning did not increase across cycles, the number of tests did, meaning that by encouraging testing we also encouraged further engagement in the engineering design process. Nonetheless, just as not all tinkering is engineering (Martinez and Stager, 2013), adding a place to test ones design during a tinkering activity does not in and of itself maximize the potential for engineering learning through tinkering. Indeed, in contrast to the first version of the program, the second and third iterations paired the design feature of a ramp with facilitation strategies by museum staff members. It was the later versions of the program that led families in this study to engage in the most testing, and in turn, redesigning, which are key engineering practices (National Research Council [NRC], 2012; NGSS Lead States, 2013).

We focused on testing and redesigning because they move *making* something to *engineering* something. Authentic engagement in an engineering design process does not stop with the first rendering of a design, nor with the first test. Rather, engineers use testing to gather information about how effective, efficient, durable, etc. their design is, to compare different design solutions, and determine what works best to solve the problem within the given constraints (National Research Council [NRC], 2012). Nonetheless, the practice of testing might not yield the best possible solution to a problem unless the ensuing redesign features the application of relevant engineering

TABLE 4 | Partial correlations between families' tests and children's reflections.

	Engineering during tinkering			
	Children's tests	Children's test repetitions	Parents' tests	Parents' test repetitions
Content of children's narrative reflections across cycles				
Discussing materials and tools	−0.15	−0.20*	−0.27**	−0.20*
Engineering-related talk	0.31**	0.16^t	0.12	−0.04
Cycle 1				
Discussing materials and tools	0.14	0.05	−0.03	0.11
Engineering-related talk	0.15	0.15	0.20	0.08
Cycle 2				
Discussing materials and tools	0.15	−0.02	−0.35^t	−0.38*
Engineering-related talk	0.44*	0.01	0.25	0.00
Cycle 3				
Discussing materials and tools	−0.09	−0.11	0.04	−0.08
Engineering-related talk	0.34**	0.28*	0.02	−0.15

$^{**}p < 0.01$, $^{*}p < 0.05$, $^{t}p < 0.10$.

principles. This idea provided the motivation for the introduction of the facilitated orientations by museum staff members, Cycle 2, and refinements of this strategy in Cycle 3, to highlight key engineering information about wheels and axles to families at the outset of the tinkering challenge.

In this project, we focused on ways that museum staff could provide relevant information to families. Prior work suggested that this might be successful. For example, Haden et al. (2014) carried out an intervention in a building construction exhibit wherein some visitors received information about triangular bracing before creating their own skyscrapers. Haden et al.'s project and some others (Eberbach and Crowley, 2017; Marcus et al., 2018; Willard et al., 2019) offering key information to visitors to support learning were fashioned to mimic museum programming. However, it is rare for empirical work to involve museum staff in carrying out the interventions (Franse et al., 2021). The current study exemplifies how this approach can be especially fruitful, yielding ecologically valid tests of effectiveness of practices that are directly applicable to enhance informal learning opportunities.

Children's Narrative Reflections

Our work also involved an effort to connect hands-on engagement during tinkering with an assessment of what children might have learned from their experiences. We elicited children's narrative reflections immediately after tinkering. We found that particularly in the second and third cycles of our design-based research, the more children engaged in testing and retesting during tinkering, the more their narratives contained engineering-related content. The following example from a child who participated in Cycle 3 illustrates this result. Here the child describes several tests, and how they led to diagnosing what might need to be fixed and trying different solutions, in a series of tests and redesigning efforts:

Child: The first time I tested it, it was all, it started going wonky.

Researcher: Oh no!

Child: And then the second time we tested it, we realized it's the back wheels, so then we changed it.

Child: The third time we tested it, we added a couple of more things to make it more even like light in the back.

Child: And then the final time I tested it, it worked!

Researcher: Wow and did it roll?

Child: Yes.

Researcher: It did?

Researcher: Very cool.

Child: But it didn't roll that far.

Researcher: That's okay.

Child: It went to one feet.

A challenge with assessing learning in museum environments is to do so in ways that respect the character of an informal educational setting. Our museum partners previously developed a special multi-media exhibit—*Story Hub: The Mini Movie Memory Maker*—to encourage families to tell stories together about their exhibit experiences. In fact, as part of our larger project, a subset of the families we observed in this project in Cycle 2 were invited to reflect together on their tinkering experience in Story Hub (see Pagano et al., 2020). We developed the procedures used in this study to elicit children's independent reports of their learning (in contrast to family reminiscing), in part, because earlier work suggested that children will report more engineering content when they have their projects with them than when they do not (Pagano et al., 2019). We also wanted to create a simple procedure that could be put into practice by museum staff, one that could potentially further boost learning from hands-on experiences by virtue of the opportunity for children to verbally express their experiences.

Reflection is foundational in modern STEM education. Part of the reason for this is the ways that reflection can reveal learning outcomes. Indeed, in our work, the content of the children's reflections were diagnostic of how changes in the design of the Make it Roll program were advancing engineering learning opportunities. As children's engagement in the engineering practice of testing increased across variations of the tinkering program, so too did children's talk about engineering in their reflections. As parents tested more across iterations of the program, children talked less about tools and materials. The content of the reflections therefore provided insights into what the children understood about their experiences, and potentially what was most meaningful and memorable, information that is useful to not only researchers, but also educators and parents, who seek to support children's STEM learning.

Narrative reflections also present the opportunity to extend children's learning beyond the hands-on experience itself and may help with consolidation of learning from hands-on activities such as tinkering (Marcus et al., 2018; Pagano et al., 2019). Reflection can extend the initial learning through hands-on activity to support the creation of a richer and more meaningful representation of the experience, one that may be more memorable and transferable beyond the museum's walls (Haden, 2014; Marcus et al., 2017). In support of this idea, Marcus et al. (2021) had some families reflect on a building experience in a museum exhibit immediately afterward, whereas others did not engage in the post-building reflection. They found that compared to families who did not engage in the narrative reflection at the museum, those who did talked more about STEM when working on a related building activity at home. In light of this and other similar work (e.g., Jant et al., 2014), success in increasing the engineering talk in the children's reflections can be important as part of an overall process of learning and learning transfer that a museum visit may engender.

Limitations and Future Directions

This research makes important contributions to the literature on children's learning as well as to informal educational practices. Nevertheless, there are several limitations of the work. First, our design-based research involved successive iterations of the tinkering program which were introduced one after another into the exhibit space, and therefore random assignment of participants was not possible. Relatedly, our sample sizes for each cycle varied based on the duration of the program in the museum's calendar, and the days it was possible to collect data. During Cycle 2, on different days of the week, post-tinkering narrative reflections were either collected in *Story Hub* or elicited from the children by a researcher—the post-tinkering narrative reflections by children that are presented in this paper. The uneven number of participants across cycles is not ideal. Additionally, although museum staff received training on the information that was to be included in the orientations regarding wheels and axles, testing, and sliding vs. rolling, there was variation in how this information was delivered to families. Again, this is an example of how our work differed from a standard experimental study. Nonetheless, it would be interesting in future work to consider how natural variations in the ways the staff delivered the orientations—such as to what extent they directly explained or engaged families in a give and take conversation to convey the information—might further predict variation in the families' subsequent engagement in tinkering, and the children's narrative reflections.

This project did not combine a focus on hands-on testing and the conversations parents and children engaged in together during tinkering. This is an important next step, as indeed, the way we frame our larger project theoretically speaking is that conversations add layers of understanding to children's experience beyond hands-on activity alone (Haden et al., 2016). Moreover, it is clear from research on STEM learning in museums that parent-child conversations can support children's learning. In future work, we are especially interested in examining contingencies between verbal and non-verbal behavior during tinkering. For example, when a child engages in testing, what does the parent say? Does the parent ask a question or provide an explanation? This approach is encouraged by recent work by Callanan et al. (2020) that shows that the timing of parents' talk when children are engaging in a hands-on activity can provide a specific mechanism by which joint hands-on and conversational engagement scaffolds children's STEM learning.

Implications for Enhancing Engineering Learning Opportunities for Children in Informal Educational Settings

Our work is situated at a children's museum and also grounded in a unique partnership between university researchers and museum practitioners. Engaging in developmental psychology research in museums is a growing trend, but the nature of the working relationships forged between researchers and museum practitioners is highly variable (Callanan, 2012; Sobel and Jipson, 2016; Haden, 2020). One critical dimension along which these working relationships vary is the degree to which the research might offer insights into effective practices for supporting children's learning. Working *with* the museum, we iterated the Make it Roll program to determine how to maximize this potential engineering learning opportunity. Important indicators of our success came in the form of our observations of parents and children testing their creations, and children's narrative reports of what they learned from the tinkering experience. Our results point to several specific practices that can be readily implemented in museums. One is providing families with exhibit-related information to support their engagement in science and engineering practices. Another is offering places for testing to encourage participation in engineering practices. After Cycle 1, the ramp was redesigned, not only to encourage measurement of distance, but also to lessen success due to the creation simply sliding. In other words, the design of the testing station was altered to require use of key engineering principles—to make the wheels or axles rotate. Our measure of testing is one that can be observed live, so that museum educators could alter their testing stations to promote engagement with the engineering concepts relevant to the task at hand. Finally, we also see the narrative reflection procedure as a tool that educators can use to understand what works to promote learning in their spaces.

The opportunity to engage in jointly negotiated collaborative research with the children's museum is important not only in advancing our understanding of children's STEM-related learning. The work can also directly impact educational practices that can support that learning. This is an important effort broadly speaking, because so much STEM learning happens outside of school, with estimates of children spending 80% of their waking hours learning in informal educational environments, including museums (National Research Council [NRC], 2009). Research-practice partnerships like the one our team enjoys can provide critical insights into children's learning in real-world contexts, while at the same time advancing practices that enhance STEM learning opportunities for children.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board, Loyola University Chicago. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Verbal assent was also obtained from children. Consent was obtained from the individual(s), or minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

DU and CH were PIs for the NSF grant that supported this work. MM, DU, and CH contributed to conceptualization and study design. MM, DA, and PT contributed to the data collection. MM, DA, PT, and CH designed and executed the coding. MM conducted the statistical analyses. MM and CH wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Tell Me About Your Visit With the Lions: Eliciting Event Narratives to Examine Children's Memory and Learning During Summer Camp at a Local Zoo

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School-aged children often participate in school field trips, summer camps or visits at informal learning institutions like zoos and museums. However, relatively little is known about children's memory and learning from these experiences, what types of event details and facts are retained, how retention varies across age, and whether different patterns are observed for different types of experiences. We aimed to answer these questions through a partnership with a local zoo. Four- to 10-year-old children ($N = 122$) participated in a weeklong summer camp, during which they engaged in dynamic events, including visits to zoo animals. On the last day of camp, we elicited autobiographical event narratives for two types of experiences: a child-selected animal event (visit to their favorite animal) and an experimenter-selected animal event. We coded event narratives for length and breadth using previously used autobiographical memory (AM) narrative coding schemes. In addition, we created a coding scheme to examine retention of semantic information (facts). We report the types of autobiographical event details and facts children recalled in their narratives, as well as age group differences that were found to vary depending on the type of information and type of event. Through this naturalistic, yet controlled, study we gain insights into how children remember and learn through hands-on activities and exploration in this engaging and dynamic environment. We discuss how our results provide novel information that can be used by informal learning institutions to promote children's memory and retention of science facts.

Keywords: memory development in children, autobiographical memory, episodic memory, narratives, STEM learning, informal learning environments, semantic memory

INTRODUCTION

Visits to informal learning institutions like science centers, museums and zoos are common experiences (see discussion Haden, 2010). Thousands of children visit such institutions each year, whether through school field trips, day trips with parents and caregivers, or as part of registered camps (e.g., summer camp). Not only do such visits create memorable experiences, but such visits can also supplement formal (i.e., classroom) learning (Hudson and Fivush, 1991; Birney, 1995; Falk and Dierking, 1997; DeMarie, 2001; Davidson et al., 2009; see also Cox-Peterson et al., 2003).

Multiple memory systems are involved in experiences like a museum trip or a visit to the giraffe exhibit at a zoo. Our episodic memory system allows us to remember the details of events that occurred at a specific time and place in the past (Tulving, 1984). Such memories can be autobiographical, in that they are based on personally significant or self-relevant events (e.g., Nelson and Fivush, 2004; Palombo et al., 2013). A child stating that the giraffe was eating leaves when she visited its enclosure is an example of an episodic memory. Another type of memory, semantic memory, allows us to retrieve general world knowledge or memory of facts (Tulving, 1972). For example, a child stating that giraffes have dark-colored tongues is a semantic memory or fact. Together these memory systems allow us to convert our experiences into lasting memories. However, relatively few studies have examined children's autobiographical and semantic memories about these personal experiences (e.g., Imuta et al., 2018). In the present study we examined 4- to 10-year-old children's memory and learning after a week-long summer camp at a local zoo by examining their event narratives.

Much of our understanding of autobiographical memory (AM) and its development is based on examination of autobiographical event narratives (for reviews see Nelson and Fivush, 2004; Pasupathi et al., 2007; Fivush, 2011; Haden and Hoffman, 2013; Bauer, 2015; Habermas and Reese, 2015). Narratives can be elicited via interviews in which an experimenter asks a participant to describe a past event with an open-ended question (e.g., "Tell me about the time you [event]"), followed-up with more specific *Wh*-questions (what, when, where, who, why and how; example "who was there when you [event]") (see Haden and Hoffman, 2013). These questions allow a thorough description of the event in addition to participants' thoughts, motivations and emotions related to the event (Nelson and Fivush, 2004). Researchers can then code and analyze narratives to further our understanding of changes across childhood.

This research shows that AM and the ability to narrate a past event emerges during the preschool years (Nelson and Fivush, 2004; Fivush, 2014). Between 16 and 18 months of age, infants can speak two-word utterances, and show some evidence of talk about past experiences (see Bloom, 1991, and discussion by Fivush, 2011). In early conversations, adults provide much of the structure and support of the content, however, children's ability to provide narratives of their early experiences improves dramatically over subsequent years (Ornstein and Haden, 2001; Reese, 2002, 2014). With age, narratives begin to demonstrate organization through the inclusion of temporal and causal connections that allow children to link different actions together (Van den Broek, 1997). By 3.5 years, children become more capable of providing fairly coherent narratives of past experiences even after relatively long delays with slight prompting from adults (Fivush et al., 1987, 1995; Reese, 2002). Narrative skills continue to develop, showing increasing complexity and elaboration, throughout the preschool years into middle childhood (Haden et al., 1997) and afterward. In a 3-year longitudinal study, Bauer and Larkina (2019) reported steady increases in AM development across the age range of 4–10 years old. Researchers elicited narratives from 4-, 6-, and 8-year-old children about events that parents noted occurred within the past 4 months, and included events like celebrations, family outings and after-school events. With increasing age, children provided longer narratives (measured by the number of propositional units within the narrative). In addition, researchers found that with increasing age, narratives became more complete, as measured by narrative breadth (the number of different event detail or narrative categories mentioned, like who, what, when, etc.; see Bauer and Larkina, 2014, 2019). Further, past research shows that certain event details are more common in children's event narratives than others. For example, in a study with a group of 7- to 10-year-olds, researchers found that the what-action (reference to actions or activities) and what-object (reference to objects present) narrative categories were most often present in children's event narratives, whereas the why narrative category (reference to causation or justification) was least often present, for both recent and distant events (Bauer et al., 2007). Overall, the examination of children's narratives about past events has been fruitful in furthering our understanding of what types of event details children provide, and in showing age-related improvements in AM across childhood (Reese, 1999; Bauer, 2007; Habermas and de Silveira, 2008; Pasupathi and Wainryb, 2010; Fivush, 2011; see also Peterson and McCabe, 1994; Wang and Leichtman, 2000; Hoerl, 2007).

Semantic memory and knowledge in childhood has been tested and discussed in various ways (e.g., see Chi, 1978; Nelson et al., 1983; Bjorklund, 1985; Mareschal and French, 2000). However, relatively few studies have examined both episodic or AM along with semantic memory measures in childhood (e.g., Robertson and Köhler, 2007; Sipe and Pathman, 2020) and few have examined the different types of semantic knowledge reported in AM narratives or interviews. Those that have seem to focus on one of two aspects of semantic memory. In one line of work, researchers have examined children's semantic knowledge in terms of scripts or schemas for familiar events (school day, class trips; see also DeMarie et al., 2000). For example, Fivush et al. (1984) demonstrated that 5-year-old children were capable of retrieving both general information about a familiar experience (what happens during a class trip) and details about a specific episode of a novel experience (what happened during a particular class trip). In another line of work, researchers have examined personal semantic information provided in narratives or interviews. For example, Piolino et al. (2007) interviewed 7- to 13-year-olds about both personal semantic information (e.g., home address, names of childhood friends) and episodic information (describing particular events) from past time periods (e.g., current school year and last school year). They found age-related increases in their episodic memory measure, but not for their personal semantic information measure. In contrast, Picard et al. (2009) found that age was positively correlated with both the amount of episodic and personal semantic information provided by 6- to 11-year-olds. Willoughby et al. (2012) also found a similar pattern with 8- to 16-year-old children. Thus, the examination of autobiographical interviews in these studies have shown that with increasing age, children provide more episodic details. In terms of a type of semantic memory – personal semantic details – these studies have shown both age invariance and age-related increases. The purpose of the present paper was not to examine semantic memory in terms of schemas or event representations, nor examine semantic memory in terms of personal facts (e.g., "I am 9 years old"). Instead, one of our goals was to examine children's inclusion of science-related and animal-related facts in their AM narratives based on particular experiences at a local zoo.

Zoos, and other informal learning institutions like museums and science centers, are ideal settings to study children's memory and learning. Not only do such settings allow developmental scientists to study phenomena in the "messiness of the real world" (Golinkoff et al., 2017, p. 1407), but these settings have several features that are advantageous. First, unlike in lab-based studies in which children both experience and are tested on events within the lab, children can experience events in informal learning environments without knowing they will later be tested on those events. Further the events themselves are engaging and dynamic, especially compared to lab-based stimuli like pictures on a computer screen or even staged lab events. Since there are limits to ecological validity in lab-based settings (Schmuckler, 2001), naturalistic settings like zoos are a more representative place to test memory as a natural phenomenon. Second, visits to informal learning institutions are invaluable experiences because children can more directly interact with or see the objects they are learning about (see Davidson et al., 2009). Third, zoos, museums, and related institutions allow for social interactions among peers and educators which can be different than the social interactions during classroom learning; these social interactions have positive implications for learning (Birney, 1995; Davidson et al., 2009). Last, during visits to zoos, children can be given freedom to explore various exhibits or portions of exhibits, and thus be a source of free choice learning (Tofield et al., 2003). Further, qualitative research suggests that high personal involvement is one factor that makes museum experiences more memorable (Wolins et al., 1992).

Personal involvement or self-relevance has also been shown to affect the developmental trajectory of children's memory performance. In a study by Pathman et al. (2011), children and adults took photographs during a museum visit; they were asked to reflect on how they felt about the object or exhibit they were photographing (*high* self-relevance; AM condition). Participants also answered questions about photographs of the same objects or exhibits taken by someone else, shown on a laptop at the museum (*low* self-relevance; episodic condition: mimicked lab-based studies). The participants were then invited to the laboratory 1–2 days after they visited the museum to test recognition of the photographs they had taken (autobiographical condition) and photographs they had viewed on the laptop (episodic condition). All age groups had higher levels of correct recognition in the autobiographical relative to the episodic condition. Importantly, younger children (7–9 years old) were less accurate than older children (9–11 years old) in the episodic condition, but these groups did not differ in the autobiographical condition. This work suggests that self-involvement and self-relevance can boost children's memory and minimize age-related differences (Pathman et al., 2011) and parallels a robust literature in both adults and children showing better memory for words or events related to the self (e.g., Zhu et al., 2012; Cunningham et al., 2014; see Symons and Johnson, 1997, for review).

In the present study, we elicited memory narratives from 4- to 5-year-old, 6- to 7-year-old, and 8- to 10-year-old children about two particular events from a weeklong summer camp experience at a local zoo. Children described what they remember and learned from a visit to their favorite animal (child-selected event) and from a visit selected by the experimenter (experimenter-selected event). We then analyzed children's memory narratives to examine the types of event details they included in their event narratives (both using a traditional AM coding scheme and a semantic fact coding scheme we created). We examined whether there were age-related differences in their narratives (narrative length, narrative breadth, and number of animal-related facts). Further, although we do not directly compare the child-selected and experimenter-selected event narratives, we explore whether patterns were similar or different across event types. We predict the autobiographical coding to show age-related improvements in both narrative length and breadth, paralleling past research. We cannot make strong predictions about the number or types of semantic facts recalled, given the novelty of this work, but expect older children to provide more facts in their narratives given improvements in language and ability to integrate events to produce new semantic knowledge (e.g., Bauer and Larkina, 2017; Varga et al., 2019). Different patterns of results for the child-selected compared to experimenter-selected event narratives could be expected given the literature on the importance of self-relevance in the memory literature and recommendations for museum educators (see Wolins et al., 1992).

MATERIALS AND METHODS

Participants

Participants were 4- to 10-year-old children who took part in a 5-day summer camp at the Toronto Zoo that occurred during the months of July and August. Parents who had registered their children for camp received an email from the zoo advertising the study and were asked if they wanted their child to participate. The parental consent form was submitted online, and children gave verbal assent the day of the interview (Friday; see procedure below). The interview included two open-ended questions regarding the child's experience visiting exhibits and animals while at zoo camp: child-selected event and experimenter-selected event (see procedure below). Only participants who had time to be asked at least one of the event questions are included in this study. Specifically, participants in this study were 122 children: 36 4- to 5-year-olds (M_{age} = 62.84 months, SD = 6.26; 20 girls, 16 boys), 39 6- to 7-year-olds (M_{age} = 84.03, SD = 7.16; 24 girls, 15 boys), and 47 8- to 10-year-olds (M_{age} = 108.5 months, SD = 8.70; 25 girls, 22 boys).

Demographics completed by parents online revealed that 55.74% percent of the children were Caucasian or White, 21.31% were Asian, 15.58% were mixed race, 3.28% were Latin American, 0.82% were Aboriginal/First Nations, and 0.82% were Black or African American/Canadian. An additional 2.46% of parents chose not to specify their child's ethnicity. Most of our sample reported family income (before taxes; Canadian funds) greater than $90,000. The specific percentages are as follows: 52.46%

reported family income greater than $120,000, 25.49% reported family income as $90,000–120,000, 9.84% reported family income as $60,000–90,000, 3.28% reported family income as $40,000–60,000, 1.64% reported family income as $25,000–40,000, and 0.82% reported family income as less than $15,000. An additional 7.38% of parents chose not to specify family income.

From the total of 122 participants, 102 of the participants have data for both the child-selected (favorite animal) and experimenter-selected animal question. Eighteen participants have data for the child-selected event question, but not the experimenter-selected event question. This was due to time constraints (n = 13), the child was absent on the day the experimenter-selected animal was visited (n = 1), they were not able to remember the event or animal visited (n = 1), or the child did not talk about the animal the experimenter selected (n = 3). Two additional children answered both questions, but their child-selected response was not included in the analysis. This was because the child-selected animal was not at the zoo (n = 1) or because the child discussed multiple favorite animals so we could not target their narrative to one event (n = 1). In sum, data analysis includes 120 children for the child-selected event (favorite animal) question, and 104 children for the experimented-selected event.

The protocol was reviewed by the York University Research Ethics Board. Children received a "Junior Scientist" certificate and parents were entered into a draw for a free 1-year membership or membership renewal to the Toronto Zoo.

Procedure

Children took part in a 5-day summer zoo camp (Monday–Friday; full-day) that included various fun activities, crafts, games and interactions with zoo staff. Importantly, the camp also included visits to animals exhibits. During these visits children heard information about animals from camp counselors, zookeepers and staff. The schedules of which animal exhibits would be visited at which particular times during the week was pre-determined by zoo staff and provided to experimenters. Schedules varied per week depending on the theme and camp group. The schedules listed the specific areas of the zoo that would be visited each day, and experimenters knew which animals were located in each area of the zoo. Thus, if a child mentioned that they visited a giraffe, we could confirm this by checking whether this child's schedule included a visit to the area of the zoo where the giraffe was located. In addition to the schedule listing the particular areas of the zoo the camp groups visited on a particular day, the schedule also listed specific animals visited during zookeeper talks ("Meet the Keeper," "Behind the Scenes," and "Enrichment"). These talks were scheduled at particular times of the day during which children saw the animal while they heard information about the animal from a zookeeper or zoo staff. Experimenters provided "camp counselor checklists" to each camp counselor so they could note any deviations from the pre-determined schedule each day (e.g., changes due to weather).

On a Friday, the last day of zoo camp, experimenters interviewed the children during planned "downtime" (e.g., after lunch), so as not to take children away from scheduled camp activities. The focus of the present work is on the elicitation of narratives about two events: a child-selected event (favorite animal) and an experimenter-selected event. For the first narrative obtained, the experimenter asked the participant to talk about the visit to their favorite animal. Since the child was able to select an animal of their choice, this event (hereafter referred to as the "child-selected event") can be considered to have high self-relevance. For the second narrative obtained, the experimenter asked the participant to talk about a visit to an animal exhibit selected by the experimenter, based on the schedule (see below). Since the experimenter selected the event, this event (hereafter referred to as the "experimenter-selected event") can be considered to have relatively low self-relevance. See **Table 1** for the specific script and questions used to elicit the narratives. The experimenter asked free recall questions (e.g., "What do you remember . . .") followed by WH-questions (e.g., "Who was there . . ."), adapted from previous AM narrative studies (e.g., Bauer and Larkina, 2019). In addition, the experimenter asked a question that was aimed at children's fact knowledge ("What are some neat/cool things you learned about [animal]"). Questions/prompts for both events were similar but included some variations. Specifically, for the child-selected event, the experimenter asked the child the reason for selecting that animal as their favorite. However, this sub-question was not relevant for the experimenter-selected event.

The event that would be used for the experimenter-selected event narrative was selected prior to testing. This event always included a scheduled talk about an animal (the local zoo's names for these talks were: "Meet the Keeper," "Behind the Scenes," and "Enrichment" talks). During these talks the child visited the animal exhibit and a zoo staff or zookeeper presented information about the animal. Scheduled talks were used for this event narrative because these events were the only ones for which we could guarantee the child visited and saw the animal selected. For other parts of the schedule, only the exhibit location was mentioned so we could not be certain that an animal from an exhibit area was seen by a particular child. Thus, randomly selecting a scheduled talk from the child's schedule ensured the child visited that animal.

The interviews were audio-recorded using a portable recorder. In addition, the experimenter wrote down responses on a data profile sheet as the child was speaking.

Coding and Reliability

Audio recordings were transcribed verbatim and then reviewed by a second transcriber for accuracy. Whenever the participant's voice was faint in the recording due to background noise, transcribers referred to the data profile sheet to fill in any gaps. Participants had two types of ID numbers: a participant ID created prior to the interview for identification purposes which was based on age group and a coding ID that was used while coding narratives to minimize coder bias. This coding ID was generated for each participant at random and gave no indication to the age group of the participant. The goal for reliability procedures was to have at least 20% of narratives coded by a reliability coder following guidelines and past papers (see Haden and Hoffman, 2013); precise percentages for the final data set are below for each type of coding system. The intraclass correlation coefficients reported for reliability analysis throughout this paper meet or exceed recommendations by Haden and Hoffman (2013).

Narrative Length

Propositional coding was conducted such that "one individual parsed all on-task contributions into propositional units (i.e., unit of meaning that included subject-verb construction)" (Bauer and Larkina, 2019, p. 66). That is, propositional coding was centered around verbs or verb phrases. For example, a child could say "We watched the lemurs eat" which would be parsed as [We watched] [the lemurs eat] (2 propositional units). To account for repeated information by children, we counted *unique* propositional units which contained unique and non-repeated information. These unique propositional units were summed to come up with a total number of propositional units, and provided us with what we will hereafter call "narrative length." One primary coder coded all the transcripts and a reliability coder coded approximately 25% of transcripts for each of the two narratives (child-selected and experimenter-selected events). Intraclass correlation coefficients for child-selected and experimenter-selected events were 0.92 and 0.96, respectively. The primary coders' judgments were used in all analyses.

Autobiographical Memory Coding and Narrative Breadth

We used the extensive coding manual developed by Bauer and colleagues (e.g., Bauer and Larkina, 2014; Bauer et al., 2017) to quantify the autobiographical event details children included in their narratives. This coding scheme is described in detail in previous studies (e.g., Bauer et al., 2007) and referred to as "narrative coding" (to describe the coding scheme) and "narrative categories" to refer to the individual codes. Given that our study involves additional coding of the narratives (i.e., semantic coding) we will refer to this as "AM coding" and "AM categories" instead.

We adapted the previously used AM coding category "WHAT-OBJ" to add a "WHAT-OBJ-A" category for mention of an animal or animal name. See **Table 2** for explanation of the individual AM categories. For example, the sentence "The three cheetahs were sleeping" would receive the codes [HOW-DESC], [WHAT-OBJ-A], [WHAT-ACT]. Repeated information was not coded, such as repeat mentions of an animal name, unless it provided additional or novel detail. For each participant the number of codes in each particular AM code category was summed.

For AM coding, two primary coders coded 50% of the documents each that were in equal amount for gender and age group. To assess reliability, a third coder independently coded a randomly selected 27% of transcripts for the child-selected narratives and 31% for experimenter-selected narratives (transcripts were randomly selected; roughly proportional to the presentation of age groups; to meet goal that at least 20% of each primary coders' transcripts would be coded by the independent reliability coder). This split of 50% of transcripts per primary coder has also been similarly employed in previous research (see Bauer and Larkina, 2016; Bauer et al., 2019). Intraclass correlation coefficient for the child-selected event was 0.99 for the total sum of all AM codes (individual AM categories intraclass correlation coefficients ranged from 0.91 to 0.99). Intraclass correlation coefficient for the experimenter-selected event was 0.99 for the total sum of all AM codes (individual AM categories intraclass correlation coefficients ranged from 0.90 to 0.99). The primary coders' judgments were used in all analyses.

A narrative breadth score was calculated and used as a way to assess narrative completeness following past studies (e.g., Bauer et al., 2007; Bauer and Larkina, 2019). Specifically, AM codes were divided into 8 different categories used in past work (all categories from **Table 2**; note that What-Obj and What-Obj-A were considered 1 category for these purposes). For each event, children received one point for a code reflective of the category, regardless of the numbers of codes provided (max narrative breadth score = 8).

Semantic Coding (Animal Related Facts)

To assess semantic memory, scientific facts about the animals or related to the animals were coded for both the child-selected event and experimenter-selected event. Every meaningful unit or phrase that conveyed new information was coded (e.g., Benjamin et al., 2010; Imuta et al., 2018). Coding was based

TABLE 1 | Autobiographical narratives elicitation script (interview questions).

Child-selected event	Experimented-selected event
You saw lots of different animals at the zoo this week. What was your favorite animal you saw at the zoo this week?	Your camp counselor took you to see an animal called the [animal name]. You got to see the [animal] while a keeper taught you all about it
• Why was it your favorite animal? • What do you remember about the time you saw the [name of animal] this week? • Who else was there? • What did you do when you were there? • What was the [animal] doing when you were there? • Where were you? • When was this? • How did you feel when you saw the [name of animal]? • What are some neat things you learned about the [name of animal]?	• What do you remember about the time you saw the keeper and the [animal]? • Who was near you when you saw the [animal]? • What did you do when you were there? • What was the [animal] doing when you were there? • Where were you? • When was this? • How did you feel when you were there? • What are some cool things you learned about the [name of animal]?

on different mutually exclusive categories and included the following: behavior fact (BF), targeting fact (TF), abstract fact (AF), concrete fact (CF), and evaluative fact (EF). See **Table 3** for examples of all semantic fact codes. A BF is reference to animal movement or action or any habits which may or may not be seen at the time of zoo visit. A TF is given when a child mentions a specific type of animal ("spider monkey" or "golden lion monkey") or subgroup of animal ("baby monkey" or "female monkey"). However, a TF code is not awarded when a child refers to a general term "monkey." Participants received credit for an AF if they referred to any unobservable scientific information at the time of zoo visit. AFs could include information about the animal or information directly related to the animal (e.g., habitat). Any information about the physical appearance of the animal, animal-relevant objects or surroundings that is directly observable was coded as a CF. Any description, explanation or information about the animal that could be considered an evaluation based on facts or what the child may know about the animal received the code EF. Multiple examples are provided in **Table 3** for each semantic code category.

One point was assigned for each code and summed for each of these coding categories. Then all codes across all categories were summed to create an "overall semantic score." A unit of information could not receive more than one of these codes. For example, if participant stated, "Zebras stay together so that their stripes are confusing to the other animals" they received three codes including [*stay together*] (BF), [*stripes*] (CF), and [*confusing to the other animals*] (AF).

The entire narrative (i.e., all on-topic talk in response to the questions asked in **Table 1**) was coded for both AM coding (described in previous sub-section) and semantic coding. For AM coding, we did not focus on particular sentences or sentence tense paralleling past AM narrative studies that have used this AM coding scheme (e.g., Bauer and Larkina, 2014). However, only certain sentences were considered facts for semantic coding. Specifically, information that was generalized or given in the present tense were considered facts; only such sentences received

TABLE 2 | Autobiographical memory coding scheme for narrative breadth (children's descriptions about events).

Narrative category (AM codes)	When code was applied
Who	Specific mentions of people, gender, or a class of people present for or participating in the event (e.g., "Tim" and "camp counselor")
What-object	Specific objects or things present in the event or activity being described (e.g., "soccer ball")
What-object-animal*	The mention of an animal or specific name of an animal (e.g., "tiger")
What-action	Actions or activities performed by a character or an object in the narrative (e.g., "jump")
Where	Location of the event in place; a place/location that a person or object can go to (e.g., "in," "on top of," and "grandma's house")
When	Reference to time or placing the event in time, including indications of order of events within an experience (e.g., "yesterday" and "Tuesday"). Note this "when" category was split into a new coding scheme created by our lab which included individual sub-codes for "when," but we summed sub-codes to create the "when" category for the present study to parallel past research
Why	Justification or causation statements illustrating the dependency of different aspects of the event (e.g., "because" and "until")
How-description	Adverbs, adjectives, words, or prepositional phrases that describe the observable characteristics of an object or an action, such as length, height, number, color, and texture. This observation is without any personal evaluation (e.g., "it was pink")
How-evaluation	A personal evaluation of the event, for example, through the use of an intensifier (e.g., "largest"), the use of a subjective modifier (e.g., "it was pretty"), or mention of an internal state (such as a term conveying information about emotion, cognition, perception, or physiological states) (e.g., "I am happy")

**Code created for present study.*

TABLE 3 | Semantic coding scheme.

Type of code	Definition	Examples
Behavior fact (BF)	Any information referring to animal movement or action or any habits which may or may not have been seen at the time of zoo visit	Tigers are good *climbers* Male bats *fly* quickly
Targeting fact (TF)	Mention of the specific type/kind of animal or subgroup of animal. Not just a label of an animal but requires narrowing or targeting to a more specific animal or animal category.	*Amur tigers* are going extinct *Spider monkeys* are clever *Male* deer have antlers
Abstract fact (AF)	Any scientific information about the animal or related to the animal which was unobservable at the time of zoo visit	Rainforests are *warm* Elephants *are hunted for* their tusks
Concrete fact (CF)	Any fact related to the physical appearance of animal (or animal-relevant objects or surroundings) that was directly observable at the time of zoo visit	Giraffes have *dark tongues* The males use their *antlers* to fight Polar bears swim in cold *water*
Evaluative fact (EF)	Any description, explanation or information about the animal that could be considered an evaluation based on facts or what the child may know about the animal	Tortoises are *nice* Otters are *cute*

The above italics highlight particular fact codes for that category. However, these sentences can contain multiple different semantic codes. Examples: Amur tigers (TF) are going extinct (AF). The males (TF) use (BF) their antlers (CF) to fight (BF). Elephants are hunted for (AF) their tusks (CF). Polar bears swim (BF) in cold (AF) water (CF).

semantic codes. This coding scheme is consistent with the scientific information category in Imuta et al. (2018). In our study, "Cheetahs run fast" would receive the following AM codes for *Cheetahs* [WHAT-OBJ-A] *run* [WHAT-ACT] and *fast* [HOW-DESC]. This sentence would also receive semantic codes for Cheetahs *run* [BF] *fast* [AF]. However, a sentence like "the cheetah was yellow" would receive AM codes, but not semantic codes, since it referred to a specific episodic memory and not generalized semantic knowledge. In addition, only semantic details that were plausible were given semantic codes; if a child had said "Cheetahs are purple and green," that would not have received semantic codes.

Our identification of the sentences that would and would not receive semantic codes shares some parallels to previous research about conceptual development that distinguish "generic" statements (statements about a kind of category) and "non-generic" or "specific" statements (statements about a particular member of a category; statements about a particular point in time) (e.g., Brandone and Gelman, 2009; Rhodes et al., 2012; Gelman et al., 2013; Foster-Hanson et al., 2016). In our coding scheme, statements considered "generic" by Gelman and colleagues would be coded as semantic facts in our study if they were in present tense. Sentences in past tense that referred to a specific point in time would be coded as "non-generic" by Brandone and Gelman (2009); such a sentence would not receive semantic codes in our study. However, some "non-generic" statements in present tense would receive semantic codes in our study. For example, "*some* cougars can run faster than others" would be considered "non-generic" (e.g., Gelman et al., 2013) because it does not refer to the entire category of cougars; this statement would be given semantic codes in our study.

One primary coder coded all the transcripts and a reliability coder coded 23% of transcripts for each of the two narratives (child-selected and experimenter-selected events). The intraclass correlation coefficient for the child-selected event was 0.98 for the overall semantic score (individual semantic code intraclass correlation coefficients ranged from 0.90 to 0.96). Intraclass correlation coefficient for the experimenter-selected event was 0.96 for the overall semantic score (individual semantic code intraclass correlation coefficients ranged from 0.85 to 0.96). The primary coders' judgments were used in all analyses.

Semantic Propositional Units

In order to determine the amount of talk that was "semantic-related talk" we counted the unique propositional units that were from sentences that were in the present tense and seemed to convey generalized knowledge. For example, the phrase [Cougars run fast] conveys a scientific animal-related fact and was counted as a semantic propositional unit, but [the cougar was lying down] was considered an episodic description of what the cougar was doing during the time the child was observing it and as such was not considered a unique semantic proposition. Unique semantic propositions were summed for each participant. Percentages of the sum of unique semantic propositions (e.g., sentences like "cougars run fast") relative to the overall number of unique propositional units (i.e., "narrative length") were calculated. These values are used in analyses to assess whether there are age-related differences in the percentage of fact-like statements provided in the entire unique, non-repeated narrative, for both the child-selected and experimenter-selected events.

RESULTS

We report the number and types of details provided by children for each event narrative (child-selected event and experimenter-selected event), and whether there were age group differences in narrative length and breadth (completeness of narratives), and whether there were age group differences in the semantic information provided by children. Analyses were planned to be conducted for each event narrative separately, since various known methodological differences prevent us from directly comparing values obtained for these two narratives (e.g., we knew that not all children would have time to complete both narratives, and thus child-selected event was always discussed before experimenter-selected event; experimented-selected event were associated with keeper talks, which was not always the case for child-selected events).

Child-Selected Event Narrative (Favorite Animal)

Preliminary Analyses

Delay

We conducted preliminary analyses to determine whether age groups varied in the delay between each child's favorite animal visit and the testing session. Delay was determined by examining individual camp schedules and camp counselor checklists and noting what day of the week the child-selected animal was visited. For example, if a child selected the cheetah visit for this event narrative, and they visited the cheetah on Tuesday, then this child's delay would be 3 days. Precise delay information was not available for 14 children because a child's report of their favorite animal visit (e.g., "rhino") did not allow us to isolate the visit to one particular location/time on the child's schedule (e.g., both the Indian Rhino and White Rhino were visited on different days).

An analysis of variance (ANOVA) found no main effect of age group on delay, $F(2,103) = 0.11$, $p = 0.90$, $\eta_p^2 = 0.002$. Thus, the delay between the event and the testing session did not vary by age group (mean delay was between 2.00 and 2.14 days for each age group).

Gender

To determine whether gender differences influenced memory narratives, we conducted the analyses reported below (narrative length, narrative breadth, and semantic coding) with both age group and gender as factors. No significant main effects or interactions with gender were found (all $ps > 0.05$), and thus gender is not considered further for this event narrative.

Narrative Length

As a reminder, narrative length refers to the number of propositional units produced by the child across the entire narrative (unique information, not repeated; on-task contributions). The ANOVA indicated a main effect of age group, $F(2,117) = 12.98$, $p < 0.001$, $\eta_p^2 = 0.18$. Pairwise comparisons showed that narratives produced by 8- to 10-year-olds ($M = 19.91$, SD = 7.28) were longer than both 4- to 5-year-old ($M = 11.71$, SD = 8.25) and 6- to 7-year-old ($M = 14.58$, SD = 6.83) children ($ps < 0.01$). The length of narrative between the two youngest age groups did not differ ($p = 0.10$).

We found significant differences in narrative length, paralleling previous papers. Thus, subsequent analyses are reported both without and with narrative length controlled. Paralleling the rationale used by Bauer and colleagues (2017), we report both because "each permits a valid – and unique – perspective on the data" (p. 419). Not controlling for narrative length allows us to determine the number and types of AM and semantic codes that are naturally recalled in the narrative; after all, providing a coherent and complete narrative requires words. At the same time, controlling narrative length allows us to determine potential age group differences above and beyond variance explained by talkativeness. Our measure of narrative length involves unique, not repeated, talk. Still, one could argue that any age differences in the amount of AM or semantic codes could be explained by differences in how long individuals speak, since this increases opportunities to showcase particular AM or semantic codes. Thus, like past research (Bauer et al., 2017) we describe both ANOVA and ANCOVA (analysis of covariance) findings.

Autobiographical Memory Coding and Narrative Breadth

Descriptive statistics for the sum of individual AM code categories for each age group are reported in **Table 4**. **Table 4** also includes analyses examining whether there are age group differences for each AM code category.

To test for age-related differences in the breadth or completeness of children's narratives an ANOVA was conducted with age group as a between-subjects factor. We found a main effect, $F(2,117) = 5.90$, $p = 0.004$, $\eta_p^2 = 0.09$, and pairwise comparisons revealed the following pattern: 4- to 5-year-olds ($M = 6.71$, SD = 1.51) had a lower narrative breadth score than both 6- to 7-year-olds ($M = 7.21$, SD = 0.88) and 8- to 10-year-olds ($M = 7.53$, SD = 0.78), $ps < 0.05$. The two oldest age groups did not differ in narrative breadth ($p = 0.17$).

The ANCOVA, with narrative length as a covariate, found no main effect of age group on narrative breadth score, $F(2,116) = 1.11$, $p = 0.33$, $\eta_p^2 = 0.02$. Thus, once narrative length was considered, age group differences in narrative breadth or completeness of narratives disappeared for the favorite animal event.

Semantic Coding (Animal Related Facts)

As a reminder, we coded children's narratives for various types of semantic facts. Each participant received a score for the different semantic code categories (BF, TF, AF, EF, and CF), in addition to an overall score which summed values across all semantic code categories. Overall semantic score was assessed with an ANOVA, and then followed by an ANCOVA, controlling for narrative length, for reasons described earlier.

The ANOVA showed age-related improvements in the overall number of facts children recalled in their narratives $F(2,117) = 6.55$, $p = 0.002$, $\eta_p^2 = 0.10$. Pairwise comparisons revealed that 8- to 10-year-olds ($M = 7.80$, SD = 5.07) reported more facts than both 4- to 5-year-olds ($M = 4.14$, SD = 4.31) and 6- to 7-year-olds ($M = 5.47$, SD = 4.35), $ps < 0.03$. The two youngest groups did not differ ($p = 0.22$). The descriptive statistics for each age group and analyses of age differences for separate semantic codes are reported in **Table 5**. As can be seen in **Table 5**, age group differences in overall semantic score seems to be driven by age group differences in TF, AF, and CF codes.

The ANCOVA revealed no main effect of age group, $F(2,116) = 0.09$, $p = 0.91$, $\eta_p^2 = 0.002$. Thus, when narrative length was considered in the analysis, age group differences in the overall number of semantic facts provided was no longer apparent.

We also conducted an analysis to determine what percentage of the overall narrative length would be considered semantic-related talk (see section "Semantic Propositional Units"). As a reminder, we calculated the percentage of unique *semantic* propositional units (e.g., sentences like "Flamingos are pink" or "Amur tigers are endangered") from the overall number of unique propositional units in the narrative (the value used in the "narrative length" score above). For the child-selected (favorite animal) event narrative there were no age-group differences in the percentage of the narrative that could be considered semantic talk, $F(2,117) = 0.93$, $p = 0.40$, $\eta_p^2 = 0.02$. Percentages for each age group were as follows: 4- to 5-year-olds ($M = 32.14\%$, $SD = 15.34$), 6- to 7-year-olds ($M = 28.60\%$, SD = 10.57), and 8- to 10-year-olds ($M = 28.57\%$, SD = 12.75). Thus, although there were age group differences in the amount of overall talk, there were no age group differences in the amount of talk in which children made generalizations or fact-like statements.

Post hoc Analyses

A partial correlation, controlling for both age in months and narrative length, revealed no relation between narrative breadth score and overall semantic score, $r(116) = 0.06$, $p = 0.53$. (Note there is a positive correlation between these variables when narrative length is not included as a control variable).

Experimenter-Selected Event

Preliminary Analysis

Delay

Similar to the child-selected question, we conducted a preliminary analysis to determine whether age groups varied in the delay between the time in which they visited the experimenter-selected event and the testing session. Delay was determined in the same manner as described in the child-selected event narrative delay analysis. All children who answered the experimenter-specified question were considered for this analysis as the exact time and day of this event was specified in the schedule.

The ANOVA found a main effect of age group on delay, $F(2,100) = 12.70$, $p < 0.001$, $\eta_p^2 = 0.20$. Pairwise comparisons revealed that 8- to 10-year-olds ($M = 2.71$, SD = 0.56) had a longer delay than 6- to 7-year-olds ($M = 2.20$, SD = 0.93) ($p = 0.006$), and 6- to 7-year-olds had a longer delay than 4- to 5-year-olds

(M = 1.74, SD = 0.86) (p = 0.02). As time delay does differ with age group, later analysis will report values with and without time delay controlled. This will allow us to determine whether this significant interaction with time-delay later impacts narrative length, breadth, and semantic coding.

Gender

To determine whether gender differences influenced memory narratives, we conducted the analyses reported below (narrative length, narrative breadth, and semantic coding) with both age group and gender as factors. No significant main effects of gender or interactions with gender were found for narrative length nor narrative breadth ($ps > 0.05$). Thus, gender is not discussed further for narrative length or narrative breadth subsections below. For semantic coding, a significant interaction between age group and gender was found ($ps < 0.05$). Follow-up revealed the effects were due to gender differences for the 8- to 10-year-old age group in facts recalled. These results are reported in the semantic coding subsection below.

Narrative Length

An ANOVA conducted for narrative length indicated a main effect of age group, $F(2,101) = 14.90$, $p < 0.001$, $\eta_p^2 = 0.23$. Pairwise comparisons showed that narratives produced by 8- to 10-year-olds (M = 18.85, SD = 9.85) were longer than both 4- to 5-year-olds (M = 8.85, SD = 4.28) and 6- to 7-year-olds (M = 12.92, SD = 6.49) children ($ps < 0.001$). The length of narrative between the two youngest age groups also showed that 6- to 7-year-olds produced longer narratives than 4- to 5-year-olds (p = 0.04).

TABLE 4 | Descriptive statistics for each AM code for the child-selected event.

Narrative category	Age groups				
	Overall	**4- to 5-year-olds *M* (SD)**	**6- to 7-year-olds *M* (SD)**	**8- to 10-year-olds *M* (SD)**	**Age-group differences *M* (SD)**
Sum of narrative codes	35.87 (22.60)	26.20 (16.97)	32.50 (21.18)	45.77 (23.82)	**$F(2, 117) = 9.26$, $p < 0.001$, $\eta_p^2 = 0.14$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
Who	2.57 (2.51)	1.31 (1.02)	2.11 (1.69)	3.87 (3.17)	**$F(2, 117) = 13.85$, $p < 0.001$, $\eta_p^2 = 0.19$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
What-object	2.93 (3.79)	2.49 (3.40)	2.29 (3.50)	3.79 (4.18)	$F(2, 117) = 2.02$, $p = 0.14$, $\eta_p^2 = 0.03$
What-object-animal	3.43 (2.79)	2.57 (2.02)	3.18 (2.93)	4.26 (2.98)	**$F(2, 117) = 4.06$, $p = 0.02$, $\eta_p^2 = 0.07$** [4- to 5-year-olds < 8- to 10-year-olds]
What-action	9.45 (7.09)	6.94 (6.27)	8.42 (7.30)	12.15 (6.70)	**$F(2,117) = 6.56$, $p = 0.002$, $\eta_p^2 = 0.10$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
Where	2.18 (2.28)	1.23 (1.28)	2.26 (2.40)	2.81 (2.57)	**$F(2, 117) = 5.18$, $p = 0.007$, $\eta_p^2 = 0.08$** [4- to 5-year-olds < 6- to 7-year-olds and 8- to 10-year-olds]
When	3.26 (2.94)	1.51 (1.58)	3.63 (4.96)	4.25 (3.89)	**$F(2, 117) = 5.49$, $p = 0.005$, $\eta_p^2 = 0.09$** [4- to 5-year-olds < 6- to 7-year-olds and 8- to 10-year-olds]
Why	1.42 (1.24)	1.29 (1.02)	1.24 (0.97)	1.66 (1.54)	$F(2, 117) = 1.51$, $p = 0.23$, $\eta_p^2 = 0.03$
How-description	3.58 (3.30)	2.31 (1.94)	2.76 (2.54)	5.17 (3.97)	**$F(2, 117) = 10.74$, $p < 0.001$, $\eta_p^2 = 0.16$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
How-evaluation	4.04 (3.70)	2.60 (2.77)	3.71 (2.73)	5.38 (4.51)	**$F(2, 117) = 6.42$, $p = 0.002$, $\eta_p^2 = 0.10$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]

For significant main effects of age (bolded statistics), pairwise comparison of age group differences that had a p < 0.05 are summarized in square brackets.

TABLE 5 | Types of recalled facts for child-selected event.

Type of fact	Age groups			Age-group differences
	4–5 *M (SD)*	**6–7 *M (SD)***	**8–10 *M (SD)***	
Behavior fact	1.09 (1.69)	1.18 (1.81)	1.66 (1.55)	$F(2,117) = 1.42$, $p = 0.25$, $\eta_p^2 = 0.02$
Targeting fact	0.54 (0.74)	0.79 (1.04)	1.11 (1.13)	**$F(2,117) = 3.25$, $p = 0.04$, $\eta_p^2 = 0.05$** [4- to 5-year-olds < 8- to 10-year-olds]
Abstract fact	1.14 (1.60)	1.89 (2.00)	2.55 (2.56)	**$F(2,117) = 4.37$, $p = 0.02$, $\eta_p^2 = 0.07$** [4- to 5-year-olds < 8- to 10-year-olds]
Concrete fact	1.03 (1.32)	1.08 (1.10)	1.81 (1.66)	**$F(2,117) = 4.13$, $p = 0.02$, $\eta_p^2 = 0.07$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
Evaluative fact	0.34 (0.68)	0.47 (0.80)	0.66 (0.64)	$F(2,117) = 2.10$, $p = 0.13$, $\eta_p^2 = 0.04$

For significant main effects of age (bolded statistics), pairwise comparison of age group differences that had a p < 0.05 are summarized in square brackets.

As a significant effect for narrative length was found for all age groups, further analyses will be reported both without (ANOVA) and with (ANCOVA) controlling for narrative length.

Autobiographical Memory Coding and Narrative Breadth

Descriptive statistics for individual AM codes for each age group are reported in **Table 6**. Analyses of age group differences for each AM code category are also provided in **Table 6**.

To test for age-related differences in the breadth or completeness of children's narratives, an ANOVA was conducted with age group as a between-subjects factor. We found a main effect, $F(2,101) = 13.89$, $p < 0.001$, $\eta_p^2 = 0.22$, and pairwise comparisons revealed the following pattern: 4- to 5-year-olds ($M = 5.48$, SD = 1.76) had a lower narrative breadth score than both 6- to 7-year-olds ($M = 6.17$, SD = 1.42) and 8- to 10-year-olds ($M = 7.20$, SD = 0.90); $ps < 0.05$; 8- to 10-year-olds' narrative breadth scores were higher than 6- to 7-year-olds' scores ($p = 0.001$).

An ANCOVA, controlling for time delay, revealed a main effect of age group for narrative breadth, $F(2,99) = 14.14$, $p < 0.001$, $\eta_p^2 = 0.22$. Pairwise comparisons revealed that, with time delay used as a covariate, the above pattern holds: 8- to 10-year-olds had a higher narrative breadth score than 6- to 7-year-olds, and 6- to 7-year-olds had a higher narrative breadth score than 4- to 5-year-olds, $ps < 0.02$.

The ANCOVA, controlling for narrative length, did not reach significance for age-related differences on narrative breadth score, $F(2,100) = 2.63$, $p = 0.08$, $\eta_p^2 = 0.05$. The ANCOVA, controlling for time delay and narrative length, showed a main effect of age group, $F(2,98) = 3.38$, $p = 0.04$, $\eta_p^2 = 0.06$. Pairwise comparisons revealed that 8- to 10-year-olds had a higher narrative breadth score than 4- to 5-year-olds ($p = 0.01$). The two younger groups did not differ from one another ($p = 0.17$). Similarly, the two oldest age groups did not differ from one another in their narrative breadth ($p = 0.09$). Thus, after accounting for time delay and narrative length, we continue to see age-related differences for narrative breadth.

Semantic Coding (Animal Related Facts)

Overall semantic score was assessed with an ANOVA, which was followed by ANCOVAs controlling for narrative length and time delay for reasons mentioned above. The ANOVA showed age-related improvements in the overall number of facts children recalled in their narratives $F(2,101) = 11.48$, $p < 0.001$, $\eta_p^2 = 0.19$. Pairwise comparisons revealed the narratives of 8- to 10-year-olds ($M = 6.71$, SD = 5.65) included more semantic facts than the narratives of 6- to 7-year-olds ($M = 4.22$, SD = 3.91), $p < 0.001$. Four to 5-year-olds ($M = 1.59$, SD = 1.76) included fewer semantic facts than both older age groups ($ps < 0.02$). The descriptive statistics for each age group as well as analysis of age difference for separate semantic codes are reported in **Table 7**. Age group differences in overall semantic codes seems to be driven by the age group differences in BF, TF, and AF codes.

With an ANCOVA controlling for time delay, a main effect of age group was found, $F(2,99) = 9.41$, $p < 0.001$, $\eta_p^2 = 0.16$. The above age group pattern holds: 4- to 5-year-olds had a lower overall number of semantic codes compared with 6- to

TABLE 6 | Descriptive statistics for each AM code for the experimenter-selected event.

Narrative category	Age group				Age-group differences
	Overall	4–5 *M* (SD)	6–7 *M* (SD)	8–10 *M* (SD)	
Sum of narrative codes	31.86 (27.02)	19.11 (8.06)	28.94 (14.74)	42.80 (37.52)	**$F(2, 101) = 7.39$, $p = 0.001$, $\eta_p^2 = 0.13$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
Who	2.38 (1.80)	1.67 (1.11)	2.22 (1.67)	2.98 (2.09)	**$F(2, 101) = 4.83$, $p = 0.01$, $\eta_p^2 = 0.09$** [4- to 5-year-olds < 8- to 10-year-olds]
What-object	2.73 (3.49)	1.52 (1.58)	2.83 (3.96)	3.44 (3.80)	$F(2, 101) = 2.57$, $p = 0.08$, $\eta_p^2 = 0.05$
What-object-animal	3.24 (3.98)	1.81 (2.15)	2.86 (2.02)	4.51 (5.58)	**$F(2, 101) = 4.24$, $p = 0.02$, $\eta_p^2 = 0.08$** [4- to 5-year-olds < 8- to 10-year-olds]
What-action	9.31 (9.13)	4.97 (2.47)	8.22 (5.04)	13.12 (12.64)	**$F(2, 101) = 7.80$, $p = 0.001$, $\eta_p^2 = 0.13$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
Where	1.99 (2.70)	0.89 (1.15)	1.64 (1.59)	3.02 (3.68)	**$F(2, 101) = 6.15$, $p = 0.003$, $\eta_p^2 = 0.11$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
When	2.78 (4.47)	1.52 (1.45)	2.25 (1.86)	4.12 (6.64)	**$F(2, 101) = 3.30$, $p = 0.04$, $\eta_p^2 = 0.06$** [4- to 5-year-olds < 8- to 10-year-olds]
Why	0.65 (1.85)	0.19 (0.48)	0.31 (0.89)	1.27 (2.70)	**$F(2, 101) = 4.00$, $p = 0.02$, $\eta_p^2 = 0.07$** [4- to 5- and 6- to 7-year-olds < 8- to 10-year-olds]
How-description	3.06 (3.42)	1.74 (2.18)	2.83 (2.80)	4.12 (4.22)	**$F(2, 101) = 4.32$, $p = 0.02$, $\eta_p^2 = 0.08$** [4- to 5-year-olds < 8- to 10-year-olds]
How-evaluation	2.81 (2.35)	1.30 (0.10)	2.78 (1.80)	3.83 (2.85)	**$F(2, 101) = 11.38$, $p < 0.001$, $\eta_p^2 = 0.18$** [4- to 5-year-olds < 6- to 7-year-olds < 8- to 10-year-olds]

For significant main effects of age (bolded statistics), pairwise comparison of age group differences that had a p < 0.05 are summarized in square brackets.

7-year-olds and 8- to 10-year-olds, *p*s < 0.02; 6- to 7-year-olds had a lower overall number of semantic codes than 8- to 10-year-olds ($p = 0.02$).

With an ANCOVA controlling for narrative length, there was no main effect of age group in the overall semantic score, $F(2,100) = 1.19$, $p = 0.31$, $\eta_p^2 = 0.02$. When we conduct an ANCOVA controlling for both narrative length and time delay, there were no main effect for age group in the overall semantic score, $F(2,98) = 0.94$, $p = 0.39$, $\eta_p^2 = 0.02$. Thus, when controlling for narrative length and time delay, we do not find significant age-related differences in overall number of facts provided.

For the experimenter-selected event narrative the percentage of semantic-related talk for each age group were as follows: 4- to 5-year-olds ($M = 9.48\%$, SD = 10.38), 6- to 7-year-olds ($M = 18.33\%$, SD = 16.48), and 8- to 10-year-olds ($M = 19.96\%$, SD = 11.64). Not only did we find age group differences in the amount of overall talk, but we also found age group differences in the amount of talk in which children made generalizations or fact-like statements, $F(2,101) = 5.52$, $p = 0.005$, $\eta_p^2 = 0.10$. Pairwise comparisons revealed 4- to 5-year-olds' percentage of semantic talk was lower than that for both older age groups (*p*s < 0.02). Six to 7-year-olds and 8- to 10-year-olds did not perform differently (*p*s = 0.59). Thus, there were age-related differences in the percentage of fact-like statements children included in their narratives for the experimenter-selected event.

Gender

A significant interaction between age group and gender was found when gender was included as a factor in the above analyses. For example, for overall semantic score the ANOVA for this experimenter-selected event narrative revealed an interaction between age group and gender, $F(2, 98) = 4.37$, $p = 0.02$, $\eta_p^2 = 0.08$. To follow-up this analysis, we conducted analyses for each age group separately and found that for the 8- to 10-year-old group only, boys ($M = 9.11$, SD = 6.18) included more semantic facts in their narratives than girls ($M = 4.64$, SD = 4.29), $t(39) = 2.72$, $p = 0.01$. There were no gender differences for the two youngest age groups, *t*s < 0.5, *p*s > 0.62. To check whether the gender difference for the 8- to 10-year-olds could be due to a difference between boys and girls in the delay between experience of the experimenter-selected event and test, we conducted a *t*-test but found no difference between boys and girls in delay, $t = 0.31$, $p = 0.76$. To determine whether outliers could explain these results, we removed 2 boys whose overall semantic score was greater than 18 (mean score for age group + 2 × SD for age group). Even with these outliers removed from the analysis, the gender difference for overall semantic score remained: $t(37) = 2.12$, $p = 0.04$.

Post hoc Analyses

A partial correlation, controlling for both age in months and narrative length, revealed no relation between narrative breadth score and overall semantic score, $r(100) = 0.05$, $p = 0.61$. (Note there is a positive correlation between these variables when narrative length is not included as a control variable).

Descriptive Comparison of Both Events

Overall children provided relatively long narratives, and anecdotally, children in our study were excited to talk about their experiences visiting the animal exhibits at this local zoo. We do not directly compare the child-selected and experimenter-selected narratives in analyses for the reasons described previously. However, we did plan to compare patterns found on an exploratory basis and report this here.

For both the child-selected and experimenter-selected event narratives, we found age-related increases in narrative length. For the child-selected event, 8- to 10-year-olds provided longer narratives compared to the two youngest age groups, which did not differ. For the experimenter-selected event, all three age groups were different from each other and showed steady increases. We note the different age patterns for the child-selected event (favorite animal) compared to experimenter-selected event narratives. Specifically, the 4- to 5- and 6- to 7-year-old groups did not differ in narrative length for the child-selected event, but 6- to 7-year-olds provided longer narratives than 4- to 5-year-olds for the experimenter-selected event.

For the child-selected event narrative, we found that the two oldest age groups (which did not differ from each other)

TABLE 7 | Types of recalled facts for experimented-selected event.

Type of fact	Age groups			Age-group differences
	4–5 *M* (SD)	6–7 *M* (SD)	8–10 *M* (SD)	
Behavior fact	0.37 (0.69)	1.11 (1.35)	1.80 (1.85)	**$F(2,101) = 8.06, p < 0.001, \eta_p^2 = 0.14$** [4- to 5-year-olds < 6- to 7-year-olds < 8- to 10-year-olds]
Targeting fact	0.15 (0.36)	0.56 (1.54)	1.05 (1.55)	**$F(2,101) = 3.78, p = 0.03, \eta_p^2 = 0.07$** [4- to 5-year-olds < 8- to 10-year-olds]
Abstract fact	0.56 (0.97)	1.78 (2.06)	2.71 (2.76)	**$F(2,101) = 7.99, p < 0.001, \eta_p^2 = 0.14$** [4- to 5-year-olds < 6- to 7-year-olds and 8- to 10-year-olds]
Concrete fact	0.44 (0.93)	0.56 (1.08)	0.98 (1.80)	$F(2,101) = 1.48, p = 0.23, \eta_p^2 = 0.03$
Evaluative fact	0.07 (0.39)	0.22 (0.42)	0.15 (0.36)	$F(2,101) = 1.14, p = 0.33, \eta_p^2 = 0.02$

For significant main effects of age (bolded statistics), pairwise comparison of age group differences that had a p < 0.05 are summarized in square brackets.

had a higher narrative breadth score than the youngest age group. When we controlled for narrative length, however, the age-related differences in narrative breadth for the child-selected event narrative disappeared. For the experimenter-selected event narrative, all three age groups differed with age-related improvements throughout this period of childhood (when we did not control for narrative length). When we did control for relevant factors (delay, narrative length, both delay and length) we found that age group differences remained.

In terms of the semantic facts included in narratives, we found that for the child-selected event, 8-year-olds' narratives contained a higher number of facts (overall semantic score) compared to both younger age groups, which did not differ from each other. However, when we controlled for narrative length the age groups no longer differed in the number of overall facts for the child-selected event narrative. For the experimenter-selected animal, we found that all 3 age groups differed from each other and showed steady increases in the number of facts provided in this 4- to 10-year-old age range. However, when we controlled for narrative length, these age-group differences disappeared.

DISCUSSION

The purpose of the present research was to examine children's memory and learning from a week-long experience at a local zoo. Our primary goals were to examine 4- to 10-year-olds' autobiographical event narratives to determine what types of event details and facts are recalled in narratives and how narratives differ between age groups. We also examined whether there would be relations between individual differences in event details and facts (i.e., are the children who included more types of AM details also the children who included more facts?). To achieve these goals we adopted coding schemes, measures and analysis procedures routinely used in the AM literature (AM coding; narrative length and breadth measures), but also introduced a new coding scheme to examine children's inclusion of semantic facts in their narratives (i.e., facts about animals and animal-related science facts). A secondary and exploratory goal was to determine whether different patterns are observed for different types of experiences. For one event narrative, children described their favorite animal visit (child-selected event; high self-relevance) and for the other event narrative children described an animal visit selected by the experimenter. For various methodological reasons we did not directly or quantitatively compare these two types of events in analyses. However, we can discuss the pattern of findings for each event type and discuss whether patterns differed, while being mindful that self-relevance alone may not fully explain any pattern differences (see limitations below). The present work complement and extend past AM development research. Further, our findings can be useful for staff in informal learning institutions like science centers and zoos, who support children's education and promote curiosity and excitement about science.

Examination of the types of AM categories (event details) children provide in our study is consistent with past work and can be useful to museum and zoo educators. For example, examination of **Table 4** shows that children often included event details that fell into the "what-act" category, similar to past work with autobiographical events from further in the past (Bauer et al., 2007). It is possible that children include more details pertaining to actions because they attend to those features of events. This is consistent with DeMarie (2001) who found that young children often chose to photograph actions when provided with cameras during a field trip to a zoo. Further, our study adds to knowledge about the number and types of animal-related facts that were retained and spontaneously included when children were asked to describe particular events at the zoo (visits to animal exhibits). We found that children included a relatively high number of fact-like details in their narratives, but there was more representation of some fact categories than others as can be seen in the descriptive information provided in **Tables 5**, **7**. Previous studies have found that different age groups tend to focus on different things during field trips to informal learning environments (see Farrar and Goodman, 1992; Birney, 1995; DeMarie, 2001) which has implications for what they will learn from these events and how school programs and field trip programs can be developed based on this knowledge. Educators may also be interested to know that individual differences in narrative breadth was not correlated with individual differences in the overall number of semantic facts. In other words, it is not the case that the children who provided more complete accounts of the events (included more different types of AM categories) were also the children who included more facts in their narratives.

Our findings of age-related improvements in narrative length (for both event types) are consistent with past research that also find that older children provide longer memory narratives than younger children (e.g., Habermas et al., 2010; Bauer and Larkina, 2019; see also Bauer et al., 2019). It is interesting that the 4- to 5- and 6- to 7-year-old groups did not differ in narrative length for the child-selected event, but 6- to 7-year-olds provided longer narratives than 4- to 5-year-olds for the experimenter-selected event. Thus, it is possible that self-relevance increased how much the youngest children wanted to talk about their experiences for this child-selected (favorite animal) event.

In addition to the amount of talk, we also measured the completeness of children's memory narratives. Given age-related differences in narrative length, we conducted analyses on the narrative breadth measure both with and without controlling for length, an approach used previously (e.g., Bauer et al., 2017). This is important because focusing on only one or the other limits our ability to see the full pattern. For the child-selected event narrative, we found that older children provided more complete narratives (included more different types of AM details; narrative breadth score) than the youngest age group. Once we considered length of narratives, the age-related differences in narrative breadth for the child-selected event narrative disappeared. For the experimenter-selected event narrative, there were age-related improvements (whether or not we controlled for different factors like length). Age-related improvements in narrative breadth scores have been found in several past AM studies (e.g., Bauer and Larkina, 2014, 2019), but not all studies (e.g., Van Abbema and Bauer, 2005). Our finding that 4- to

5- and 6- to 7-year-olds did not differ in narrative length but did show differences in narrative breadth for the child-selected (favorite animal) event narrative is important to note. It suggests that even though these two age groups talked similar amounts, and thus had similar opportunities to provide details in their narratives, they still differed in the number of traditional event detail categories (who, what, where, etc.) that were represented in their narrative (at least when length was not controlled). This particular finding is consistent with Bauer and Larkina (2014) who found that age groups did not differ in their talkativeness, but 5- and 6-year-olds scored lower than 8- and 9-year-olds for narrative breadth.

The present study's findings on narrative breadth extends past work by comparing general patterns for the two event types. We showed that there were minimal age-related differences in narrative breadth for our self-relevant event (oldest age group only scored higher than younger groups without covariates in analysis; there were no age group differences once we accounted for covariates), but robust age-related differences for the less self-relevant event (age group differences found between all 3 age groups without covariates; age group differences between youngest and oldest groups remained even with all relevant covariates). This pattern of findings is reminiscent of Pathman et al. (2011) because they found that age-related differences in recognition memory accuracy were minimized for a condition which involved high personal involvement compared to a condition that was designed to be less self-relevant. These patterns add to evidence that increasing self-relevance and ownership can boost children's memory (e.g., Turk et al., 2008; Cunningham et al., 2013, 2014, 2018) and affect adults' memory accuracy, content, or elaborative processing (see Rogers et al., 1977; Barney, 2007).

Our study is useful for staff at informal learning institutions (and other education settings) because their exhibits and experiences cannot often be tailored to narrow age ranges. Although exploratory, our results suggest that when an event is less self-relevant, there may be larger age gaps in what children include in their AM narratives. It is useful for educators to know that increasing self-relevance or personal involvement may help younger children recall as many types of AM event details as older children. This is also consistent with recommendations from a qualitative study by Wolins et al. (1992) in which they asked children why certain field trips stood out and led researchers to recommend that educators "allow children opportunities for choice, for ways to personalize the experience" (p. 26).

Unlike our findings for AM coding, self-relevance did not seem to boost children's inclusion of facts in their narratives. We found, for both the child-selected and experimenter-selected events, that older children's narratives contained more facts (overall semantic score) compared to younger children. However, when we controlled for narrative length, age groups differences were no longer apparent. Thus, our results suggest that although self-relevance impacts the amount of autobiographical/episodic event details, it may not impact the total number of facts children choose to discuss. We also see that the particular fact categories driving age differences (before controlling for covariates) showed both similarities and differences across the two event narratives. For both event types, age-group differences were apparent for the TF and AF categories. Thus, compared to younger children, older children included more facts that required remembering unobservable concepts and semantic details and required remembering names of subgroups for which particular information applied. In other words, for both event narratives older children included, arguably, more challenging semantic information than younger children – more challenging because this information is unlikely to be produced or reconstructed based on memory for event details. Age group differences for target facts is consistent with age-related improvements in children's ability to learn and perceive conceptual hierarchies in early to middle childhood (e.g., Schaeffer et al., 1971; Whitney and Kunen, 1983) and remember specific labels in generic statements (Gülgöz and Gelman, 2015). Age group differences for AFs is consistent with improvements across childhood in the ability to associate knowledge with existing mental concepts during the learning process (see discussions Gelman and Brenneman, 2004). At the same time, two fact categories did not show similar effects for the two types of event narratives. Older children provided more CFs (e.g., visually observable information) than younger children for the child-selected event narratives, but this age difference was not there for the experimenter-selected event narrative. For the experimenter-selected event narrative, older children included more facts having to do with an animal's behavior in their narratives, compared to younger children. We do not want to make strong claims about these differences between the two event types. Overall, however, it is useful for museum educators to know what types of facts are included when children are asked to recall their experience visiting an exhibit and the things they learned (as a reminder, our autobiographical interview included the standard questions used in past research, plus an additional sub-question question in which children were asked about the cool/neat things they learned). Further, it is useful to know for what types of fact categories younger and older children are showing similar levels of learning and for what types of fact categories younger children are trailing behind older children. Future studies are needed to see if our findings about the different fact categories represented would be replicated in other zoo or science centers that contain animal exhibits.

Our goals were to examine children's memory and learning following engaging experiences at a local zoo. By examining both autobiographical event details and semantic details included in response to open-ended questions we determined what types of details were recalled and whether there were age group differences in their recall. Unlike previous AM coding studies that did not distinguish past event details from fact-like details (they were both included in AM coding), we additionally determined different categories of semantic facts that were represented in children's autobiographical narratives. These facts could have been remembered because they heard a zoo staff member providing that information, and the child was able to then recite that information in their narrative. These facts could also have been generated by the child based on their own observations at the zoo. For example, it is possible that a child stated that giraffes have dark tongues because they remembered that the particular giraffe they visited had a black tongue and generalized this information to all giraffes. Of course, the latter example is more likely to have occurred for some semantic codes in our study (e.g., CFs) and the former is more likely to have occurred for other semantic codes (e.g., AFs). However, this is an empirical question and future studies could observe or record children's experiences during the animal visit to determine the various sources of new semantic information children later incorporate into their narratives.

Observing and/or recording children's experiences and conversations during museum visits have been successfully used in several past studies (e.g., Benjamin et al., 2010; Cox-Peterson et al., 2003; Palmquist and Crowley, 2007; Rigney and Callanan, 2011), two of which are especially relevant to the present work because they discussed both autobiographical/episodic memory and learning. Jant et al. (2014) recorded children and their parents during their visit of two museum exhibits and, for a subset of participants, also obtained recordings of conversations parents had with their children about their memories for the museum experiences. These researchers observed that the conversations consisted of both episodic details and semantic details. Imuta et al. (2018) built on this observation in their study. Researchers interviewed 5- and 6-year-old children after a science lesson that they experienced in either a field trip context or in a classroom context (between-subjects design). They asked children what they remembered about each experience and coded children's responses into two categories: autobiographical information (i.e., info about what happened during that event) and scientific information (i.e., information about something they learned). Researchers found that for autobiographical information, but not scientific information, children recalled more in the fieldtrip context than the classroom context after a delay of 1–2 days. Although the goal of the present study was not to compare different learning contexts, our study extends the work of Imuta and colleagues by examining multiple sub-categories of details within the autobiographical and semantic information categories. Imuta and colleagues found that the amount of autobiographical information children recalled was predictive of the amount of scientific information they recalled. This is in contrast to our study because we did not find that individual differences in AM narrative breadth was correlated with individual differences in the overall semantic score, at least when we controlled for narrative length. As far as we can tell, Imuta and colleagues did not control for the amount of talk in their analyses, which could account for the different findings. Future studies could help to clarify whether or not children who provide more autobiographical details also provide more semantic details. Future work would also benefit from examination of other types of individual differences that could impact children's learning and memory.

We did not find gender differences in any of our AM measures (length and breadth) for either event. We also found no gender differences for the semantic measure for the child-selected event. However, for the experimenter-selected event we found that for the 8- to 10-year-old age group boys included more semantic information in their narratives than girls. Given that this gender difference is isolated to only one age group and only to one of the two event narratives, this effect should be interpreted cautiously, and future studies are needed to determine if this effect would be replicated. If this effect is replicated, then additional research would help to explain why there may be an effect of gender on our semantic memory measure. For example, did older boys ask more questions from zoo staff and thus hear more semantic information during the experimenter-selected event? Imuta and colleagues did not examine gender effects in their study. However, advantages for boys have been found in other studies about science learning. For example, Crowley et al. (2001b) examined parent-child conversations at a science exhibit and found that parents provided more explanations when speaking with boys compared to girls. Further, Tenenbaum et al. (2005) showed mothers playing with magnets with their children engaged in more science talk with boys compared to girls (and with older children compared to younger children). Still, other museum studies have found no systematic gender differences (Crowley et al., 2001a; Benjamin et al., 2010; Haden et al., 2014; Jant et al., 2014). Thus, there are mixed findings about gender differences in relation to science learning. Studies are also mixed in terms of gender differences in AM narratives such that some have found girls provide longer and/or more complete AM narratives than boys (e.g., Buckner and Fivush, 1998; Bauer et al., 2007), whereas other studies have not found gender differences (see review Grysman and Hudson, 2013). We also did not find gender differences in our AM narratives. Our original goal was not to examine gender differences, and so these results should be interpreted cautiously. Future studies on children's experiences at informal learning environments that are designed to examine both gender and age group differences, but also individual differences in other domains, are needed and would help to determine ways to optimize memory and learning outcomes.

Several caveats and limitations about the present study should be noted. First, our data were based on open-ended questions, paralleling past AM studies. We examined the number and types of semantic facts children included in their narratives spontaneously. It is possible that children would have recalled more information with more specific cueing (e.g., "What did you learn about a rhino's horn tissue?"). As such, future work could incorporate both open-ended narrative questions and direct fact-based questions. Second, we did not video-record individual children's visits to exhibits throughout the week and thus do not know exactly what was seen and heard by children. Thus, our study cannot tell us about the proportion of total *possible* event details and facts that were recalled and how much of that was accurate. Such a study would be laborious (coding videos for all possible episodic and semantic details to determine what exactly was experienced by each child), but is a needed extension of the present work.

Another planned limitation was that the order in which we elicited the narratives for the two events were always the same: child-selected event narrative was obtained before the experimenter-selected event narrative. This was necessary in our study for several reasons, including knowing that time limitations would not allow us to test both event types in all children, that the experimenter-selected event was constrained to particular experiences, and importantly we needed the child-selected event narrative to occur first so that the experimenter-selected event would not be about the same event. Thus, we planned not to include both event types in the same analysis. However, this meant that in addition to the two events differing in the amount of self-relevance, it is also the case that describing the experimenter-selected event could have been more taxing for children because it was always later in the interview. Future studies could extend this work by making the primary goal of the study directly comparing event types based on these findings. Future studies could also examine why there may have been an advantage for the child-selected event. In the present work we do not know whether children chose a particular animal as their favorite because this preference existed prior to attending zoo camp, and if this preference caused children to have increased attention to that particular animal visit. Studies have found a link between curiosity and learning (see Gruber et al., 2014; Oudeyer et al., 2016). On the other hand, it is possible that children established a particular animal as their favorite after seeing that exhibit. A future adaptation of the present work could involve interviewing children before attending zoo camp to determine how pre-existing preferences may influence later memory and learning, similar to a study that examined children's knowledge about what usually happens during visits to the zoo before and after a zoo experience (DeMarie et al., 2000).

Finally, one of the features of the present study was that it involved an extended set of experiences over a 5-day span. However, this meant that children had multiple opportunities for conversations with others about their experiences during this time period, before our test session on the last day of camp. For instance, it is likely that children spoke about their camp experiences, including animal visits, with parents at home. Leichtman et al. (2017) found that parents' conversational styles influenced the amount of information children contributed during the conversation with parents, and this in turn was correlated with how much they remembered in an interview with researchers 6 days later. In the present work, we did not examine how conversations with peers during the camp, or at home with their parents, influenced their retention of event details and fact knowledge, but this would be an interesting line of future work.

Field trips or trips to informal learning institutions not only act as a naturalistic learning setting but have also exhibited a strong potential for improvement of cognitive development, critical thinking skills and as motivators for advanced learning (Hurley, 2006; Greene et al., 2014). Our work echoes these findings and demonstrates that informal learning institutes are an engaging method for children to learn and recall information. Educators can captivate children's attention by actively asking children questions to help them attend to specific details rather than requiring them to passively listen to information. This may be especially helpful for younger age-groups who displayed a lower number of autobiographical and semantic recall than older age groups for certain types of events. Encouraging children and parents to discuss the event and what children learned about can also prove to be helpful for recall of scientific information (Leichtman et al., 2017).

To conclude, using a controlled naturalistic study, we examined children's memory for event details and the retention of fact knowledge after a week-long summer camp at a local zoo. In addition to extending previous studies on AM, we determined the types of science-related facts children included in their AM narratives and how that changed across early to middle childhood. We also discuss the various ways future studies can extend our results. We hope the present line of work along with the existing literature (e.g., Birney, 1995) can be useful for science educators and informal learning environments to promote children's memory and learning outcomes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research Ethics Board at York University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

TP conceptualized, designed, supervised the research, and conducted the analysis. TK, PP, and TP contributed to the data collection. TK, PP, and GF contributed to the narrative coding, reliability analysis, and data entering/processing. All authors contributed in different ways to writing and revising the manuscript. TK and GF used portions of the data for their undergraduate honors thesis projects. All authors contributed to the article and approved the submitted version.

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"He Fell in and That's How He Became a Fossil!": Engagement With a Storytelling Exhibit Predicts Families' Explanatory Science Talk During a Museum Visit

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Parent-child conversations in everyday interactions may set the stage for children's interest and understanding about science. Studies of family conversations in museums have found links to children's engagement and learning. Stories and narratives about science may spark children's interest in science topics. This study asks whether a museum exhibit that provides opportunities for families to create narratives might encourage families' explanatory science talk throughout the rest of the exhibit. The project focused on the potential impact of a hands-on story-telling exhibit, the "spin browser" embedded within a larger exhibition focused on fossilized mammoth bones—*Mammoth Discovery!* at Children's Discovery Museum of San Jose. Participants were 83 families with children between 3 and 11 years (mean age 7 years). We coded families' narrative talk (telling stories about the living mammoth or the fossil discovery) and connecting talk (linking the story to other nearby exhibits) while families visited the spin browser, and we also coded families' explanatory science talk at the exhibits that contained authentic fossil bones and replica bones. The parents in families who visited the spin browser ($n = 37$) were more likely to engage in science talk at the fossil exhibits than those in families who did not visit the spin browser ($n = 46$). Further, a regression analysis showed that family science talk at the fossil exhibits was predicted by parents' connections talk and children's narrative talk at the spin browser. These findings suggest that families' narratives and stories may provide an entry point for science-related talk, and encourage future study about specific links between storytelling and science understanding.

Keywords: storytelling, science, informal science learning, parent-child conversation, museum learning, children's science understanding

INTRODUCTION

Around the world, stories and storytelling are part of everyday life for many children. Bruner (1986) identified narrative and storytelling as a fundamental human cognitive process, arguing that it is perhaps more natural to human thought than are logical or scientific modes of reasoning. Building on these ideas, researchers have argued that narrative may be a more effective way to communicate about science, technology, engineering, and mathematics (STEM) fields to children and students than the typical type of expository language used in textbooks (Avraamidou and Osborne, 2009; Wilson-Lopez and Gregory, 2015). Similarly, children's museum educators and early childhood educators recognize stories as a developmentally appropriate way to communicate about science and other topics with young children (Frykman, 2009). Despite growing attention to this potential connection, not much research has directly investigated the link between storytelling and science understanding.

We explored the link between stories and science in family conversations as part of an interdisciplinary collaborative project (Callanan et al., 2017) situated within a long-standing research-practice partnership (Callanan et al., 2016). Working in parallel with the design of a new children's museum exhibition, we investigated the effectiveness of a storytelling exhibit as a potential motivator for young children's engagement with science thinking in the domain of paleontology. The project focused on the potential impact of a narrative-based museum exhibit embedded within a larger children's museum exhibition regarding fossilized mammoth bones. In this NSF-funded research-practice partnership, paleontologists, science educators, and developmental science researchers worked with children's museum experts to create a developmentally appropriate exhibition focused on paleontology within a children's museum.

To provide background for the study, we first consider relevant research on children's learning through family conversations, on how narratives can support scientific thinking, and on how museum practice can support informal science learning. Finally, we introduce the study.

Cognitive Developmental Change Through Parent-Child Conversation

Parent-child conversations in everyday interactions set the stage for children's interest and understanding about science. Research on parent-child shared book-reading has uncovered ways that family conversations can contribute to children's developing vocabulary, causal understanding, and general knowledge (Reese et al., 2010). Shirefley et al. (2020) found that family book-reading conversations can also be effective in engaging children with science practices and topics within specific fields such as astronomy.

Beyond book-reading, studies of family conversations in museums have focused on ways that family conversations introduce children to science practices such as questioning (Haden et al., 2014), observing (Eberbach and Crowley, 2017), and explaining phenomena (Crowley et al., 2001; Callanan et al., 2017, 2021). Other studies have found links from parent-child conversation to children's engagement and learning experiences (Rigney and Callanan, 2011; Haden et al., 2014). For example, Benjamin et al. (2010) found that the frequency of parents' *Wh*-questions while engaged with a museum exhibit was related to children's understanding and retention of information from the exhibit. In a recent study, Callanan et al. (2020) found that the particular timing of parents' explanatory talk was important; parents' causal talk offered when children were beginning to explore a gear exhibit predicted more systematic exploration by children. Further, Booth et al. (2020) found that parents' causal talk in conversations with young children predicts children's causal stance (i.e., their preference for causal information about novel artifacts and animals) as well as their scientific literacy.

Because parent-child explanatory conversations about science have been shown to be important for children's science learning and understanding, we asked in this study whether engagement with story-telling in a children's museum exhibit predicts more focus on explanatory science talk during the same visit.

Stories as a Basis for Learning Science

Building on Bruner's (1986) call for cognitive science to focus on a narrative mode as well as a logical-scientific mode of human understanding, researchers have asked whether using narrative may help children better understand and connect with science topics. Communicating scientific ideas through stories may better engage non-experts with science by making the ideas more meaningful and relatable (Avraamidou and Osborne, 2009).

Further, creating narrative is arguably part of doing science: scientists such as paleontologists and astronomers put together evidence and create plausible stories of what may have happened in the past. Despite the reliance on the standard scientific method in science classrooms, Judy Scotchmoor and colleagues showed, in the website (Understanding Science, 2021), that there are many complex aspects to how science really works (see Thanukos et al., 2010). This website, which serves as a tool for science teachers and students, uses narratives of how scientific discoveries were made to illustrate how scientific arguments rely on evidence and are embedded in the scientific community and the broader world.

Listening to and creating narratives about science have been argued to relate to children's interest in science-related activities (Dahlstrom, 2014; Siegel and Cid, 2021). Further, two recent attempts to teach children complex concepts (both related to evolution) through story-telling have been quite successful (Kelemen et al., 2014; Evans et al., 2016). For example, Kelemen et al. (2014) created a storybook about natural selection and found evidence that the book supported sophisticated understanding of this abstract topic in children as young as 5 years.

Stories in Museum Exhibit Design

Museums use narratives in their written and web-based materials to engage visitors with their activities (Frykman, 2009). Little is known about how effectively specific variations in museum exhibit design may create opportunities for families to build narratives and encourage thinking about science topics. Stories and narratives about science have been argued to relate to children's interest in science-related activities (Dahlstrom, 2014).

Perhaps exhibits that provide opportunities for families to build narratives could encourage families' explanatory talk throughout the museum.

A few museum studies have shed particular light on the role of stories and narrative as a framework for children's understanding. In particular, Evans et al. (2016) found that 5–14-year-old children engaged in less anthropomorphic reasoning about species change and more reasoning about natural selection after visiting a narrative-based museum exhibit about dinosaur-bird evolution compared with visiting a control exhibit on a different topic. Further, Haden et al. (2016) explored connections between how families were prompted to interact at a building exhibit (either "build" information about how to create strong buildings, or "talk" information about having open-ended conversations with children, or both) and the narratives children told later (either after reuniting with their other parent or at home later). In this study, children's narratives were an informative measure of children's understanding because they differed depending on the prompts families were given. Both for reunion narratives and later memory narratives, children from the build + talk group talked more about engineering as a way to design and redesign their buildings, and also offered more spontaneous talk (not in answer to questions) than children in other groups. In more recent work, Pagano et al. (2019) studied children's narrative reflections about their activities in a tinkering lab at a nearby "Story Hub" exhibit. They found that families who engaged in a tinkering design challenge elaborated more in their narratives than did children who engaged in open-ended tinkering.

It is clear from the review of previous research that narratives and stories may support children's science understanding. The next step is to ask about whether a story-based exhibit might facilitate children's and families' thinking about science at related exhibits.

Current Project

This project began with an exciting opportunity and a daunting challenge. Fossilized mammoth bones were found near Children's Discovery Museum of San Jose, and the museum was given the opportunity to build an exhibit around those bones. The NSF-funded research-practice partnership project, "Lupe's Story," resulted, with co-PIs Jennifer Martin from Children's Discovery Museum of San Jose, Judy Scotchmoor from UC Museum of Paleontology, and Maureen Callanan from University of California, Santa Cruz. The project resulted in the permanent exhibit *Mammoth Discovery!*

The initial challenge of this project involved how to present a natural history style exhibit in a children's museum that values hands-on, active engagement with materials and phenomena. Two components of the team's solution emerged: (a) a goal of encouraging families to consider the bones as *evidence* as a way to answer questions, and (b) a focus on the developmentally appropriate activity of telling *stories*. The exhibition includes a number of opportunities for families to tell stories—including stories about the life of the animal whose remains were on display as a fossil, as well as stories about how the fossils were discovered, and how they made their way to the museum.

This study focuses on one exhibit in particular—the *Spin Browser,* a hands-on animation exhibit that allows visitors to spin a dial to view the story of the mammoth whose fossilized bones are displayed nearby. Visitors can move the dial in different speeds and directions, and can watch how the mammoth went through living, dying, being fossilized, being discovered, and being transported to the museum. The main focus of this study is whether and how engagement with story-telling at the Spin Browser might relate to scientific talk at other parts of the *Mammoth Discovery!* exhibition.

We coded families' narrative engagement with the Spin Browser, and we also coded families' explanatory talk at the exhibits that contained authentic fossils, replica bones, and large-scale skeleton replicas. Our research questions are: (1) Did families who visited the spin browser engage in more science explanatory talk at the fossil and replica bone exhibits than families who did not visit the spin browser? (2) Did family narrative talk at the spin browser predict science explanatory talk in the fossil and replica bone exhibits?

METHODS

Participants

Eighty-three families were invited to participate as they visited Children's Discovery Museum of San Jose (San Jose, CA) on weekend days. Families agreed to be videotaped while visiting the *Mammoth Discovery!* exhibition. The exhibition was new at the time, but we also checked with families and only included those who had not yet visited. Forty-one children were in a younger group ranging from 3 to 6 years ($M = 64$ months) and 42 were in an older group ranging from 7 to 11 years ($M = 106$ months). The overall average age was 85 months. Target children included 40 boys and 43 girls. Visitors to the museum were from diverse ethnic backgrounds; families who participated described their ethnicity as White (or European-American or Caucasian): 35%, Asian (or Chinese, Chinese American, Korean, Taiwanese, or Vietnamese): 21%, South Asian (or Indian, or Asian Indian): 18%, Latino (or Hispanic, or Mexican-American): 12%, and mixed heritage (e.g., Mexican-Filipino, White-Pacific Islander): 12%. Parents were asked about their years of formal schooling as a proxy for socioeconomic level. On average, parents reported completing 16 years of school ($SD = 3.05$; range = 5–24 years). Half the families visited the exhibition first, and then took part in a series of activities in a research room; the other half engaged with the research room activities first and then visited the exhibit. A subset of 37 families (19 who visited the exhibit first and 18 who visited the research room first) visited the Spin Browser exhibit, 23 with girls and 14 with boys. The mean age of this group of children was 91 months.

Procedure

Families were approached within the museum and asked to participate in a research project about how children learn with their parents. Families who agreed to participate were asked for permission to be videotaped while visiting the *Mammoth Discovery!* exhibition. Half the families were randomly selected

FIGURE 1 | Child seated at Spin Browser exhibit in *Mammoth Discovery!* exhibition at Children's Discovery Museum of San Jose. The full-scale mammoth replica is visible outside the window and one of the Dig Pit exhibits is visible at lower left.

to visit the exhibit first, and then come to a research room to complete several tasks and questionnaires; the other half of the families visited the research room first and then explored the exhibit. While in the exhibit, one member of the parent-child dyad (usually the parent) wore a lavalier remote microphone. A stationary video camera captured most of the dyad's movement through the exhibition; even when the family was not visible on camera, their audio was captured. While in the research room, parents filled out demographic and attitude questionnaires while children engaged in two tasks: a sorting task where they were chose the "same kinds of thing" from triads including fossils and human-made items, and an evidence task in the form of a storybook about finding out who spilled some paint. Finally, the parent and child were shown a "mystery object"—which was a fossilized mammoth tooth, and asked to discuss what it might be and how one would know. These measures are not considered in the present analyses.

For this study, we were particularly interested in family narrative talk occurring at the Spin Browser exhibit, an exhibit embedded within the mammoth exhibition, as shown in **Figure 1**. This exhibit contains a hands-on animation that allows visitors to view the story of the mammoth whose fossils were found near the museum and are displayed at the mammoth exhibit. The exhibit displays pictures that visitors can animate by turning a knob—the animation can go either forward or backward; direction and speed of turning the knob determines the direction and speed of the video. There are no signs at the exhibit but a caption is visible at the bottom left of the display and a subtle marker signals where one is in the timeline from left to right. There are three sections to the animation, each with a caption: "Becoming a Fossil," "Changing Valley," and "Uncovering a Fossil." **Figure 2** shows screen shot examples from each section. The exhibit design was intended to support storytelling about the mammoth's life and death, about how bones of a living animal become fossils, about changes in the local area over time, and about the discovery of the fossilized bones.

When in the *Mammoth Discovery!* exhibition, families were free to spend as much (or as little) time as they wished, and to visit any exhibits in any order. Researchers did not prompt families to visit the spin browser or any other exhibit. This meant that visits to the spin browser were not guaranteed, and that families who did visit the spin browser might do so at any time during their visit.

We coded families' explanatory science talk at 8 exhibits, including 3 exhibits showing authentic fossilized bones, 3 exhibits showing replicas of bones or of the full mammoth, and 2 hands-on dig pits where children could work with tools to uncover replica mammoth bones. Previous research presented some of these findings (Callanan et al., 2017). See **Figure 3** for sample exhibits.

Coding

Family visits were fully transcribed. Transcriptions captured the time that families arrived and left each exhibit as well as the verbal talk and action while visiting each exhibit. If other family members were present, their talk was transcribed as well as the target parent's and target child's. However, siblings' and other adults' talk was not coded. For the purpose of this study, we were particularly interested in whether families visited the Spin Browser exhibit, and if so, what types of talk they engaged in.

Narrative Talk Coding at Spin Browser Exhibit

For families who visited the Spin Browser, family interactions at the exhibit were divided into 10 second segments. Both the target parents' and children's talk were coded into four categories in terms of which category best captured each segment. Narrative talk was coded when parent or child expressed or elicited stories about the life, death, or discovery of the mammoth. Connections talk was coded when parent or child made links from the Spin Browser to other parts of the exhibition or to other aspects of children's experience. Observation was coded when parent or child observed the Spin Browser without speaking. A miscellaneous Other category captured instructions on how to use the exhibit as well as science facts about mammoths, and non-engagement with the exhibit. Using transcripts and video, two coders established inter-rater reliability on twenty percent of the videos: percent agreement was 85%, Cohen's kappa = 0.83. **Table 1** provides more information about the coding categories as well as example coded utterances.

Explanatory Science Talk Coding at Fossil and Replica Exhibits

Both parents and children were coded at the utterance level in terms of the explanatory science talk they used at the eight fossil and replica exhibits. Building on previously published data (Callanan et al., 2017), our measure of explanatory science talk for these analyses included a composite total frequency of several types of explanatory talk. For our composite measure of Explanatory Science Talk we combined the frequency of *Causal explanations* about where the mammoth bones came from, what the mammoth was like when it was alive, and how scientists found the bones (e.g., "They must have dug them out of the ground!"), *Evidence talk* (e.g., "I can tell it's a mammoth because

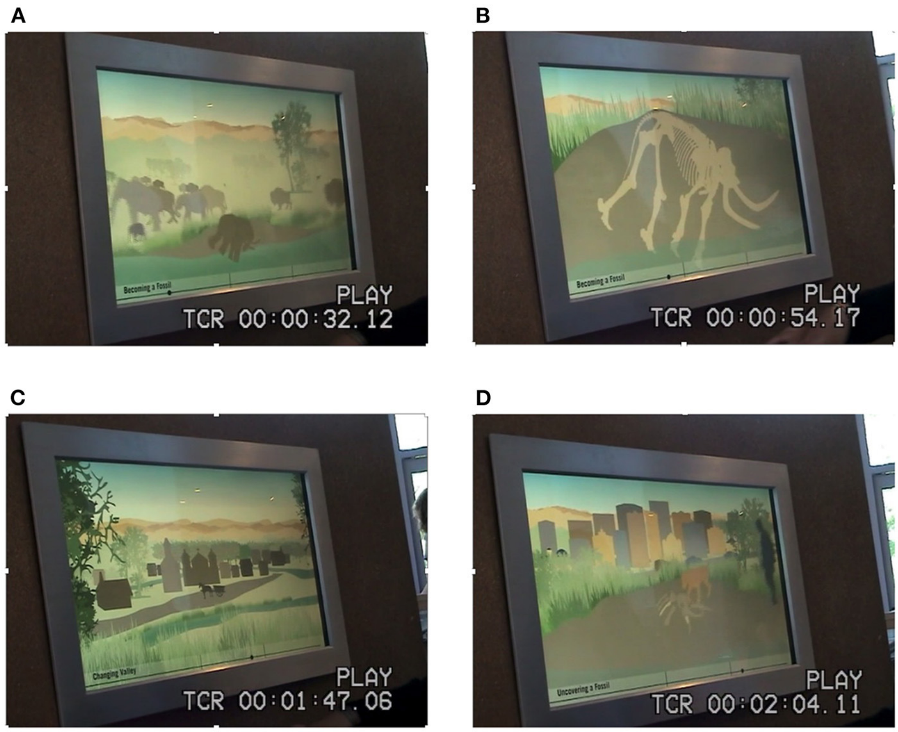

FIGURE 2 | (A–D) Screenshots of the Spin Browser, showing **(A)** an early frame in the section on "Becoming a Fossil," **(B)** a later frame in the section on "Becoming a Fossil," **(C)** a frame from the section on "Changing Valley," and **(D)** a frame in the section on "Uncovering a Fossil."

of the tusks"), *Personal connections* (e.g., "This reminds me of the elephant at the zoo"), and *Requests* for all such types of information in question form. For each of these types of talk, two coders independently coded 20% of the data and percent agreement for each type of talk ranged from 80 to 95% (Cohen's kappas ranged from 0.62 to 0.93). **Table 2** provides definitions and examples for this coding scheme.

RESULTS

To investigate whether the storytelling activity at the Spin Browser encouraged scientific engagement at the fossil exhibits, we first compared the frequency of Explanatory Science Talk for families who visited the Spin Browser, compared to those who did not. Next, we investigated the patterns of types of talk at the Spin Browser, asking whether families' narrative and/or connections talk predicted their science explanatory talk at the fossil exhibits in other parts of the *Mammoth Discovery!* exhibition.

Spin Browser Visit—Narrative Talk

We first explored the talk that families engaged in at the Spin Browser exhibit. **Table 3** shows the mean number of 10-s segments coded for parents and children as narrating, connecting and observing. On average, families spent 2.7 min at the spin browser (SD = 1.39 min), with a range from 10 s to 7 min, 5 s. Overall, 92% of parents and 81% of children engaged in some narrative talk. Regarding connecting talk, 51% of parents and 24% of children made at least one connection. Preliminary analyses showed no significant differences in narrative talk or connections talk by children's gender.

To provide a sense of the type of narrative talk that sometimes occurred, we present an example conversation where a father, a 6-year-old child, and an older 9-year-old sibling spoke while the younger child turned the Spin Browser knob:

9 year old: There's a mammoth. Go to that side.
6 year old: Oh my gosh.
Dad: There's a mammoth. Whoa. You're in the city. There's gonna be no mammoths there. Oh, that's where we're at right now.
9 year old: That's where they dig the body.
Dad: Mammoth, they found it near. It said on the sign they found it near, um, Guada,- some lake or river. Probably was here before.
9 year old: Ok, so look it.
Dad: They're showing water buffalo.
9 year old: It's cool.
Dad: It is, huh? Oh there's people there. Now, see it's developing. See? You're just moving down the timeline, see? Now look it, like missions… this is a small town… now it's becoming farm, farmland, the town is growing. . . .and now a city's coming up and all of a sudden, all of a sudden, this guy comes across and finds mammoth bones here in San Jose [laughing].

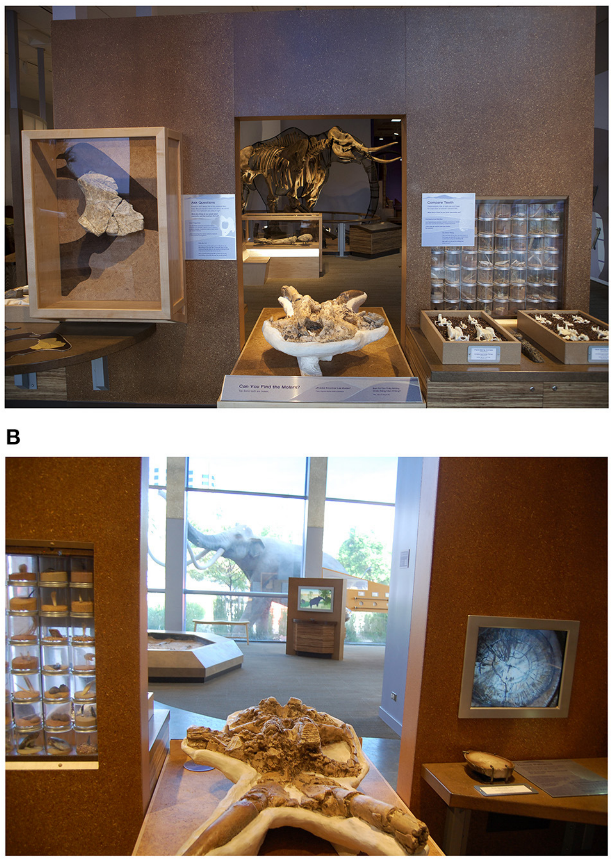

FIGURE 3 | (A) Sample bone exhibits: Authentic pelvis bone on wall on left; replica skull in lower center; full-scale mammoth skeleton and femur bone visible through opening. **(B)** Sample bone exhibits: Replica skull lower center; Full-scale mammoth replica outside window; dig pit through opening on lower left (spin browser visible right of dig pit).

TABLE 1 | Coding categories for parents' and children's talk and engagement at the spin browser exhibit (coded in 10 s segments).

Type of talk/engagement	Definition	Examples
Narration talk	Stories about life, death, discovery of mammoth	*"And then the bones get covered with dirt..."*
Connections talk	Links from Spin Browser to other exhibits or to previous experience	*"You wanna go see the real one?"* *"Remember in the movie Ice Age?"*
Observation	Parent or child observed without speaking	
Other	Instructional talk, off-topic talk, lack of engagement	*"Let me show you how"* *"I'm hungry"*

TABLE 2 | Coding categories for parents' and children's explanatory science talk at the 8 fossil and replica bone exhibits (coded in number of utterances).

Type of talk	Definition	Examples
Causal explanation statements and requests	Explaining where mammoth bones came from, how mammoth lived, or how scientists found the bones	*"They use brushes to uncover the bones."* *"With teeth like that it must have chewed its food a lot!"*
	Requesting explanations about the bones	*"What do you think it looked like when it was alive?"*
Evidence statements and requests	Explicitly stating how they used evidence to draw a conclusion	*"I can tell it's a mammoth because of the tusks"*
	Requesting evidence for a claim	*"How do they know if it's a boy or a girl?"*
Personal connections statements and requests	Making connections to previous experience or knowledge	*"This is what Uncle Ted does." (while digging)* *"They found this near where Daddy works."*
	Requesting connections to previous experience or knowledge	*"What does this remind you of?"*

What a find, huh? To be out walking with your dog and to be like "Oh look it, this looks interesting." Call up the right people have them come out and got a, got a mammoth.

Spin Browser Visit—Links to Explanatory Science Talk

We next asked whether families who visited the Spin Browser engaged in more Explanatory Science Talk at the fossil and replica bone exhibits compared to families who did not visit the spin browser. **Table 4** shows the mean number of explanatory utterances for both parents and children, as well as the percentage of parents and children who engaged in any science talk. Comparing the explanatory science talk utterances for parents who visited vs. did not visit the Spin Browser, a t-test was not significant, $t_{(81)} = 1.46, p = 0.15$. Next we conducted a chi-square test of independence, asking whether the number of parents who used any Explanatory Science talk varied depending on whether or not they visited the Spin Browser exhibit. We found a significant relation between the two variables; parents who visited the Spin Browser were more likely to engage in Explanatory Science talk than parents who did not visit the Spin Browser, $\chi^2_{(1,\,N=83)} = 5.64$, $p = 0.018$. Overall, 81% of the parents who visited the Spin Browser used some explanatory talk at the fossil exhibits, while only 56% of parents who did not visit the Spin Browser engaged in any explanatory talk at the fossil exhibits. In contrast, children's explanatory talk at the fossil exhibits did not differ depending on whether they visited the Spin Browser, $\chi^2_{(1,\,N=83)} = 1.95, p = 0.162$.

We also asked whether parents' and children's science talk differed depending on whether they visited the Spin Browser in the first half of their exhibit visit vs. in the second half (see **Table 4** for the relevant means). There were no significant differences for parents' or children's mean frequency of science talk, nor for the proportion of parents or children who engaged in science talk.

TABLE 3 | Parents' and children's talk and action at spin browser—Mean Number (SD) of 10-s segments coded (*n* = 37; 23 families with girls, 14 families with boys).

Type of talk/action	Mean (SD)
Children's narrative talk	4.24 (4.13)
Children's connections talk	0.35 (0.72)
Children observing	9.27 (5.99)
Parents' narrative talk	7.35 (6.64)
Parents' connections talk	1.22 (1.54)
Parents observing	3.81 (4.11)

Predicting Explanatory Talk From Spin Browser Narrative Talk

We next addressed our main question regarding whether specific types of family talk at the Spin Browser predicted explanatory talk at the fossil and replica bone exhibits. Multiple regression analyses were conducted to determine whether different types of parent and child talk at the spin browser predicted explanatory science talk at the fossil and replica bone exhibits. Because roughly half the families engaged with the researchers in the research room prior to visiting the exhibit, and the other half visited the exhibit first, we conducted preliminary regressions including order as a variable; order was not significant in these regressions and we removed it from further analyses.

In the first regression model, the outcome measure was children's explanatory science talk at the fossil exhibits. The predictors were child age and parents' years of schooling in the first block, and then adding the number of time segments coded as parents' narrative talk, children's narrative talk, parents' connection talk, children's connection talk, and parent-child observing. The regression model was marginally significant, $R^2 = 0.35$, $F_{(7, 36)} = 2.25$, $p = 0.058$; **Table 5** shows the results. Age was not a significant predictor, nor was parents' years of schooling. However, children's connection talk was significant and explained 16% percent of the variance in predicting children's explanatory science talk at the fossil exhibits ($\beta = 0.54$, $p = 0.006$), and parents' narrative talk at the Spin Browser significantly predicted children's explanatory talk at the fossil exhibits, accounting for 6.2% of the variance ($\beta = 0.49$, $p = 0.046$).

In a second regression model, the outcome measure was parent-child explanatory science talk, combining both parents' and children's explanatory utterances at the fossil exhibits. The same predictors were entered: children's age, parents' years of schooling, number of time segments coded as parents' narrative talk, children's narrative talk, parents' connection talk, children's connection talk, and parent-child observing. This regression model was marginally significant, $R^2 = 0.33$, $F_{(7, 36)} = 2.05$, $p = 0.082$. In this model, shown in **Table 6**, the significant predictors were parents' narrative talk, $\beta = 0.62$, $p = 0.015$, and children's connection talk, $\beta = 0.39$, $p = 0.043$. Parents' narrative talk predicted 14% and children's connections talk predicted 6.3% of the variance in parent-child explanatory talk at the fossil exhibits.

These results support findings that have suggested that the use of narratives may relate to children's engagement and interest in science. Specifically, in our study it was parents' narrative talk and children's connections talk that seemed to relate to families' engagement in explanatory conversations in other areas within the *Mammoth Discovery!* exhibition. This study provides some evidence that narratives may relate to other forms of science related talk, raising questions for future study about specific links between story-telling and science understanding. Understanding these links is important for the design of informal and formal science environments and fostering children's engagement in science.

DISCUSSION

This research project reveals ways that studies of family conversations in informal learning institutions can provide valuable insights regarding children's developing science understanding. Our findings are relevant for both research and practice; evidence regarding the hypothesis that narratives or stories may help children engage with science concepts is relevant both for theories about cognitive development and policies for creating science learning opportunities. We provide a brief summary and interpretation of our findings, consider the implications of the findings for future research and then for practice, and then end with a discussion of potential future directions.

Summary and Interpretation of Findings

In our study, parents' narrative talk and children's connecting talk predicted explanatory science conversations in other areas within the *Mammoth Discovery!* exhibition. This study provides some evidence that families' discussions of narratives and stories may provide an entry point for forms of science-related talk, raising questions for future study about specific links between story-telling and science understanding.

These intriguing findings must be hedged, however, by acknowledging that in this type of naturalistic study it is not possible to distinguish children's engagement in storytelling or science from their interest, understanding, or learning. While it would be ideal to be able to make these distinctions, it is difficult to do so within the real life complexity of families' interactions. Indeed, we would argue that there is no perfect independent assessment of children's science understanding, and that spontaneous engagement in meaningful talk about science topics needs to be taken as seriously as test-like assessments which come with a different set of limitations. That said, we fully appreciate the need for the field to integrate these data with data from more carefully controlled studies.

It is also important to acknowledge that, because this is a naturalistic and quasi-experimental study, it is not possible to draw causal inferences from the findings. Families were not randomly assigned to visit or not visit the spin browser; instead they chose their own path and timing through the *Mammoth Discovery!* exhibition. Although it is tempting to suppose that engaging with storytelling at the spin browser exhibit might have subsequently increased families' engagement with science explanations at other exhibits, our data do not allow us to make that conclusion. Indeed, our exploration of the rough timing of

TABLE 4 | Mean number of explanatory science talk utterances by parents and children and percent of families with any science talk as a function of whether they visited the Spin Browser exhibit.

	Mean frequency of science talk utterances			Percent of families with any science talk		
Visited Spin Browser (number of families)	**Parents**	**Children**	**Combined**	**Parents (%)**	**Children (%)**	**Combined (%)**
Did not visit (46)	2.26	0.53	2.78	56	26	63
Did visit (37)	3.38	0.81	4.19	81	40	83
1st half of visit (22)	3.09	1.05	4.14	63	41	73
2nd half of visit (15)	3.80	0.47	4.27	100	40	100

TABLE 5 | Hierarchical regression: predictors of children's explanatory science talk at the fossil and replica bone exhibits.

	B	**BSE**	**β**
(Constant)	0.24	0.78	
Age in months	0.01	0.01	0.11
Parents' years of school	−0.04	0.07	−0.08
(Constant)	0.26	1.5	
Age in months	0.01	0.01	0.15
Parents' years of school	−0.06	0.07	−0.14
Children's narrative talk	−0.11	0.07	−0.35
Children's connections talk	0.96	0.32	0.54*
Parents' narrative talk	0.09	0.04	0.49*
Parents' connections talk	0.17	0.13	0.20
Parent and child observing	0.002	0.03	0.01

*$p < 0.05$.

TABLE 6 | Hierarchical regression: predictors of combined parent-and-child explanatory science talk at the fossil and replica bone exhibits.

	B	**BSE**	**β**
(Constant)	10.01	3.2	
Age in months	−0.03	0.04	−0.16
Parents' years of school	−0.14	0.29	−0.09
(Constant)	3.44	5.77	
Age in months	−0.01	0.03	−0.02
Parents' years of school	−0.09	0.27	−0.06
Children's narrative talk	−0.35	0.27	−0.31
Children's connections talk	2.56	1.22	0.39*
Parents' narrative talk	0.45	0.17	0.62*
Parents' connections talk	0.68	0.49	0.22
Parent and child observing	−0.07	0.11	−0.12

*$p < 0.05$.

spin browser visits (comparing those in the first half vs. second half of the full visit) did not yield significant differences. Hence, it is just as likely that our findings could indicate that some other factors may account for the link between storytelling and science talk. Perhaps families who engage in more storytelling talk also happen to engage in more explanatory science talk. Nevertheless, we see this observational study as an important first step; future studies should more directly address the possibility that stories may support children's science understanding.

Links to Cognitive Developmental Science Research

These findings are consistent with previous evidence suggesting that storytelling may support children's conceptual understanding (Ganea et al., 2014; Kelemen et al., 2014). Children whose parents engaged in storytelling in their Spin Browser interactions were also likely to engage in science talk with their parents at the fossil exhibits.

The finding that children's connecting talk at the Spin Browser also predicted both children's and families' science talk at the fossil exhibits is intriguing. While not technically narrative talk, connection talk may support children in making personal meaning of the scientific objects in the exhibition. Miller et al. (1997) discuss children's personal storytelling as an important part of socialization. In similar ways, when parents bridge children's understanding by discussing personal connections to the topic under exploration, there is evidence that this can support children in making meaning of science topics (Haden et al., 2016; Callanan et al., 2017).

It is perhaps surprising that we found no gender differences in children's or parents' engagement with narrative talk. It is notable, however, that while approximately half (52%) of the participating target children were girls, 62% of the families who chose to visit the spin browser had daughters. Perhaps this storytelling exhibit was more interesting to girls, or seen as more relevant to girls by parents. This would be consistent with research suggesting that girls may have a more episodic or narrative memory style (Bemis et al., 2011). Future research should consider potential gender differences in the links between storytelling and science.

Links to Informal Science Practice

Narrative and storytelling are argued to be natural ways to understand the world (Bruner, 1986), and developmentally appropriate ways for children to learn language, factual content, and causal connections (Melzi et al., 2011; Kelemen et al., 2014). For these reasons, storytelling is a popular technique used effectively in the design of informal learning settings and science learning materials (e.g., Evans et al., 2016; Haden et al., 2016), as well as in facilitation in museums (Pagano et al., 2020).

Understanding links between storytelling and science learning is important for the design of informal and formal science environments and for fostering children's engagement in science.

The Spin Browser exhibit embedded non-verbal narrative into a hands-on exhibit, and provided opportunities for families to tell stories about the life and death of a mammoth in ways that could connect the pieces of the exhibit into a coherent whole. Our findings provide some support for the idea that such storytelling opportunities may enrich children's and parents' engagement with the science content of museum exhibits. Exploring diverse ways of connecting stories with science activities will provide valuable information about practical implications of these findings.

Future Directions and Implications

Recent exploration of links between storytelling and science has yielded promising results. For example, several recent projects have combined storytelling or storybook reading with hands-on STEM activities, and found evidence of families' rich engagement with STEM content (Pattison et al., 2017; Tzou et al., 2019; Callanan et al., 2021). Because storytelling is an everyday cultural practice for families in many communities around the world, combining storytelling with science opens up possibilities in terms of STEM equity and inclusion (Miller et al., 2005; Solis, 2017). Our findings suggest promising directions for future work that considers family storytelling and narrative as an engaging way for children to explore and learn about science.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article can be made available by the authors.

ETHICS STATEMENT

The study was reviewed and approved by the University of California, Santa Cruz Institutional Review Board. Written informed consent to participate in this study was provided by the participants and/or the participants' legal guardian, and verbal assent was obtained by minors who participated. Written informed consent was obtained from the individuals and minors' legal guardians for the publication of any potentially identifiable images included in this article.

AUTHOR CONTRIBUTIONS

JM was PI of the project. MC and JS were co-PIs. SD was head exhibit designer. MC and ML conceptualized the research. ML led data collection efforts. MD contributed to data collection and coding and wrote an undergraduate senior thesis based on some of the data. CC led coding efforts and data analysis. GS and SM contributed to data analysis. MC supervised the research and wrote the initial draft of the paper. All authors contributed to revisions.

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