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Conversational reflections about tinkering experiences in a children's museum

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Abstract

We examined the conversational reflections of 248 families with 6–11-year-old children shortly after they visited a tinkering exhibit. Our aim was to understand the conditions of tinkering and conversational reflection that can enhance STEM learning opportunities for young children. Some families visited the exhibit when there was a design challenge and others when there was not. Some families chose to leave the exhibit with their creations, and, therefore, had them with them during the conversational reflection, and others did not. Children who participated in the design challenge, and had their tinkering creation present during the reminiscing, answered a greater percentage of adults' elaborative open-ended questions. Children also elaborated more if they visited the exhibit when there was a design challenge compared with those who did not. Children and adults made more elaborative statements if they had their tinkering creation with them than if they did not. Families with their tinkering creations talked most about engineering and the value of tinkering, and those who participated in the design challenge talked the most about engineering practices, and least about tools. We discuss implications for the design of tinkering and reflection activities that can both reveal and advance STEM learning.

KEYWORDS
communication, learning, memory, museums, parent-child relations

Conversations between children and adults are important to the process of early learning in informal educational settings, such as museums (e.g., Allen, 2002; Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001; Haden, 2010; Jipson & Callanan, 2003; Leinhardt, Crowley, & Knutson, 2002; National Research Council, 2009; Palmquist & Crowley, 2007). For example, a growing body of research suggests that the conversations young children have with their parents during science, technology, engineering, and mathematics (STEM) experiences in museum exhibits can foster STEM learning (e.g., Benjamin, Haden, & Wilkerson, 2010; Callanan, Castañeda, Luce, & Martin, 2017; Crowley, Callanan, Tenenbaum, & Allen, 2001; Eberbach & Crowley, 2017; Geerdts, Van de Walle, & LoBue, 2015; Jant, Haden, Uttal, & Babcock, 2014; Vandermaas-Peeler, Massey, & Kendall, 2016; Yu, Bonawitz, & Shafto, 2017). Moreover, caregivers and children often reminisce about their shared exhibit experiences in conversations after museum visits (e.g., Anderson, Storksdieck, & Spock, 2007; Ellenbogen, 2002; Falk & Dierking, 1992; Fivush, Hudson, & Nelson, 1984; McManus, 1993; Stevenson, 1991). Although there has been more attention given to family conversations during exhibit visits, reminiscing afterward can also play an important role in increasing informal STEM learning opportunities for young children (Benjamin et al., 2010; Jant et al., 2014).

In the current study, children engaged in conversational reflections with familiar adults (i.e., their parents or other caregivers) about experiences they shared in an exhibit designed for tinkering, a form of creative, open-ended problem-solving (Vossoughi & Bevan, 2014). Using a multi-media station within a children's museum to record their reflections, caregivers and children reminisced about their tinkering experiences shortly after visiting the *Tinkering Lab* exhibit. Our general aim in this project was to identify conditions under which parent-child conversational reflections advance opportunities for STEM learning from tinkering. The two independent variables in our quasi-experimental study were: (a) the open-endedness of the tinkering program in the exhibit; and (b) whether families chose to leave the exhibit with the creation they had made, and therefore, had it with them when reminiscing about their exhibit experience. The dependent variables were codes used to characterize the elaborativeness and STEM content of families' conversational reflections. The research questions were as follows:

1. Are there linkages between the open-endedness of tinkering programs families experience and the elaborative style and STEM-related content of their conversational reflections after tinkering?
2. Is the presence of the tinkering creation associated with the elaborative style and STEM-related content of families' conversational reflections?

1 | HANDS-ON TINKERING

Our focus on tinkering is important because tinkering is rapidly being integrated into informal educational settings as a powerful way to engage young people from diverse backgrounds in the practices of science and engineering (Honey & Kanter, 2013; Quinn & Bell, 2013; Vossoughi & Bevan, 2014). Tinkering can provide potentially meaningful STEM educational opportunities for young children that connect to learning goals outlined in the *Next Generation Science Standards* and *Framework for K-12 Science Education* (National Research Council, 2012; NGSS Lead States, 2013). Furthermore, tinkering is a nearly ideal context to explore connections between constructivists' theories about the importance of learning through direct experiences interacting with objects (Piaget, 1970; Vygotsky, 1978) and sociocultural theories that emphasize that learning is co-constructed through social and conversational exchanges (e.g., Rogoff, 1990; Vygotsky, 1978). Tinkering experiences are designed to encourage active, hands-on engagement with objects (e.g., Honey & Kanter, 2013; Leinhardt et al., 2002; Paris & Hapgood, 2002). These experiences are also frequently social, with learning and problem solving being distributed across multiple individuals (e.g., children, caregivers, museum staff).

Tinkering often involves open-ended questions and goals, as well as intentionally selected tools and materials that support various approaches to problems and multiple solutions (Bevan, 2017). Bevan (2017) and others (see

Honey & Kanter, 2013) distinguish between tinkering and other forms of making (e.g., assembly-like making from kits). We add to this conceptualization the idea that there are also differences among activities called tinkering. Indeed, from our perspective, it is possible to view variations in tinkering activities along a continuum from more to less open-endedness (Koin, Marcus, Haden, & Cohen, 2018).

Make something-type activities are the most open-ended. A wide variety of examples and ideas are presented, and learners are invited to set their own agendas for what they create and whether and how they measure success. Toward the middle of the continuum are tinkering activities with themes and materials that offer a direction for the activity, but leave it to the learner to define the problem and purpose (i.e., what to make and what it will do), such as a program to *Make something that moves* featuring a variety of materials to make contraptions with wheels, wings, sails, and so forth. Other tinkering activities where learners are invited to *Make something that does X* can still be open-ended. For example, programs to make something that rolls, to make something that flies, or to make a circuit to ring a bell, offer a range of paths to problem-solving, as well as many possible solutions, while nevertheless suggesting ways to measure success toward a goal. Tinkering activities that pose a challenge often include clear opportunities to gain feedback, such as a ramp to test if something rolls, or a bell to test if a circuit makes it ring.

It is important to note that variations in open-endedness do not mean that the products of any tinkering activity would all be the same. Furthermore, across the whole continuum, different types of tinkering activities still afford deep engagement in activities that can be personally meaningful to the learners. Even so, there is a paucity of research addressing whether and how the open-endedness of tinkering activities may differentiate STEM learning opportunities. In this study, we consider this by examining linkages between the open-endedness of tinkering programs and families' conversational reflections about tinkering.

2 | CONVERSATIONAL REFLECTIONS

The conversations children and their caregivers have about their experiences after visiting an exhibit can be considered both an outcome and a process of family learning in museums (Benjamin et al., 2010; Crowley, Callanan, Jipson et al., 2001; Eberbach & Crowley, 2017; Jant et al., 2014; Jipson & Callanan, 2003). The content of what children say during conversational reflections, for example, can reveal evidence of what they understood about their experiences, which can be useful to educators, researchers, and parents, in their efforts to advance learning opportunities for children. In addition, conversational reflections are also part of the learning process that includes encoding, consolidation, and retrieval of information (e.g., Brown, Roediger, & McDaniel, 2014). Most of the work involving observations of parent-child STEM conversations in museums has focused on the scaffolding of learning during the encoding of an exhibit experience as it unfolds. Nevertheless, conversational reflection shortly after an experience in a museum can support consolidation, the step in the learning process by which labile and fleeting patterns of experience are strengthened and transformed into long-lasting memory representations (see McGaugh, 2000; Wixted, 2004, for discussion).

Reflection is foundational in modern STEM education (e.g., *Next Generation Science Standards*, NGSS Lead States, 2013; *Framework*, National Research Council, 2012; *Strands of Informal Science Learning*, National Research Council, 2009). It may be especially important for the consolidation of learning from hands-on activities, such as tinkering (see Haden, 2014, for similar arguments). This is because conversational reflection can facilitate what Sigel (1993) called *distancing* and what Goldstone and Sakamoto (2003) called *concreteness fading* – learning to focus less on the specific objects and more on the general knowledge and concepts that can be learned from object manipulation (Fyfe, McNeil, Son, & Goldstone, 2014; Uttal, Liu, & DeLoache, 2006). Conversational reflection can provide mechanisms for parents and children to create meaning, as these conversations fill in the blanks in understanding, connect new and prior knowledge and experiences, and elaborate what was initially encoded (Haden, Cohen, Uttal, & Marcus, 2016). At the same time, conversational reflection as part of consolidation in the learning process should enable the storage of information in long-term memory, and retrieval of learning for later use (Haden, 2010; Haden 2014).

Conversational reflection may be most influential in the learning process when parents use an elaborative reminiscing style. This idea extends from sociocultural theories and research on memory development emphasizing the importance of mother-child reminiscing for learning and remembering. In many studies, children show mnemonic benefits from elaborative conversational interactions with caregivers (see Fivush, 2014; Fivush, Haden, & Reese, 2006, for reviews). Adults who use an elaborative reminiscing style ask many open-ended questions to elicit children's linguistic participation (e.g., *"What did we do?" "How did we do that?"*), and make many statements (e.g., *"We used a clamp so we could drill it."*) about past events (e.g., Haden, 1998; Reese, Haden, & Fivush, 1993). Children's robust recall of past experiences is especially evident in these conversations when they are highly responsive to adults' open-ended questions and contribute many elaborative statements during reminiscing. Longitudinal (e.g., Farrant & Reese, 2000; Haden, Ornstein, Rudek, & Cameron, 2009; Reese et al., 1993); and experimental studies (e.g., Peterson, Jesso, & McCabe, 1999; Reese & Newcombe, 2007; Tessler & Nelson, 1994) show that use of these elaborative conversational techniques during reminiscing can facilitate children's later abilities to report on past experiences in a detailed manner.

With regard to advancing STEM learning, it is also important to consider conditions associated with conversational reflections that are rich in STEM-related content. Prior research shows that the frequency of specific language inputs, such as spatial and relational language (Loewenstein & Gentner, 2005; Pruden, Levine, & Huttenlocher, 2011), and number words (Gunderson & Levine, 2011; Levine, Gunderson, & Huttenlocher, 2011) can predict children's skills in STEM domains. Work on family conversations in museums further suggests that the content of parent-child conversational interactions can support STEM learning (Callanan & Jipson, 2001; Crowley, Callanan, Jipson et al., 2001; Crowley, Callanan, Tenenbaum, & Allen, 2001; Falk & Dierking, 1992; Haden, 2010; Leinhardt et al., 2002; National Research Council, 2009). STEM talk during science and engineering activities in museum exhibits has been linked to children's recall of STEM-related information immediately after an exhibit experience (Haden et al., 2014), and days and weeks later (Benjamin et al., 2010; Jant et al., 2014). Therefore, in this study, we consider both the elaborative style and STEM content of families' conversational reflections that might advance the STEM learning opportunities from tinkering.

3 | CURRENT STUDY AND HYPOTHESES

In this study, we compared the conversational reflections of a convenience sample of families who happened to visit *Tinkering Lab* during one or the other of two programs that varied with regard to open-endedness of the activities. The Woodshop Plus program was on the more open-ended part of the continuum. This program encouraged tool use, with no design challenge posed, and no exhibit elements for testing (e.g., ramps, wind tunnels). In contrast, the Make it Roll program was less open-ended, inviting learners to engage in a particular kind of engineering design challenge, and testing stations (i.e., ramps) in the exhibit offered families a place to test their designs. Other differences between the two programs aligned with differences in themes (see Method, for further details).

The conversational reflections were recorded voluntarily by families after their tinkering experiences with a multi-media component called *Story Hub: The Mini Movie Memory Maker* that was located outside of the tinkering exhibit in the museum. We thought that the design challenge might support distancing from individual actions on objects, which might be associated with greater understanding during the experience, and more detailed and elaborated reporting of it afterward (cf. Haden, Ornstein, Eckerman, & Didow, 2001). Moreover, consistent with work showing mnemonic benefits of props as a means for eliciting children's reports of past events (see Salmon, 2001, for review), we anticipated that the presence of the creation during conversational reflections might be positively related to the elaborative talk. Specifically, our hypotheses regarding elaborative reminiscing during families' conversational reflections were as follows:

1. Families who experienced the Make it Roll program should engage in more elaborative reminiscing during the conversational reflections compared with families who experienced Woodshop Plus.
2. Children who had their tinkering creations with them during the conversational reflections should engage in more elaborative reminiscing compared with children who did not have their creations with them.

With regard to content, our analyses counted instances of families' naming and describing their tinkering creations (e.g., color, function), as well as naming and describing of the technologies (i.e., tools, materials) used during tinkering. Further, we coded discussion of engineering practices, such as brainstorming, designing, testing, redesigning, and collaboration. Finally, we examined whether there were differences in the value families ascribed to their tinkering experiences. With regard to the content of the reflections, we hypothesized the following:

3. Families experiencing the more tool-focused Woodshop Plus program should talk more about tools and materials than families who experienced Make it Roll. Moreover, talk closely tied to objects, about tools, and naming and describing the creations should be more frequent among families who had their creations with them during the reflection than those who did not.
4. Consistent with the idea that the program with a design challenge would advance opportunities for engagement in engineering practices during tinkering, the conversational reflections of families who experienced Make it Roll should include more engineering content than those who experienced Woodshop Plus. The presence of the creation might make it easier for children to talk about what they did to design, test, and redesign their creations. Therefore, among children who experienced Make it Roll, there should be more engineering talk if the creation was present compared to if it was not.

Although we did not advance any hypotheses regarding talk about the value of tinkering, this content conveys the meaning and significance of the the experience, and connects tinkering to experiences the child had in the past or will have in the future. Therefore, talk about the value of tinkering is important to consider because of its association with meaning making and consolidation in the learning process (Haden, 2014).

4 | METHOD

4.1 | Sample

The sample consists of 248 family groups who made recordings (96% in English) in which they reflected on their experiences in Chicago Children's Museum's *Tinkering Lab* exhibit. The number of adults per family group averaged 1.34 (range 1–4) and the number of children per family group averaged 1.67 (range 1–4). During Woodshop Plus (November 14, 2015–April 30, 2016), 180 recordings about *Tinkering Lab* were made by 68 (38%) families who had their tinkering creation with them in *Story Hub*, and 112 (62%) who did not. During the Make it Roll program (June 30–August 26, 2016), 68 recordings about *Tinkering Lab* were made by 28 (41%) families who had their tinkering creations with them, and 40 (59%) who did not. The shorter duration of the Make it Roll program (57 days) versus Woodshop Plus (168 days) accounted for the difference in sample size between programs; the number of recordings per day were similar, at $M = 1.07$ per day and $M = 1.19$ per day for Woodshop Plus and Make it Roll, respectively. Although no demographic information is gathered from families in *Story Hub*, the names of children mentioned in the videos, and visual inspection, indicated that 50% of the families had female children only, 27% had male children only, and 23% had male and female children. We estimated that the oldest (or only) child in the visitor group was between 6 and 11 years old. Sixty-one families (25%) made recordings when admission to the museum was free.

4.2 | Museum exhibit and program

Tinkering Lab is a permanent exhibit at Chicago Children's Museum. It is a large workshop space with various tools and materials (e.g., wire, rope, cardboard), some of which are at a toolbar (e.g., chop saws; power drills) where staff facilitators help guide their use. Consistent with the themes of the programs, there were some differences in the tools and materials available during Woodshop Plus and Make it Roll. Specifically, hammers and saws were present during Woodshop Plus but not during Make it Roll. Materials that could be used to make wheels (e.g., bottle caps, spools) and axles (e.g., dowels, straws, skewers) were always available during Make it Roll. During Make it Roll, there was a two-lane wooden ramp placed in the exhibit and small ramps on each worktable that could be used for testing the creations (see Figure 1). The number of staff in the exhibit was the same across programs, with one facilitator at a time in *Tinkering Lab* (out of a pool of about 30 staff members), unless it was very busy in the exhibit, in which case more than one staff member would be present. When facilitators greeted visitors entering the space, they invited children to make whatever they liked or to make something that rolls, for Woodshop Plus and Make it Roll, respectively. In addition, invitations to "make something" or "make something that rolls," were written in English and Spanish on a large chalkboard in the exhibit. In the natural course of events, some families chose to bring their tinkering creations away with them when they finished tinkering, and therefore had their creations with them during their conversational reflections in *Story Hub*.

Story Hub: The Mini Movie Memory Maker is a permanent exhibit at Chicago Children's Museum (see Figure 2). In *Story Hub*, families video record their conversational reflections about their exhibit experiences. Upon entering *Story Hub*, families choose whether to hear the prompts in English or Spanish. They see images from each of the museum's exhibits on a touch-screen computer and select an exhibit about which they will record a reflection conversation. Families then select from a set of digital images of exhibit ones that will be included in their video. The *Story Hub* computer then instructs the family to "Talk together about what you did." Families can see themselves on the screen as they record their video. Families can discuss each exhibit for up to 2 minutes. Once they are finished talking about one exhibit, families have the option to select another exhibit. Once they have

FIGURE 1 *Tinkering Lab* set up for Make it Roll program. During the Make it Roll program, *Tinkering Lab* featured a large, two-lane ramp, table ramps, and a design challenge that was communicated on a chalkboard and by facilitation staff greeting visitors [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 2 *Story Hub* exhibit for visitors' conversational reflections. *Story Hub* provides visitors with the opportunity to video record their reflections about their exhibit experiences [Color figure can be viewed at wileyonlinelibrary.com]

finished with their reflections, families can email the video of their *Story Hub* reflections to themselves as a keepsake from their museum visit.

Table 1 provides descriptive data about the types of creations made in *Tinkering Lab* during Woodshop Plus and Make it Roll, on the basis of families' naming of their creations. When talking about Woodshop Plus in *Story Hub*, 37% of families mentioned making more than one creation (M = 1.38, SD = 0.66, range 1–4). When talking about Make it Roll, 29% of families mentioned making more than one creation (M = 1.53, SD = 0.76, range 1–3). As shown in Table 1, nearly half of the creations named from Make it Roll (48%) were things that could roll, and another 9% were non-rolling vehicles. Only 14% of the creations were house or household-related. There were also fewer robots, characters, and animals from Make it Roll (4%) compared with Woodshop Plus (14%). By contrast, 8% of the tinkering creations made during Woodshop Plus were things that rolled, and another 13% were other, non-rolling vehicles (e.g., boats). Just over one-third of Woodshop Plus creations were houses (16%) or household items (16%, e.g., tables, chairs).

4.3 | Procedures

All families freely chose to visit *Tinkering Lab* and *Story Hub*. Families never directly interacted with researchers, and none of the families included in the sample were observed in *Tinkering Lab*. Before recording in *Story Hub*, one member of the family group could check a box on the screen to confirm that they were over 18 years old; videos without an adult caregiver were not included in the data set. Once the families finished recording their videos, they had the option to check a box giving permission for their video to be used "for research and marketing purposes." The data set includes only recordings made by families who gave permission and selected to reflect on their experiences in *Tinkering Lab*. Families in the Creation Present group were identified by visually inspecting the

TABLE 1 Types of creations made by families by program

Creation	Number	Percent
Woodshop Plus program		
Something that rolls (e.g., car, truck, wheelbarrow)	19	8%
Other, non-rolling vehicle (e.g., boat, airplane)	31	13%
House (e.g., house, birdhouse)	40	16%
Household (e.g., table, chair, bed)	39	16%
Robot, character, animal	33	14%
Weapon (e.g., sword)	7	3%
Shape, number, letters	15	6%
Food	6	2%
Other (e.g., memory box)	6	2%
Unknown (e.g., thingamajig), unnamed	48	20%
Total	244	
Make it Roll program		
Something that rolls (e.g., car, truck, hoverboard)	50	48%
Other, non-rolling vehicle (e.g., boat)	9	9%
House (e.g., house, birdhouse)	5	5%
Household (e.g., table, chair)	9	9%
Robot, character, animal	4	4%
Weapon (e.g., sword, gun)	2	2%
Shape/number/letters	1	1%
Food	1	1%
Other (e.g., pinwheel, wings)	6	6%
Unknown, unnamed	17	16%
Total	104	

videos. While talking about their experiences in *Tinkering Lab*, these families held at least one of their tinkering creations up to the video camera in *Story Hub*.

4.4 | Coding

Story Hub videos were transcribed verbatim and coded using two systems, one that focused on the elaborativeness of the conversational reflections, and another that characterized the content of the reflections.

4.4.1 | Elaborative talk coding

Using a system adapted from Haden (1998), this coding captured the frequency of adults' elaborative open-ended questions and children's elaborative responses to adults' open-ended questions, as well as the number of elaborative statements made by adults and children that added new information to the conversational reflection. *Adults' elaborative open-ended questions* requested an informational response, including who, what, where, when, why, and how questions (e.g., "What did you make in *Tinkering Lab*?", "How did you fix your creation?", "Why do you think that happened?", "What else do you remember that we did?"). Children's provision of new information to answer adults' open-ended questions counted as *elaborative responses* (e.g., "I don't know." responses were not counted). Declarative *elaborative statements* by adults and children were counted when they provided new information to the conversation, and in the case of children's statements, were not in response to an adults' question (e.g., "I got to use a saw for the first time," or "I really liked the way our creation turned out."). All codes capturing elaborativeness were mutually exclusive. The coding units were parsed by unique subject and/or verb, such that, for example, "I used the saw." received credit for one unit of information, whereas "I used a hammer, and nailed the nail, and it stayed on." would be credited with three units.

Interrater reliability based on 20% of the data was Cohen's Kappa κ = 0.96 for adults' open-ended questions, κ = 0.80 for children's responses to adults' open-ended questions, κ = 0.80 for adults' statements, and κ = 0.78 for children's statements.

In addition to counting the frequency of these codes, we also calculated the ratio of children's responses to adults' open-ended questions by dividing the total number of children's responses by the total number of adults' open-ended questions. We calculated the ratio of children's to adults' statements as the total number of children's statements divided by the total number of adults' statements (Reese et al., 1993). These measures provided information about the degree to which the adults were structuring the conversation, with values below 1 indicating more adult structuring (the adult asking more questions, or making more statements than the child), and values greater than 1 indicating less adult structuring of children's contributions to the conversation.

4.4.2 | Content coding

The coding units in this system were words or groups of words expressing specific content. Therefore, within a question or statement, there could be multiple content codes. For example, "I had fun building our car." would receive a code for "fun"/*Value* and a code for "car"/*Creation Name*. As with the structure coding, the codes were mutually exclusive, and only new information not previously mentioned was coded. Therefore, when "car" was mentioned earlier in the reflection conversation, for example, "Today I made a <u>car</u>.", it was not coded subsequently when the child said: "My car was green." Only the new information in this later sentence – "green"/*Creation Description* – was coded. In the following definitions of the content codes, underlined text in the examples indicate the word or phrase that was assigned the content code being defined.

1. Creation Name: naming or identifying the tinkering creation (e.g., "Today I made a <u>car</u>.").
2. Creation Description: describing the appearance of their tinkering creation, such as its color or shape, or describing its intended function (e.g., "I put this <u>lever</u> so you could <u>open the door</u> of the birdhouse.").
3. Tools: labeling a tool (e.g., glue, tape, nails), describing activities performed with a tool (e.g., hammering, gluing), or describing functions of a tool (e.g., "We had a <u>saw</u>. We used it to <u>cut the wood</u>.").
4. Materials: labeling or describing materials (e.g., wood, paper, cardboard, string, fabric).
5. Engineering Practice: talk about the engineering design process, including planning, defining problems (e.g., "The wood was <u>splitting in half</u> and then <u>it would break</u>."), brainstorming solutions (e.g., "We couldn't find a piece that was long enough so <u>we had to saw instead</u>."), prototyping, trying things out, not knowing how to do things, figuring things out, measuring, weighing, counting, testing (e.g., "I took my car to the ramp <u>to test it</u>."), redesigning, things not working, and being successful or unsuccessful. Also talk about collaboration, teamwork, or working together (e.g., "<u>My dad helped me</u> with this part.").
6. Value: talk that expressed what the experience meant to the visitor (i.e., its value), including evaluations of the experience (e.g., "The Tinkering Lab was my <u>favorite</u> part of the museum,") and emotional expressions, such as feeling frustration or excitement (e.g., easy, difficult, noisy, surprising). Also explicitly mentioning the value of the experience in terms of things that had been learned while tinkering (e.g., "Today I <u>learned how to</u> use a saw."), and connections between the experience in *Tinkering Lab* and prior or future experiences (e.g., what the child might do with their creation in the future; comparing what they had made to something the child has at home).

The analyses combine content talk counted for the adults and children. Interrater reliability based on 15% of the data was ϰ. = 0.87 for creation naming, ϰ. = 0.80 for creation descriptions, ϰ. = 0.95 for tools, ϰ. = 0.85 for materials, ϰ. = 0.77 for engineering practice, and ϰ. = 0.76 for value.

5 | RESULTS

All hypotheses were tested using 2 (*Tinkering Lab* Program: Woodshop Plus, Make it Roll) x 2 (Creation Present in *Story Hub*: Yes, No) analyses of variance (ANOVAs). Preliminary ANOVAs revealed neither main effects of program or creation present, nor Program x Creation Present interactions for the number of adults and the number of children in the family groups; therefore, we did not include the number of adults or the number of children as covariates in the reported analyses. Preliminary chi-square tests indicated that the distribution of male and female children (see Appendix) was not different across the two programs, $\chi^2 = 6.79$, $p = .15$; given this, and the fact we advanced no hypotheses regarding sex differences, sex was not considered further in the analyses.

5.1 | Elaborative reminiscing during reflections in *Story Hub*

The first two hypotheses concerned differences in elaborative reminiscing as a function of the tinkering program and presence of the creation. Table 2 lists the means for each dependent variable used to measure elaborativeness by program and creation present. There were no main effects or interactions for adults' elaborative open-ended questions, $Fs < 1.97$, $ps > 0.16$, or children's elaborative responses to adults' open-ended questions, $Fs < 0.35$, $ps > 0.55$. Therefore, adults asked similar numbers of elaborative open-ended questions, and children provided similar numbers of elaborative responses to these questions, regardless of the program they experienced in *Tinkering Lab*, and regardless of whether they had their tinkering creation with them. For the ratio of children's elaborative responses to adults' open-ended questions, although there was no main effect of creation present, $F(1, 178) = 0.88$, $p = .39$, there was a significant main effect of program, $F(1, 178) = 9.22$, $p < .01$, $\eta^2 = 0.05$, that was qualified by a Creation Present x Program interaction, $F(1, 178) = 4.87$, $p < .05$, $\eta^2 = 0.03$. As shown in Table 2, simple effects tests following the significant interaction indicated that among those who had their tinkering

TABLE 2 Summary of means (and standard deviations) for measures of elaborativeness of families' reflections

Elaborativeness	Woodshop Plus				Make it Roll			
	Yes creation present		No creation present		Yes creation present		No creation present	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Frequency of utterances								
Adults' open-ended questions	2.43	(1.91)	2.21	(2.18)	1.68	(1.57)	2.10	(2.54)
Children's responses to adults' open-ended questions	3.09	(3.45)	3.10	(3.57)	3.29	(3.54)	2.70	(3.09)
Adults' statements	3.34	(4.10)	2.36	(2.99)	3.25	(3.16)	2.20	(2.63)
Children's statements	5.13	(4.45)	3.42	(3.53)	7.71	(4.55)	4.98	(4.63)
Ratio child utterances divided by adult utterances								
Child responses-to-adults' open-ended questions	1.20	(0.80)	1.45	(1.12)	2.26	(2.01)	1.62	(1.24)
Child statements-to-adult statements	2.05	(2.57)	1.28	(1.92)	2.30	(1.56)	2.63	(3.72)

creation with them, children who were reflecting on experiences of Make it Roll answered the greatest proportion of adults' open-ended questions, compared with those reflecting on Woodshop Plus ($p < .01$).

For adults' elaborative statements, a main effect of creation present, $F(1, 244) = 4.50$, $p < .05$, $\eta^2 = .02$, revealed that adults who had the tinkering creation with them made more elaborative statements ($M = 3.31$, $SD = 3.83$) than those who did not ($M = 2.32$, $SD = 2.89$). Neither the main effect of the program nor the interaction for adults' statements was significant, $Fs < 0.06$, $ps > 0.80$. For children's elaborative statements, the main effect of creation present was likewise significant, $F(1, 244) = 12.08$, $p < .01$, $\eta^2 = 0.05$, such that children who had their tinkering creation made more elaborative statements ($M = 5.89$, $SD = 4.60$) than children who did not ($M = 3.83$, $SD = 3.89$). Furthermore, a main effect of program, $F(1, 244) = 13.99$, $p < .001$, $\eta^2 = 0.05$, indicated that children who experienced Make it Roll ($M = 6.10$, $SD = 4.76$) made more elaborative statements than children who experienced Woodshop Plus ($M = 4.07$, $SD = 3.97$). The interaction for children's elaborative statements was not significant, $F(1, 244) = 0.74$, $p = .39$. There was no main effect of creation present nor interaction for the ratio of child-to-adult statements, $Fs < 1.73$, $ps > 0.19$, and the main effect of the program was a statistical trend, $F(1, 171) = 3.67$, $p = .057$, $\eta^2 = 0.02$. Thus, the ratio of child-to-adult statements tended to be higher for families who experienced Make it Roll ($M = 2.49$, $SD = 2.95$) compared with Woodshop Plus ($M = 1.61$, $SD = 2.25$).

In summary, contrary to the first two hypotheses, the overall frequency of adults' open-ended elaborative questions and children's elaborative responses to these questions did not vary by program or presence of the creation. Nevertheless, children who participated in the Make it Roll program provided proportionally more responses to adults' open-ended questions than children who participated in Woodshop Plus, and across programs, children and adults who had their creations with them made more elaborative statements than those who did not. Also, compared with children who participated in Woodshop Plus, children who participated in the Make it Roll program made more elaborative statements, both in terms of sheer frequency, and relative to adults' elaborative statements.

5.2 | Content of families' reflections in *Story Hub*

Table 3 shows the means by program and creation present for each dependent variable measuring content. For naming the creation, the hypothesized main effect of creation present, $F(1, 244) = 4.33$, $p < .05$, $\eta^2 = 0.02$, was qualified by an interaction of creation present and program, $F(1, 244) = 8.46$, $p < .01$, $\eta^2 = 0.03$, with no main effect of program, $F(1, 244) = 0.00$, $p = .98$. Simple effects analyses indicated that families who participated in Make it Roll more often named their tinkering creation if they had it with them than families who did not ($p < .01$), but families participating in Woodshop Plus were equally like to name their creation whether or not it was present for the conversational reflection. For creation descriptions, the hypothesized main effects of program $F(1, 244) = 10.13$,

TABLE 3 Summary of means (and standard deviations) for content measures of families' reflections

Content code	Woodshop Plus				Make it Roll			
	Yes creation present		No creation present		Yes creation present		No creation present	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Creation name	1.35	(0.97)	1.22	(1.08)	0.89	(0.83)	1.68	(1.37)
Creation description	1.47	(1.63)	0.54	(1.28)	2.21	(2.27)	1.30	(1.91)
Tools	3.18	(2.49)	3.31	(2.45)	1.71	(1.70)	1.55	(1.92)
Materials	1.19	(1.57)	1.21	(1.54)	1.75	(1.97)	1.30	(2.08)
Engineering practice	1.32	(1.78)	0.87	(1.35)	3.21	(3.05)	1.58	(1.77)
Value	3.25	(2.59)	2.38	(2.29)	3.00	(2.42)	2.18	(1.89)

$p < .01$ $\eta^2 = 0.04$, and creation present, $F(1, 244) = 10.13$, $p < .01$ $\eta^2 = 0.06$, were found. Therefore, families who participated in Make it Roll ($M = 1.68$, $SD = 2.10$) described their tinkering creations more than those who experienced Woodshop Plus ($M = 0.89$, $SD = 1.49$), and families with their tinkering creation described their creations more ($M = 1.69$, $SD = 1.86$) than families who did not have their creations with them ($M = 0.74$, $SD = 1.50$). There was no Creation Present x Program interaction for creation descriptions, $F(1, 244) = 0.00$, $p = .98$.

For tool names and functions, the hypothesized main effect of the program was found, $F(1, 244) = 23.113$, $p < .001$, $\eta^2 = 0.09$, with no main or interaction effects of creation present, Fs < 0.20, ps > 0.66. Indeed, tool names and functions were mentioned twice as often in the reflections of families who experienced the Woodshop Plus program ($M = 3.26$, $SD = 2.46$), compared with Make it Roll ($M = 1.62$, $SD = 1.82$). There were no main effects nor interaction for talk about materials, Fs < 1.71, $p > .19$.

Consistent with the fourth hypothesis about engineering practice talk, main effects of creation present, $F(1, 244) = 16.17$, $p < .001$ $\eta^2 = 0.06$, and program, $F(1, 244) = 24.86$, $p < .001$ $\eta^2 = 0.09$, were qualified by a Creation Present x Program interaction, $F(1, 244) = 5.14$, $p < .05$, $\eta^2 = 0.02$. As shown in Table 3, simple effects analyses revealed that, among families who participated in Make it Roll, those who had their tinkering creations with them engaged in more engineering practice talk than those who did not have their creations with them ($p < .001$). Among families who participated in Woodshop Plus, having the creation present also tended to be associated with more engineering practice talk ($p = .07$). Further, among families with their creations, families who participated in Make it Roll engaged in more engineering practice talk during the conversational reflections than families who participated in Woodshop Plus ($p < .001$).

Finally, we examined families' talk about the value of their tinkering experience and found a main effect of creation present, $F(1, 244) = 6.28$, $p = .01$, $\eta^2 = 0.03$, with no main or interaction effects of the program, Fs < 0.44, ps > 0.51. Families who had their creations with them reflected more on the value of their experience in *Tinkering Lab* ($M = 3.18$, $SD = 2.53$) compared with families who did not have their creations with them ($M = 2.32$, $SD = 2.19$).

Overall with regard to content, although there were no differences by creation present or program for talk about materials, talk about tools was more prevalent for families who took part in Woodshop Plus compared with those who participated in Make it Roll. Also consistent with the hypotheses, compared with families without their creations, families with their tinkering creations named and described their creations more, and talked more about engineering practices. Engineering practice talk was greatest among families who participated in Make it Roll who also had their creation present during the conversational reflections. There were no differences in talk about the value of tinkering across the two programs, but families with their creation talked more about the value of tinkering than those who did not have their creation with them during reminiscing.

6 | DISCUSSION

6.1 | Summary of findings and illustrative examples

The results of this study point to conditions of tinkering and reflection that can advance STEM learning opportunities for young children. The most detailed and elaborative conversational reflections occurred among families who participated in a tinkering program with an engineering design challenge compared with those who visited when the program was most open-ended. Families who chose to exit the exhibit with their creations and had them with them during the conversational reflections elaborated more than families without their creations. Children who had the combined experience of the tinkering program with an engineering design challenge and reminiscing with their creation demonstrated the highest levels of responding to adults' elaborative open-ended questions, and the highest frequency of elaborative statements. The analyses of the content of the reflections further confirmed that talk about tools was most prevalent among families reminiscing about their engagement in Woodshop Plus, and across both programs, the presence of the creation was associated with the most describing of the creations. The most creation naming and engineering talk occurred in the conversational reflections of families who participated in the engineering design challenge to make something that rolls who also had their tinkering creation with them when reminiscing.

To illustrate these results, the following is a conversational reflection of a family who participated in Woodshop Plus and had their creations with them in *Story Hub*. The conversation begins with naming and describing the creations, and then naming tools, ending with an evaluation of the experience.

CHILD1: Okay so in the *Tinkering Lab* we made uh lots of stuff. I made an airplane.
ADULT: Show the back.
CHILD1: (*holds up creation to camera*) The back I draw my initials in.
ADULT: Show what you made (comment directed at CHILD2).
CHILD2: (*holds up creation to camera*) I made a sailboat.
ADULT: What did you use to make it?
CHILD1: Um I use a saw and…
CHILD2: Drill. And a hammer. And nails. And screws.
ADULT: And what'd we have to wear on our face?
CHILD2: Safety goggles.
CHILD1: And we have to wear safety goggles.
ADULT: And it was lots of fun?
CHILD1: Yes, it was lots of fun.

The next example is an excerpt from a family who participated in Make it Roll and had their unnamed creation with them in *Story Hub*. The first part of the conversation includes some description of the creation, and the tools and materials used to make it. As the conversation progresses, the child responds to questions from the adult about testing and evaluating how their design performed, problem-solving, and iterating their design.

CHILD: Okay so what we did today is I made this rolling thing cause that's what you were supposed to make (*holds up creation to camera*). And so I used paper um I used um a box boxes some cereal boxes. And we cut 'em out into circles. And then we punched a hole. And then we used this long thingy. And then we glued it so it would stay. And then this fabric was just to add color. And with wood…
ADULT: Yeah, but did our project work?
CHILD: No.
ADULT: It didn't roll. Why?
CHILD: Because it was too heavy and it was going to a side.
ADULT: Okay. And was everything on there circular? Did we have wheels at first?
CHILD: No.
ADULT: No. Okay. So, we had to make a few adjustments.
CHILD: Yeah.
ADULT: And then we did the challenge.
CHILD: Uh huh.
ADULT: And did it roll?
CHILD: Yeah!
ADULT: We did it. Way to go!
CHILD: But the first time it didn't work…

Children who participated in the program with the engineering design challenge to make something that rolls provided proportionally more responses to adults' elaborative open-ended questions than those who participated in Woodshop Plus. But, as illustrated in the following example, also from Make it Roll, many reflections primarily consisted of adults' and children's elaborative statements.

CHILD: So at the *Tinkering Lab* where the challenge to make something that rolls. We just made something and it took a long time to create this (*holds up creation to camera*).

ADULT: And we worked together. We solved the problems that came up. We worked together to solve them.

CHILD: And the problems were whenever we used some type of wheel it kept on flopping around and so we had to figure out a different way. And my very smart xx [=nickname for Adult] here. He's very smart you see. Found out a way. He did tape.

ADULT: Well some of the wheels weren't turning so we decided to connect the wheels to the axle and make the axle turn (*holds up creation to camera*). So we made the axles turn instead of the wheels turn.

CHILD: Then it would also roll…

Remember that families could see themselves on the computer screen, and this family indeed seems to be talking to the camera in *Story Hub* as they construct a joint reflection about their tinkering experience. Each conversational partner adds new information with each conversational turn. Consistent with the finding that the most engineering practice talk occurred among families who, like this one, participated in Make it Roll and had their creation with them, quite a bit of talk in this example conversation is about the families' engagement in the engineering design processes of trying, testing, figuring things out, and iterating the design.

6.2 | Reminiscing about hands-on activities

Research focusing on parent-child reminiscing about previously experienced events (Fivush, 2014; Fivush et al., 2006) guided by sociocultural theory (Rogoff, 1990; Vygotsky, 1978) is important to our conceptualization of the role that elaborative conversational reflection can play in advancing opportunities for children's STEM learning from tinkering. Children's exposure to and engagement in STEM learning at an early age often involves a combination of direct actions on objects and conversations as experiences unfold (Benjamin et al., 2010; Jant et al., 2014; Leinhardt et al., 2002; Paris & Hapgood, 2002). But conversational reflection after hands-on activities provides opportunities to extend the learning process beyond the initial encoding of the experience (Haden, 2010; Haden 2014), which may be crucial in determining whether knowledge gained from object manipulation will be represented in such a way that it might generalize to other contexts (e.g., from the museum to home) and be accessible over time (Haden et al., 2016; Jant et al., 2014).

Given this perspective about conversational reflection as a part of the learning process, it is important that there were differences in children's provision of elaborative statements and children's responding to adults' elaborative questions as a function of the program and the presence of the creation, and adults' elaborative statements as a function of the presence of the creation. In light of prior work, it might be surprising that we did not see differences in the frequency of adults' elaborative open-ended questions and the frequency of children's responses to these questions. Nevertheless, several ways that our work differs from studies in the event memory literature may contribute to these findings. For one, although elaborative questions and statements can serve different functions in learning and reminiscing about events, event memory research has not always differentiated between these types of elaborations (Fivush et al., 2006). Second, the reflections in this study were recorded shortly after tinkering in *Story Hub*, which is located immediately outside of *Tinkering Lab*. Information about children's tinkering experiences may have been fairly available for reporting with the short delay and no or few intervening events. Therefore, there might have been less need for adult prompting compared to when young children's reports are elicited days, weeks, or longer after events, as is typical in event memory studies. Third, at least some families seemed to be both talking to each other and the camera in *Story Hub* in a "reporting" fashion (see last example, above) that may have encouraged more use of statements. This set up contrasts with the typical procedure in the event memory work where parents and children are encouraged to have a conversation as they naturally would, with the camera or recorder being unobtrusive (e.g., Haden, 1998; Reese et al., 1993). The argument has been made in the literature that the sheer number of open-ended questions may be less important for children's learning and remembering than the extent to which an adult's questions were answerable (reflecting sensitive scaffolding) and answered by the child (Haden, 2010).

6.3 | Design challenges

Consistent with the first hypothesis, our results point to differences in the conversational reflections as a function of the open-endedness of the tinkering activity. One of several ways that the programs were different was that the design challenge set a goal around which tinkering could be organized. Extrapolating from research on story grammar (e.g., Mandler, 1978; Mandler & Johnson, 1977; Trabasso & Stein, 1997), the presence of the goal could have helped structure the experience so that it was encoded in a more complete and organized manner. Indeed, just like a story structure, the engineering design process can make apparent the arrangement of parts and how the parts are related in a tinkering activity, from beginning with a problem, need, or desire, to a plan to address a goal, to an iterative series of attempts to reach the goal, and outcomes that mark success or failure of each attempt. Moreover, successes and failures while working toward the goal can elicit explanations and other information that might further make an experience more understandable and memorable (e.g., Crowley, Callanan, Jipson et al., 2001; Fender & Crowley, 2007; Haden, 2010). The design challenge could have also helped to extend the tinkering activity beyond the sensory experience of engaging with tools and materials, to foster understanding and reporting of engineering practices, such as exploring, designing solutions, testing, interpreting outcomes, and iterating and improving designs. Consistent with this idea, and with the third hypothesis, families who visited when there was a design challenge talked most about engineering.

6.4 | Taking creations home

In line with the second and fourth hypotheses, having their tinkering creations present during reminiscing was associated with differences in the elaborative style and STEM content of families' conversational reflections. It is likely that having the creation present during reminiscing was important for several reasons. Prior work on children's memory recommends real objects, toys, photographs, and drawings as powerful retrieval cues (see Salmon, 2001, for review). The physical objects may also sustain children's engagement in the conversation more so than exclusively verbal prompts. In addition, the cognitive demands associated with remembering are likely reduced with the tinkering creation present. The encoding specificity principle of memory (Tulving & Thomson, 1973) predicts mnemonic benefits if information that was available at the encoding of an experience is also available at recall. All of these factors may have helped children to be better able to respond to adults' questions when reminiscing with their creation compared with children who did not have their creation present. Moreover, with regard to content, some aspects of the reports, such as descriptions of the creations, might be based on what was perceptually available (e.g., *"We used orange wheels."*). But, families who had their creation also talked more about the value of tinkering than those who did not, and those who had their creation with them and engaged in the design challenge talked most about engineering. These results suggest that the presence of the creation was associated with discussions beyond what was perceptually available: talk about scientific and engineering practices, and the meaningfulness of the experience.

6.5 | Limitations and future directions

The results contribute in several ways to understanding how tinkering and reminiscing conditions are related to children's learning processes and remembering following informal STEM experiences. Nonetheless, our conclusions are limited by the fact that we did not observe this sample during tinkering. This is an important next step in this line of work, and one that we are undertaking with a new sample (Pagano, 2019). Likewise, taking the creations home may be an indicator of the meaning and value of the tinkering experience, something this study cannot address directly. Those who had their creations with them for the conversational reflections may have chosen to bring it home with them because the creations were more successful or they felt more investment or ownership over their tinkering experience and/or creation. Essentially, the experience of tinkering that led to the choice to take a creation home, or the experience of reminiscing with the creation, or both, may have contributed to the results observed.

We also lacked the control to compare challenge/no challenge prompts for visitors while holding constant all other elements of the programs (e.g., tools, materials). Therefore, we can only point to a constellation of programmatic elements that made the tinkering programs more or less open-ended. Also, the participants were experiencing and learning in the museum by free choice (e.g., Falk, 2001), determining for themselves what activities they engaged in and reflected about. We did not randomly assign families to program condition, nor did we manipulate whether or not they had their creation present for the conversational reflection. Demographic data is also not available for the sample. The reminiscing literature suggests that the way in which families talk about shared past experiences may be a more powerful predictor of children's learning and retention of information than parental education, family socioeconomic status, or children's language and temperament (Fivush, 2014; Fivush et al., 2006). However, in future work, it will be important to consider how the funds of knowledge (González, Moll, & Amanti, 2013) that families bring with them to the museum might connect to their understanding of a design challenge, and goals for reminiscing. For example, the design challenge may have connected science and everyday practices for some families with greater knowledge about vehicles. Some families may have been better able to produce their own problems and goals as a function of prior knowledge and experiences – creating their own challenges regardless of programming (e.g., Petrich, Wilkinson, & Bevan, 2013).

6.6 | Conclusions and implications for practice

These limitations notwithstanding, our work has bearing on the design of experiences for tinkering and reflection. Part of the appeal of tinkering as a target for educational practices is the potential for it to advance early STEM learning opportunities (e.g., Bennett & Monahan, 2013; Vossoughi & Bevan, 2014). However, not all open-ended tinkering activities may be equally beneficial for supporting STEM learning outcomes. In contrast to the most open-ended of tinkering experiences, our work suggests that more elaborative and engineering design process talk occurs following tinkering programs that involve an engineering design challenge, even one as open-endedly defined as "make something that rolls." Our results also suggest that more elaborative and engineering-related talk occurs when children have their tinkering creation present when they reflect on their experiences. Creating opportunities to engage in reflection while still in exhibits, before decisions are made as to whether or not to take a creation home, may, therefore, be important (e.g., Acosta et al., 2017). When families engage in reflection with their creations, it may extend the STEM learning process from tinkering. Furthermore, encouraging families to reflect on their tinkering experiences can provide information to educators who want to better understand what learners are taking away from their experiences.

In conclusion, we have grounded our work in theory and research about children's learning and remembering. However, our motivation for asking questions about the role of conversational reflection about tinkering grows from a desire to provide evidence that can serve practice in informal educational settings. This study offers information for researchers, educators, and parents about how to increase opportunities for STEM learning through tinkering and reflection.

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APPENDIX A

Distribution of sex of Child(ren) by Program

Child sex	Woodshop Plus		Make it Roll		Total	
	Number	Percent	Number	Percent	Number	Percent
1 Male child	37	20.6%	7	10.3%	44	17.7%
2 Male children	18	10.0%	4	5.9%	22	8.9%
1 Female child	54	30.0%	26	38.2%	80	32.3%
2 Female children	34	18.9%	11	16.2%	45	18.1%
Mixed male, female children	37	20.6%	20	29.4%	57	23.0%