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Supporting family conversations and children's STEM learning in a children's museum

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ABSTRACT

This study tested the effectiveness of a facilitated educational program in a museum for promoting family conversations and children's learning about STEM. A sample of 130 families (71 European-American; 33 African-American; and 26 Hispanic-American) with children *M* age = 6.42 years were observed in a building construction exhibit. Prior to building, families were randomly assigned to conditions that varied in terms of the instructions about a key engineering principle and elaborative question-asking they received. Conversation instruction resulted in adults' asking double the number of *Wh*-questions compared to families who did not receive the instruction. The building instruction was important in promoting increases in adults' STEM-related talk during the building activity, as well as in the children's STEM talk when prompted for information about what they had learned. The effects of the instructions did not vary by families' ethnic background. Implications for facilitating family conversations and children's learning related to STEM are discussed.

The education of U.S. students in science, technology, engineering, and mathematics (STEM) subjects and fields has received considerable attention in recent years. There is the growing sense that addressing the "STEM pipeline problem" (Sanders, 2009, p. 22) – the fact that the numbers of individuals pursuing STEM fields is not sufficient to meet demand – requires bolstering both formal in-school educational opportunities and informal STEM learning experiences in non-school settings (National Research Council, 2007, 2009). In particular, researchers and educators are being called on to answer questions about what and how informal learning experiences can foster interest in and knowledge of STEM (Callanan & Oakes, 1992; Crowley, Callanan, Jipson, et al., 2001; Crowley, Callanan, Tenenbaum, & Allen, 2001; Falk & Dierking, 2002; Gelman & Brenneman, 2004; NRC, 2009; Palmquist & Crowley, 2007). One important characteristic of informal learning is that it is frequently social. Consistent with notions of *scaffolding* (Wood, Bruner, & Ross, 1976) drawn from sociocultural theory (Berk, 2001; Gauvain, 2000; Rogoff, 1990; Vygotsky, 1978), the ways adult caregivers and children behave and talk together while visiting museums, aquariums, zoos, and the like can enhance children's STEM learning (see Haden, 2010; Leinhardt, Crowley, & Knutson, 2002; NRC, 2009; for reviews). Family interactions in such informal learning environments when children are young are further linked with children's STEM achievement when they enter school and beyond (Duncan et al., 2007; Tenenbaum, Snow, Roach, & Kurland, 2005). From the perspective of the pipeline problem then, family conversations in museum exhibits designed for STEM learning may be important in building a foundation for children's future STEM educational and career pursuits (NRC, 2009; Uttal et al., 2013).

Observational studies of family interactions in museums show that children's conversations with their caregivers during hands-on learning activities are related to the quality of their engagement in exhibits (Crowley & Callanan, 1998; Crowley, Callanan, Jipson, et al., 2001; Crowley, Callanan, Tenenbaum, et al., 2001; Gleason & Schauble, 1999; NRC, 2009). Moreover, research linking parent–child conversations to children's understanding and remembering of personally experienced events in general (Haden, Ornstein, Eckerman, & Didow, 2001; Hedrick, San Souci, Haden, & Ornstein, 2009; McGuigan & Salmon, 2004, 2006; Tessler & Nelson, 1994), and STEM learning experiences in museums specifically (Borun, Chambers, Dristas, & Johnson, 1997; Callanan & Jipson, 2001; Crowley, Callanan, Jipson, et al., 2001; Crowley, Callanan,

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Tenenbaum, et al., 2001; Crowley & Jacobs, 2002; Ellenbogen, 2002; Falk & Dierking, 1992; Gleason & Schauble, 1999; NRC, 2009; Palmquist & Crowley, 2007; Rigney & Callanan, 2011; Tenenbaum et al., 2005; Valle & Callanan, 2006) points to particular forms of conversation that may be especially important for learning. Other work further documents that families from diverse ethnic and socioeconomic backgrounds engage in types of talk that can promote children's early science understanding and skills (NRC, 2009; Siegel, Esterly, Callanan, Wright, & Navarro, 2007; Tenenbaum & Callanan, 2008). This descriptive work sets the stage for this study that involves an experimental design, allowing causal statements about the influence of conversation on STEM learning. More specifically, the key manipulation in the current research is aimed at increasing the frequency with which adult caregivers engage in particular kinds of talk that previous work suggests should support children's STEM learning. Also, because little is known about how museum staff and other educators can build on families' funds of knowledge (González, Moll, & Amanti, 2013) and facilitate family learning conversations (see Pattison & Dierking, 2012, for discussion), this study is aimed at taking steps in addressing these gaps as well.

The research took place in the context of a building construction exhibit at a children's museum. The emphasis on building engineering in this exhibit is important for several reasons. First, engineering is an excellent domain in which to study STEM learning in informal contexts. Children and adults are interested in and enjoy building projects of the sort used in this study (Benjamin, Haden, & Wilkerson, 2010). Some have suggested early exposure to fun and creative science and engineering projects as a way to increase the quality and diversity of students pursuing engineering and technology education paths (Carlson & Sullivan, 2004; Cunningham, 2009; Uttal et al., 2013). Second, young children have much to learn about properties of materials, stability, and bracing that are essential to successful engineering (Davis, Ginns, & McRobbie, 2002). Third, engineering emphasizes STEM-related problem-solving skills, including defining the problem, considering different solutions, testing hypotheses, and so forth, and integrates science and mathematics in ways that make these topics accessible to young children (NRC, 2009; Uttal et al., 2013). Moreover, the process of problem solving and feedback (physical and social) is observable to both participants and researchers, as families work together to solve engineering problems. Finally, prior work (Benjamin, Haden, & Wilkerson, 2010) shows that there are reliable differences in how adult caregivers and children together solve simple engineering challenges, and these differences provide models for what is likely more or less effective in inspiring and facilitating STEM learning.

It has been suggested that question-asking and answering is fundamental to supporting learning in informal environments (Borun et al., 1997; Falk & Dierking, 2002; Haden, 2010; NRC, 2009). Given this, one focus in this study was on increasing the number of open-ended *Who, What, Where, Why*, and *How* type-questions adults asked during interactions with their children in the building exhibit. These so-called *Wh*-questions have been highlighted in prior research as important for enhancing children's understanding and the encoding of information across multiple settings (Fivush, Haden, & Reese, 2006; Haden, 2010; Jant, Haden, Uttal, & Babcock, 2014). Caregivers' *Wh*-questions can call attention to salient aspects of an experience as it unfolds, and help them determine what children may or may not know. Moreover, by requesting names, descriptions, actions, explanations, and so forth, caregivers can help children make sense of an experience in ways that may make it more accessible for use when future opportunities for remembering and learning arise (Ellenbogen, 2002; Haden et al., 2001; Jant et al., 2014). Caregivers' open-ended questions can also be essential in motivating sustained engagement in science-related activities in ways that may be crucial for early science learning (Haden, 2010; Humphrey & Gutwill, 2005; Schauble, 1996).

Several studies have shown that in contrast to caregivers who ask few *Wh*-questions during interactions with their children, parents who ask many *Wh*-questions have children who show greater understanding, retention, and subsequent recall of personal experiences (Boland, Haden, & Ornstein, 2003; Hedrick, Haden, & Ornstein, 2009), including experiences in museums (Benjamin et al., 2010; Jant et al., 2014; Tessler & Nelson, 1994). Given these results, we wanted to increase the frequency with which adults in this study asked *Wh*-questions as they interacted with children in the STEM-related exhibit. If adults could comply with our instructions to ask *Wh*-questions while building with children, then we expected that the children would demonstrate better understanding and learning from the experience. We also examined children's responding to caregivers' *Wh*-questions, because children's responsiveness during events has also been linked to their later memory reports (Hedrick, Haden, et al., 2009; Ornstein, Haden, & Hedrick, 2004). Indeed, it has been suggested that it might not just be the sheer frequency of *Wh*-questions asked by adult caregivers, but children's responsiveness to these questions, that most strongly predicts learning and retention of information. Additionally, in cases where knowledge is lacking, and questions are not met with child responses, *Wh*-questions may in turn lead to parents' explanations that have been highlighted in museum research as also contributing substantially to children's STEM learning (Callanan & Jipson, 2001; Crowley & Callanan, 1998; Crowley, Callanan, Tenenbaum, et al., 2001; Crowley & Jacobs, 2002; NRC, 2009; Tare, French, Frazier, Diamond, & Evans, 2011; Tenenbaum & Callanan, 2008; Tenenbaum, Callanan, Alba-Speyer, & Sandoval, 2002).

Finally, during the building activity, we also indexed adults' talk with children about the scientific method (e.g., planning, testing ideas), technology (e.g., building materials, techniques), engineering (e.g., building strength, bracing), and math (e.g., quantity, height). In this way, the current study also connects with research that explores how the frequency of specific kinds of language inputs, such as spatial and relational language (Loewenstein & Gentner, 2005; Pruden, Levine, & Huttenlocher, 2011), number words (Gunderson & Levine, 2011; Levine, Gunderson, & Huttenlocher, 2011; Levine, Suriyakham, Huttenlocher, Rowe, & Gunderson, 2011), emotion and mental state talk (Adams, Kuebli, Boyle, & Fivush, 1995; Laible, 2004; Lohmann & Tomasello, 2003; Rudek & Haden, 2005; Taumoepeau & Ruffman, 2008; Welch-Ross, Fasig, & Farrar, 1999), and so on, predicts children's skills in related domains. In this case, we suggest that if our intervention – without explicitly prompting for it – could increase adults' STEM talk with children in the building exhibit, children's STEM learning similarly might be increased.

We were encouraged that our instructions could indeed generalize in this way because of Benjamin et al.'s (2010) findings from a study involving a primarily European-American sample of 6-year-olds and their adult caregivers who were offered building and/or conversation instructions prior to entering a building exhibit. In Benjamin et al., families who received the information about a key engineering principle – bracing – talked more about engineering (e.g., "*Why do you think this is wobbling?*" "*This doesn't seem very sturdy.*"), when compared with those who did not receive building instructions. Caregivers asked more *Wh*-questions when they received conversation instructions than if not. Most important, the combination of building and conversation instructions was linked to the children's increased talk about engineering (e.g., "*We added a triangle so it wouldn't wobble.*" "*We needed to brace it.*") immediately after building, and children's remembering of engineering-related information 1-day and 2-weeks following the museum visit. In the current study, we developed a coding system to capture a full range