

Science, Technology, Engineering, and Mathematics (STEM) Engagement From Parent-Child Interaction in Informal Learning Environments

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Abstract

Children's engagement in science, technology, engineering, and mathematics (STEM) is fundamental to developing scientific literacy. Informal learning environments, such as children's museums, are a robust setting for fostering STEM engagement, particularly through parent-child interaction. Although the role of STEM learning has been frequently documented in informal learning environments, how children are engaged by STEM topics and STEM's relation to children's everyday lives has not been equally well studied. In this article, I suggest that there are ways that parent-child interaction during informal learning opportunities can relate to children's engagement in STEM activities. A fundamental mechanism underlying this relation is how parents support children's autonomy as they play together. Parent-child interaction relates to children's STEM engagement not only in situ but also in how they generalize that behavior to their everyday activities, which opens up promising new lines of research.

Keywords

informal learning, parent-child interaction, STEM engagement

Scientific literacy starts with the way young children learn about and become engaged by science, technology, engineering, and mathematics (STEM) topics. STEM learning can happen in many different settings (e.g., Gaudreau et al., 2021; Hassinger-Das et al., 2018, 2020; Morris et al., 2021; Ridge et al., 2015). Museums, zoos, science centers, aquariums, and other informal learning institutions provide families with the opportunity not only to learn about STEM content but also to become more engaged in the acquisition of such knowledge. How informal learning occurs at museums, for example, particularly through parent-child interaction, is well documented (e.g., Benjamin et al., 2010; Callanan et al., 2020; Crowley & Callanan, 1998; Crowley et al., 2001; Puchner et al., 2001; Sobel & Jipson, 2016; Van Schijndel et al., 2010). What is less understood is how children might become engaged by STEM topics and activities, or come to internalize such activities as being of interest to them, particularly through parent-child interaction.

Why might this be important? In formal learning environments, STEM engagement is linked to students' positive learning (e.g., Heddy & Sinatra, 2013; Tytler &

Osborne, 2012) as well as college majors and career choices (e.g., Bolstad & Hipkins, 2008; Tytler et al., 2008). More generally, positive STEM engagement might affect not only children's learning but also their everyday behaviors and the promotion of a scientifically literate society. Such engagement could promote better responses to global scientific challenges (such as pandemics, climate change, and economic inequities) as well as better public understanding of how complex information is communicated and interpreted (Kushnir et al., 2022).

What I want to explore here is the relation between (a) the ways parents and children interact at an exhibit or during an activity and (b) children's broader engagement with the exhibit, the concepts behind the exhibit, or the activity in general. What STEM engagement looks like, and how it is measured in this context, is a diverse

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topic among researchers and practitioners interested in informal learning (e.g., McCallie et al., 2009; E. Wood & Wolf, 2008). Following Bell et al. (2019; see also Klopfer et al., 2018), I define engagement as prolonged participation in a voluntary activity or the commitment to continue participation in an activity even when success on the activity is not guaranteed. Critically, engagement with an activity or topic is related to, but not the same as, learning about that activity or topic. Although one who is highly engaged can also learn well (and might be more likely to), one can learn something without being engaged by it or be highly engaged to learn something but not succeed in doing so.¹

Engagement can thus be operationalized in a number of ways in experimental settings, such as the amount of time spent exploring an exhibit, the extent to which children are willing to continue playing or discussing a topic after an activity is concluded, or the extent to which children willingly participate in challenges related to that activity or topic. As an example, children explore a museum exhibit longer with their parents than without them (Crowley et al., 2001). Parent-child dyads or families exploring together also explore more facets of an exhibit (Fender & Crowley, 2007; Van Schijndel et al., 2010). Time at an exhibit is one way to measure engagement with that exhibit, but as I will document below, there are other ways to do so as well.

Importantly, in much of the research on STEM learning and engagement that I detail here—particularly work in children's museums—participants were mostly White, affluent families in the United States. Although there are some important exceptions that focus on parent-child interaction in other cultural communities (e.g., Mejía-Arauz et al., 2005, 2007; Solis & Callanan, 2016), studies developed within a particular cultural framework might be understood differently across other frameworks and understood differently in a global setting. The relation between parent-child interaction and children's STEM engagement might be best understood as being mediated or moderated by the cultural frameworks within which the family is situated. Accordingly, the explanations for the way in which parents² might influence children's engagement that I describe below must take into account the cultural ethnotheories held by the participants (following broader suggestions by Gaskins, 2008, and Ojalehto & Medin, 2015).

Parents' Role in Facilitating Engagement

Numerous studies have examined specific behaviors parents perform that can facilitate engagement (and learning), particularly at museum exhibits. In studies of family conversations in museums in the United States, parents who generate more elaborative talk—for

example, talk that includes more *wh*-questions and more associations to prior knowledge—during free play have children who are more engaged by the play and remember more about the exhibit when asked to reflect on their experience (e.g., Benjamin et al., 2010; Jant et al., 2014). Presenting parents with causal information, facilitating their question asking, or suggesting that they draw associations among events all produced more of these kinds of elaborative conversations during free play (e.g., Boland et al., 2003; Franse et al., 2020; Jant et al., 2014; see also Knutson & Crowley, 2010). Similarly, children talked more about mental states during an activity when parents pointed out contrasts between their own beliefs and their child's (McLoughlin et al., 2020). Callanan et al. (2021) showed that the extent to which children talked about personal connections (or requests for such information from parents) related to both their and their parents' explanations at a STEM exhibit.³

These findings suggest that parents' causal, mechanistic, or STEM talk (which can include concepts such as spatial language) all relate to children's interest in learning about novel information (e.g., Booth et al., 2020; Kurkul et al., 2021; Marcus et al., 2017; see also Callanan et al., 2020, for a consideration of how the timing of such language in relation to children's exploration relates to their learning). The extent to which these types of talk overlap and relate to one another is a critical point to investigate further. However, all of the studies suggest that ways parents and children talk to each other during informal learning opportunities can support not only how children learn but also how they become engaged by the act of learning. They generally support the idea that parents scaffold not only knowledge for their children (D. Wood et al., 1976) but also their engagement with learning. But a critical question is how.

Autonomy and STEM Engagement

Collaborative interactions between parents and children can communicate information about learning as well as about engagement with learning. Early in infancy, children recognize that they share goals with others during an interaction (e.g., Tomasello et al., 2005). The capacity for setting and sharing goals also emerges early in infancy (e.g., Carpenter et al., 1998) and facilitates social interaction (e.g., Tomasello, 2019). Goal setting affects children's memory for the interaction, such that they often mistake others' actions for their own when those goals are collaborative (Sommerville & Hammond, 2007).

The way children understand how goals are set for an interaction relates to how their learning is scaffolded. According to self-determination theory (e.g.,

Ryan & Deci, 2000), what goal setting might also communicate is the extent to which children have autonomy in their actions during their participation with their parent. Autonomy support relates to teacher ratings of children's achievement in school (e.g., Joussemet et al., 2005). When parents reduce children's autonomy during their interaction, children become less engaged with the activity and are less likely to internalize and encode the nature of their participation (Grolnick & Ryan, 1987, 1989). This research has mostly focused on elementary-school-age children. Interactions that reduce children's autonomy during a STEM activity also relate to younger children's engagement in those activities. For example, Leonard et al. (2021) found that when adults take over their interaction with 3- to 6-year-olds during a challenging task—that is, when adults prevent children from performing a behavior and do it themselves—children were rated lower on a measure of global persistence.

But one can also measure how much children learn from an interaction separately from their engagement with the activity. For example, Medina and Sobel (2020) examined children's goal setting when they engaged in free play to learn a novel causal system with their parent. Dyads were introduced to the causal system in the museum; parents were told that the system had a set of rules and that their children would be asked questions about how the system worked. Preschoolers and their parents then played together with the system, and children were asked to answer questions about how the system works. Following a coding system developed by Fung and Callanan (2013), they categorized the parent-child interaction on the basis of who set the goals for the play. Some parents were more *child-directed*⁴ and let children set most or all the goals for the activity; they were more likely to let children explore on their own. Others were more *parent-directed* and set goals for the play; they took more active steps to teach their children the system and structure the play. Still others were more *jointly directed*. The children set the goals for the play, but the parents supported and made suggestions about how those goals could be accomplished.

The results of this study suggest a dissociation between what is learned from this kind of interaction and how engaged children were by the activity. The children in the jointly directed dyads played for the most amount of time with the system. The children in the parent-directed dyads answered the most questions correctly but not necessarily differently from children in the jointly directed dyads.⁵

The distinctions among these interaction styles is reminiscent of contrasts between pedagogical practices in formal educational settings. In response to considerations of the role of direct instruction versus playful interactions in educational environments (e.g., Mayer,

2004), Alfieri et al. (2011) suggested that unguided play typically resulted in lower learning outcomes than direct instruction or guided play. Guided play, in particular, showed the clearest benefit when learners engaged in certain practices that scaffolded their knowledge (such as generating explanations). These styles map nicely onto these naturalistic interactions between parents and children, particularly when combined with the idea that parents can foster elaborative, causal, or STEM talk.

But parental goal setting might be related more to children's engagement than their learning. Callanan et al. (2020) asked parents of children ages 3 to 6 to play together at a gear exhibit. They found that the proportion of children's exploration that involved systematically building and testing gear connections during free play related to the ways in which children understood the causal structure of the exhibit and how that learning generalizes to other, similar situations. But Callanan et al. (2020) also coded the dyad's interaction using the same coding system as Medina and Sobel (2020). Although children in the parent-directed dyads had a lower proportion of those systematic exploratory behaviors during their free play, those behaviors still predicted children's learning in a model that controlled for the interaction style of the dyad.

Further studies showed that different facets of parent-child interaction can relate to children's learning and engagement. Sobel et al. (2021) asked parents and children (ages 4–7) to play together at a circuit exhibit in a children's museum. They then asked children to participate in a set of progressively difficult circuit completion challenges—challenges that they were scaffolded to an answer if children did not solve each on their own. Care was taken to ensure that children knew they could stop participation in the challenges at any time. Children from parent-directed dyads participated in fewer of these challenges, although the proportion of the challenges they solved was not different from those in the other two groups. And although the proportion of challenges that children solved on their own did correlate with the number of challenges they engaged in, parental interaction style was an independent predictor of their persistence in doing the challenges, controlling for how well children solved them.

Of note is that other facets of the interaction between parents and children during their free play related to the proportion of challenges children solved on their own—that is, how much they might have learned about building circuits. The more actions that the parents (as opposed to the children) did to complete a circuit during free play related to children being less likely to solve the challenge of building that circuit on their own. That is, goal setting during parent-child interaction

might be more related to children's engagement in the activity, but who completes the goals might be more related to children's ability to demonstrate knowledge on their own. The more parents did to complete the goal, the less likely children were to demonstrate that knowledge later on. In a follow-up study, Letourneau et al. (2021) showed that when the same exhibit was facilitated by a museum educator who gave brief, open-ended prompts designed to support families' exploration, parents engaged in fewer of these goal-completion behaviors, particularly compared with a condition in which a facilitator was not present but the same prompts were written on the circuit blocks themselves.

Engagement After Parent-Child Interaction

Encouraging families to develop "juicy questions" about exhibits—questions that can be answered by interacting with the exhibit—resulted in families (in this case, parents and children between the ages of 8 and 13) displaying more behaviors in which they set goals for the investigation and generated explanations or interpretations of their observations during their interaction (Gutwill & Allen, 2010). The skills measured here center on *inquiry*—the process of reasoning about STEM topics, as opposed to simply learning STEM content. The families in this study also spent more time at the exhibits, suggesting that children were more engaged by their content (or at least by attempts to answer the question they generated). Gutwill and Allen argued that greater time on task might be dedicated to the more challenging and time-consuming process of inquiry learning. But importantly, they also found that when children were interviewed 3 weeks after their visit to the museum, those who were given the juicy-question instructions were more likely to claim that they applied these skills to other learning tasks.

There is evidence that children's informal learning experiences allow them to retain knowledge after the fact. For example, Marcus et al. (2021) found that having parents and children (5- to 11-year-olds) reflect on their play at an engineering exhibit related to children's ability to remember and use the causal knowledge learned at the exhibit when tested at home a week later. There is also evidence that the way children talk about concepts such as learning and teaching relates to how they report they learned information and how they have taught others in the past (Letourneau & Sobel, 2020; Sobel & Letourneau, 2015, 2016).

But the work cited above centers on what children have learned, not whether they are engaged by the activities. In another study, we wanted to consider whether goal setting during parent-child interaction related to children's spontaneous naturalistic behaviors

beyond the STEM content of the activity. Sobel and Stricker (2022b) observed parent-child (4- to 7-year-olds) dyads participating in or watching a STEM-based activity in their home. In the participation condition, the dyad filled a bowl of water with ground pepper, and then children stuck their finger in the water. The pepper stuck to the finger. After drying their finger off, they applied a small amount of soap to their finger and dipped it in the water with dramatically different results. The soap breaks the surface tension of the water, resulting in the appearance of the finger repelling the pepper. In the observation condition, the dyad watched a video of a woman engaging in these actions. Children were then asked to reflect on this experience, and for approximately 10 days afterward, parents were asked daily to report on their children's most recent handwashing activity—specifically whether they washed their hands (spontaneously or otherwise) after bathroom use and, if they did so, whether they used soap.

The study was designed to examine whether participation or observation of the STEM activity would relate to handwashing behaviors. In general, parents reported that older children were more likely to wash their hands spontaneously, but there was not a relation between children's age and their soap use. Instead, across these two conditions, the amount of causal knowledge about germs that children articulated when they reflected on the activity related to their spontaneous use of soap during handwashing. But what also related was the nature of the parent-child interaction in the participation condition. We coded that interaction in the participation condition using the same parent-directed, child-directed, and jointly directed scheme and found that the children in the parent-directed group were less likely to use soap spontaneously when they washed their hands, controlling for age and their causal knowledge of germs and disease transmission. Although studies of this nature are still exploratory and in need of reproduction, these data suggest that reducing children's autonomy during informal STEM activity relates to the extent to which children might internalize that they should be active participants in the activity in their everyday lives. More generally, these studies provide reason to be optimistic that STEM engagement not only transfers to important everyday activities but also can be achieved through interactions between parents and educators.

Cultural Considerations

An important point to raise before concluding is that there is not a right way for parents and children to interact in order to support STEM engagement or learning. Gaskins (2008), for example, noted that parents of different cultures engaged in different behaviors with their children in museum settings. Parents in different

cultures can also have different beliefs about the role of children's museums in supporting children's learning and the value of play for learning and engagement—their different ethnotheories about the role of play in learning (e.g., Harkness & Super, 1992). Callanan et al. (2020) showed some evidence that within their sample (which was taken from different geographic sites in the U.S.), there were distinct distributions of parent-child interaction styles among racial/ethnic groups. That suggests that STEM engagement is both potentially mediated and moderated by cultural considerations. The lesson from these studies is not that there are best practices in fostering parent-child interaction in general. Instead, there are practices within a culture that might better promote STEM engagement.

An insight to studying cultural similarities and differences in STEM engagement might come from broader observational work on parent-child interaction. For example, Koster et al. (2022) examined parent-child (specifically 2-year-olds) dinner-table conversations in five distinct cultures. They considered the ways parents teach children with their everyday conversation (following Kline, 2015). They found that parents “used a relatively uniform set of behaviors to teach meal-related content, but that there was cross-cultural variation in how frequently these behaviors occurred” (p. 438; see also Clegg et al., 2021, for similar findings looking at samples of individuals with different socioeconomic statuses). For example, in some cultures, parents directed children to engage in certain behaviors, whereas in other cultures, parents provided children with more agency about how to behave. In this study, however, parental teaching mostly focused on conventional information about meals (e.g., to eat with cutlery) or functional information about food (e.g., that carrots are orange) and not necessarily engagement with eating (or with using cutlery or learning about food). An interesting question, however, is whether the variability within a culture, relative to such observations between cultures, predicts children's beliefs about their autonomy with the activity. Promoting both within-cultural and cross-cultural investigations is potentially a way of combining different approaches to cross-cultural development work (e.g., the “breadth” and “depth” approaches suggested by Amir & McAuliffe, 2020; see also Parmar et al., 2004; Vélez-Agosto et al., 2017).

Concluding Thought

A theme of the lines of research presented here is that there might be two pathways to STEM engagement through informal learning. The first is through the content itself—as so many studies described here combine learning with engagement or find relations between how well children understand, articulate, or even hear

about the causal structure of an exhibit and their engagement with that exhibit and its content (e.g., see also Chandler-Campbell et al., 2020; Kurkul et al., 2022). Moreover, children who are more engaged in the process of learning might have better learning outcomes; certainly, some research shows that performance on a measure (particularly surprising success) relates to children's engagement with similar, subsequent measures (Doan et al., 2020).

The second, however, is through goal setting and the autonomy provided to children as they explore and engage with that content. Importantly, children may also be motivated to persist and set goals on their own from observing others do so. Children persist longer when they hear about others' life struggles (Haber et al., 2022), when they pretend to be scientific role models (Shachnai et al., 2022), or when they see others persist, even if those struggles do not necessarily result in achievement (Leonard et al., 2017, 2020). Presenting messages—even subtle ones—that promote the process of engaging in inquiry fosters engagement (e.g., Rhodes et al., 2019). Similarly, presenting messages about the open-endedness of play reduces parental goal setting during parent-child interaction and increases children's engagement (Sobel & Stricker, 2022a). Taken together, emphasizing the process of setting goals and the challenges involved in achieving them might communicate the autonomy children need to foster their engagement in STEM.

Recommended Reading

- Booth, A. E., Shavlik, M., & Haden, C. A. (2020). (See References). Investigates the relation between parents' causal language and children's early understanding of the process of engaging in scientific reasoning.
- Callanan, M. A., Legare, C. H., Sobel, D. M., Jaeger, G. J., Letourneau, S., McHugh, S. R., Willard, A., Brinkman, A., Finiasz, Z., Rubio, E., Barnett, A., Gose, R., Martin, J. L., Meisner, R., & Watson, J. (2020). (See References). Provides a comprehensive review of the literature on informal learning from parent-child interaction as well as a broad study of the dynamics between such interaction during play and children's causal understanding.
- Haber, A. S., Kumar, S. C., & Corriveau, K. H. (2022). (See References). Presents novel interventions (storybook reading and pretense) that affect children's science, technology, engineering, and mathematics (STEM) engagement and persistence with STEM-based tasks.
- Rhodes, M., Cardarelli, A., & Leslie, S. J. (2020). Asking young children to “do science” instead of “be scientists” increases science engagement in a randomized field experiment. *Proceedings of the National Academy of Sciences, USA*, 117(18), 9808–9814. Examines the role that language plays in children's STEM engagement when presented with such tasks in formal learning environments.
- Shachnai, R., Kushnir, T., & Bian, L. (2022). (See References). Presents novel interventions (storybook reading and

pretense) that affect children's STEM engagement and persistence with STEM-based tasks.

Weisberg, D. S., & Sobel, D. M. (2022). *Constructing science: Connecting causal reasoning to scientific thinking in young children*. MIT Press. Presents a broad overview of children's scientific reasoning, how it relates to and develops from their causal reasoning abilities, and the role that formal and informal learning plays in children's scientific reasoning and engagement with science.

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Notes

1. As simple examples in parenting, I have learned the lyrics of many songs from the show *Daniel Tiger's Neighborhood* from interaction with my children, even though I was not engaged to do so (and sadly I still retain that content many years later). I am also highly engaged to learn (or rather relearn) general principles to assist my children with their algebra homework but struggle with doing so.

2. "Caregiver" might be a better word to use here than "parents," but in many of the studies described below, only parents or legal guardians were considered because of institutional review board constraints. As a result, I will use "parents" throughout this article.

3. Indeed, these personal connections have been woven into coding schemes for causal language. Both Callanan et al. (2020) and Sobel et al. (2021) included such personal connection talk as part of their analyses of parents' and children's causal utterances.

4. Medina and Sobel (2020) used the terms "child leading, caregiver directing, and caregiver guiding" to describe these styles. Subsequent articles, however, have used the terms presented in the main text.

5. There are two critical points here. First, although learning overall between the parent-directed and jointly directed group did not differ, it did differ on the easiest questions (with parent-directed children responding more accurately). But that relates to a second, more critical point, which is that the way children answer these questions is only one of many possible ways to

measure "learning." Although this study suggests that learning and engagement are potentially separate constructs, further research is necessary to articulate the different ways learning can be measured.

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