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How Can Parent-Child Interactions in a Museum Support Children's Learning and Transfer of Knowledge

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HOW CAN PARENT-CHILD INTERACTIONS IN A MUSEUM SUPPORT CHILDREN'S LEARNING AND TRANSFER OF KNOWLEDGE

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It is with the deepest gratitude that I dedicate my dissertation to
Mrs. Thomas, for teaching me English.
I would not be here without you.

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ABSTRACT

This study investigated ways to support young children's STEM learning and ability to generalize their knowledge across informal learning experiences. Participants were 128 parents and their 4- to 8-year-old children (M_{age} = 6.63, SD = 1.38). Families were randomly assigned to receive engineering instructions, transfer instructions, both engineering and transfer instructions, or neither. They were then observed working together to solve an engineering problem, and immediately afterward, the children were invited to solve a second engineering problem on their own. Families who received engineering instructions – either alone or in combination with the transfer instructions - were more successful at solving the first engineering problem than those who received only transfer instructions or no instructions. Moreover, parents asked more open-ended questions and talked more about science and mathematics if they received both engineering and transfer instructions. Lastly, children who received both engineering and transfer instructions were better at solving the second engineering problem than those who received only one set of instructions or no instructions. Implications of the work for research in the field and for informal educational environments and their visitors are discussed.

CHAPTER ONE

INTRODUCTION

Informal learning experiences can play an important role in the development of young children's interest in and knowledge of science, technology, engineering, and mathematics (STEM; e.g., NRC, 2009; NSB, 2010). Children spend less than 20 percent of their waking hours in schools (Lopez & Caspe, 2014; Wallace, 2009), and an ever-growing body of research indicates that to a considerable extent science is learned outside of school (Falk & Dierking, 2010; NRC, 2009). Even before entering school, informal educational settings, such as planetariums, aquariums, and museums, offer children opportunities to engage in STEM learning and scientific discovery (Ash, 2002; Callanan & Jipson, 2001; NRC, 2009; Palmquist & Crowley, 2007). An important question, however, remains largely unanswered: how can we promote children's learning and ability to generalize what they learn in one informal educational context to learning opportunities in different contexts. Addressing this question is essential in order to gain a better understanding of how to support parents and museum educators in their endeavors to expose young children to rewarding informal educational experiences. Therefore, the proposed research is aimed at identifying ways to support young children's learning of science practices and STEM content in an informal educational setting in ways that this learning may become usable in different situations.

STEM-experiences that children have in museums and other informal educational settings may link to STEM education in school. For instance, researchers have found that children who spend time in science-related museum exhibits tend to perform better in STEM-related courses and to express more interest in STEM subjects and careers (NRC, 2009). However, less is known about the conditions that facilitate children's learning in museums in ways that enable knowledge *transfer* – that is, the recall and application of relevant parts of previously-learned information in new situations (Bransford & Schwartz, 1999; Khlar & Chen, 2011). For example, transfer is evident when a child uses what was learned in one problem solving activity when solving another related problem. At the core of the proposed research is an effort to understand how best to promote this sort of transfer across hands-on activities. A discussion of the problem of transfer is followed by a description of research and ideas about how parent-child conversations can be important for learning and transfer.

Transfer of Knowledge

Studies conducted in various contexts have yielded mixed results about young children's abilities to generalize or transfer learning across contexts (Bransford & Schwartz, 1999). Although a number of laboratory studies have suggested that children have difficulty applying their knowledge in new situations (e.g., Bransford, Brown, & Cocking, 1999; Gick & Holyoak, 1980; 1987; Lave, 1988; Thorndike, 1927), other studies that focused on what children learned in naturalistic settings have revealed that they can and do transfer even decades after the initial learning took place (e.g., Brown & Kane, 1988; Brown, Kane, & Echols, 1986; Chen & Khlar, 2008; Chen, Mo, &

Honomichl, 2004; Chen & Siegler, 2000). For instance, Chen and colleagues (2004) reported that college students spontaneously used problem-solving stories from their childhood as the basis for solving new problems. In their study, Chinese and American students were asked to solve problems that were structurally similar to problems that came from stories that were familiar in their respective cultures. One of the problems was about a treasure hunter who wanted to explore a cave and then find his way out without the benefit of a map. The solution was to drop some of his possessions along the path and follow them on his way back out. This solution is very similar to the well-known Western story of Hanzel and Gretel, who dropped pebbles and breadcrumbs to make sure they could find their way back home. The other problem involved estimating the weight of a statue without a conventional scale. The solution is very similar to the Chinese tale called Weigh the Elephant, in which an emperor's son measured the weight of an elephant by placing it in a boat, measuring the water line, and then figuring out how many standard measures would have to be placed on the boat to render the same amount of water displacement. The American students performed well on problems like Hanzel and Gretel, but poorly on problems that were like the Chinese folk tale. In contrast, the Chinese students performed well when faced with problems that had solutions like weighting the elephant, but poorly on problems that were like Hanzel and Gretel. These findings thus suggest that adult students can and do apply their knowledge across contexts and long periods of time.

Recent theoretical work on transfer from education and the learning sciences has suggested several reasons for why transfer has been rare in traditional laboratory experiments and why it nevertheless can occur in richer, more long-term learning experiences (see Bransford & Schwartz, 1999). The first reason has to do with the way in which transfer has been assessed. In classic studies the focus was on what Bransford and Schwartz (1999) called *sequestered learning*. Participants in these studies were not allowed to make use of any supporting sources of information. Yet in the real world, young children's learning often takes place in a sociocultural context, which research has shown, has the elements necessary to support learning (e.g., Zimmerman, Reeve, & Bell, 2009). In their ethnographic work, for example, Zimmerman and colleagues (2009) noted that communication and social activities are associated with transfer. Thus, there is good reason to expect that parent-child conversations as an event unfolds can foster children's learning and transfer abilities in a museum setting.

Second, Bransford and Schwartz (1999) suggested that for transfer to take place, the knowledge gained in one setting needs to be represented in a form that will make it recallable in a different setting. That is, the knowledge has to be encoded in such a way that it is not tied to particular materials or contexts, but rather is represented at a level of abstraction that allows it to be activated when recall would be useful (Karmiloff-Smith, 1991). Children may have trouble representing knowledge in this way when the knowledge is based on interactions with perceptually rich objects (e.g., McNeil, Uttal, Jarvin, Sternberg, 2009; Uttal & DeLoache, 2006; Uttal, Scudder, & DeLoache, 1997).

McNeil and colleagues (2009), for example, reported that children who were provided with perceptually rich objects – realistic bills and coins – made more errors when solving math problems involving money than children who were provided with blank bills and coins. Essentially, what is needed is what Sigel (1993) called *distancing*, or attending less to the ongoing behavioral actions and thinking more about the connections between the ongoing actions and past relevant situations or future related situations. For example, a parent might express the linkages between an ongoing event and something the child has experienced previously, saying "We should use Xs like the ones on John Hancock building to make this sturdier." It may be that in their conversations with their parents, children are able to distance, which may, in turn, enable transfer. As reviewed in the following section, there is reason to think that parent-child conversations have the potential to help children represent knowledge in a way that will make it recallable and applicable in a different situation.

Parent-Child Conversations

Parent-child conversations may provide the mechanisms necessary for transfer. Indeed, whether children apply previously acquired knowledge to new learning situations might depend greatly on the presence, style, and depth of the conversations they have with their parents. This idea draws from the sociocultural theory (Rogoff, 1990; Vygotsky, 1978), which posits that children learn through social interactions with more mature and skilled members of their society, with language providing a critical tool for this learning. It also finds support in the empirical literature focusing on parent-child conversations as events unfold (e.g., Haden, Ornstein, Eckerman, & Didow, 2001; Hedrick, San Souci, Haden, & Ornstein, 2009; McGuigan & Salmon, 2006; Tessler & Nelson, 1994).

There is now clear evidence that the way in which parents talk to their children during an event influences children's understanding and remembering of that event (for a review see Haden, 2010). Children whose parents ask many *open-ended Wh- questions* (Who, What, Where, Why, How) have better memories of the event than children whose parents ask fewer such questions (e.g., Boland, Haden, & Ornstein, 2003; Haden et al., 2001). By asking open-ended questions, parents help to focus children's attention on salient aspects of an experience, and elicit conversation about them. Question asking can also help parents gauge what their children know or do not know. Moreover, some work suggests that it isn't the number of *Wh-* questions, but rather the rate at which the child responds to these *Wh-* questions, that best predicts learning and remembering (e.g., Ornstein, Haden, & Hedrick, 2004). Hedrick et al. (2009), for instance, observed mother-child dyads as they engaged in one of two specially constructed events (camping trip or birdwatching adventure) in their homes when the children were 36 and 42 months old. The researchers found that those features and event details about which mothers asked questions and the children provided answers were better recalled than those features and event details about which mothers asked questions but the children did not provide any responses. Much of this work on conversations during events has involved fairly homogenous groups of families, but even so, it illustrates substantial individual differences among families in the ways they approach such interactions with their children. There is also work pointing to substantial variability across racial and ethnic groups in parents' conversational style in general (e.g., Bell et al., 2009; Fivush & Haden, 2003; Hoff, 2003; Miller et al., 2002), and in conversations about science in particular (e.g., Tenenbaum & Callanan, 2008; Tenenbaum, Callanan, Aalba-Speyer, & Sandoval, 2002). More specifically, research has revealed that education may trump income in influencing families' conversations in museum settings. Tenenbaum and Callanan (2008), for example, studied parent-child conversations about science among families of Mexican-descent. The researchers found that parents' educational level, and whether they had been to the museum before, were better predictors of their talk than their income level. Parents with a higher educational level provided scientific principle explanations and encouraged predictions more than parents with lower levels of education. Also, parents who had been to a museum before used more explanations in the museum than parents who had not been to a museum before.

Explanations provided by parents have also been found to play an important role in fostering children's understanding (e.g., Crowley & Jacobs, 2002; Tenenbaum, Snow, Roach, & Kurland, 2005; Vale & Callanan, 2006). Some explanations involve the making of associations to children's prior knowledge or experiences, such as in the example *"Let's add some Xs like the ones on John Hancock."* A number of studies have revealed that associative talk can boost children's understanding and subsequent recall of an event (e.g., Boland et al., 2003; Crowley & Jacobs, 2002; Tessler & Nelson, 1994).

To illustrate, Crowley and Jacobs (2002) found that 4- to 12-year-old children whose parents explained fossils by associating them to children's previous experiences recalled more names of the fossils than children whose parents did not make such associations. Likewise, Valle and Callanan (2006) reported that, in a homework-like activity, parents who connected an unfamiliar science topic to their 4- to 9-year-old children's relevant past experiences facilitated their children's understanding of the topic.

Transfer of knowledge requires that children connect what they are currently doing to what they already know (e.g., Bransford & Schwartz, 1999), and so by using associations, parents can explicitly help their children to make such connections. Indeed, parents' use of associations might be essential to the process of establishing intercontextuality (Engle, 2006; Jant et al., 2014), which is the framing of the original and transfer contexts in ways that make transfer more likely to occur. For example, associations that point out relations between different learning situations can help children notice the connections between the situations. By connecting different learning situations (e.g., "*This skyscraper we are building now is similar to the one we built out of Legos at home.")* parents make transfer the subject of discussion (Haden, Cohen, Uttal, & Marcus, 2015; Jant et al., 2014).

Consistent with Sigel's (1993) notion of distancing, parents may also facilitate transfer by helping children focus less on individual objects and more on principles and practices for problem solving. For example, asking a child to take a step back, reflect, and connect the current engineering problem they are solving with a future one (e.g., *"We* *used the triangle to make this skyscraper sturdy. So, what do you think you should use to make a bridge sturdy?"*), could help the child to abstract the solution and apply it when working on a similar engineering problem in the future.

Engineering Learning

The site for this research, a building construction exhibit in a children's museum, provides opportunities for families to engage in practices of science and engineering. The few studies that have focused on early engineering knowledge have revealed that young children have a limited understanding of engineering and of key engineering principles, such as structural integrity and cross-bracing (e.g., Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Davis, Ginns, & McRobbie, 2002; Gustafson, Rowell, & Rose, 2000; Knight & Cunningham, 2004; Marcus, Haden, & Uttal, in press). Illustrating this, Davis and colleagues (2002) asked 6- to 13-year-olds to provide suggestions for how to stabilize a wobbly bridge made out of wood. Compared to the older children, who suggested that adding triangles will make the bridge sturdier, the younger ones suggested that hammering the nails of the bridge or cementing its pylons will make it more stable. Similarly, Marcus, Haden, and Uttal (in press) presented 5- to 6-year-olds with three skyscrapers made out of straws and asked them to identify the sturdiest and wobbliest ones, to explain their choices, and to provide suggestions for how to fix the wobbliest skyscraper. The children were at chance levels in terms of their abilities to identify wobbly and sturdy skyscrapers, were more likely to provide incorrect explanations than correct explanations for their choice selections, and were more likely to provide incorrect suggestions (e.g., *"Add more straws."*) than correct suggestions (e.g., *"Include triangles.")* for how to fix the wobbly skyscraper.

In situations like this, when knowledge is lacking, parent-child conversations may be especially important in determining what children learn and represent in memory about their experiences. Specifically, parents can help their children gain understanding of an experience by asking questions aimed at assessing what children know and do not know, and then providing explanations when necessary (e.g., Boland et al., 2003). Yet, parents might not able to help if they do not have the necessary knowledge about the topics featured in a museum exhibit (e.g., Marcus et al., in press). Families come to the museum with a variety of prior knowledge, and this knowledge has the potential to help them make sense of their museum experience. Moll, Gonzalez, and colleagues (e.g., Gonzalez, Moll, & Amanti, 2013; Moll et al., 1992) coined the term "funds of knowledge" to refer to this prior knowledge and argued that it could support children's STEM learning in informal and formal educational settings. A challenge, however, lies in finding ways to help families recognize the connections between their prior knowledge and the museum exhibit.

Past work indicates that providing families with information about the topics featured in museum exhibits can facilitate parent-child interactions, as well as children's learning. Benjamin, Haden, and Wilkerson (2010), for example, observed that providing families with building instruction prior to entering a building construction exhibit enhanced their abilities to build sturdy structures. Likewise, Haden, Jant, Hoffman, Marcus, Geddes, and Gaskins (2014) found that families who were provided with building tips about how to construct sturdy structures built sturdier structures than those who were not provided with such tips. Importantly, children who received the building tips mentioned more types of STEM content when asked to report what they had learned than those who did not receive such tips.

Current Study

The current study provides information about the types of instructions that can facilitate families' interactions in informal learning environments in ways that can help children learn information that is usable in different situations. The fundamental question the work aims to address is: What conditions promote learning and transfer in such environments? All participating families were asked to work on one engineering problem together, with half of the families fixing a wobbly skyscraper and the other half fixing a wobbly bridge. The second engineering problem was presented after the first, and involved the child working alone to fix a second structure. For those who worked to fix the skyscraper with their families, the engineering problem the children performed alone was to fix the wobbly bridge, and for those who worked on the bridge with their families, the second engineering problem the children performed alone was fixing the skyscraper.

One condition of interest was whether front-loading families with exhibit-related information prior to working in that exhibit would foster their interactions and learning in that exhibit. Half of the families in the current study were provided with the opportunity to experiment with a key engineering principle - cross-bracing - prior to solving two engineering problems in the museum exhibit. They had the opportunity to test how cross-bracing stabilizes a wobbly structure. The study examined whether families used this *engineering information* to solve the problems of fixing a wobbly skyscraper or a wobbly bridge.

A second condition of interest was whether making *transfer* more salient to families would influence their conversational interactions and building outcomes. Half of the families were told about and saw the second engineering problem prior to beginning to solve the first. That is, families were shown the second wobbly structure and were told that the children would have to stabilize it on their own, without the help of the parents, after they were finished stabilizing the first wobbly structure. These transfer instructions drew attention to the problem of transfer: what is learned from solving the first problem could be used to solve the second.

The effects of these two types of instructions – engineering and transfer instructions – on learning and transfer of knowledge were examined. Families' ability to transfer the information presented during the demonstration to the engineering problem was assessed based on their inclusion of pieces that served to brace the structure and the overall sturdiness of the structure. The effects of the engineering and transfer instructions on parent-child conversations were assessed based on the number of open-ended questions asked by parents, the responses provided by children, and the number of associations made by parents and children. Moreover, the effectiveness of the instructions in stimulating conversations rich in STEM content was assessed based on parents' and children’s talk about the science process, technology, engineering, and mathematics. Children’s ability to transfer their knowledge to the second engineering problem when working on their own was also assessed based on the total number of triangular braces incorporated into the structure and the overall sturdiness of the structure.

The data was collected as part of a National Science Foundation award # 1123411 and the author was the lead data collector. The data collection took place at the Chicago Children's Museum (CCM). Parents with 4- to 8-year-old children were recruited to participate in the study as they entered the building construction exhibit called *Skyline*. As mentioned above, some families were provided with engineering instructions (only), others received transfer instructions (only), and still others receive both engineering and transfer instructions. A control group received neither engineering nor transfer instructions.

Research Questions and Hypotheses

There were two engineering problems to be solved, and so the research questions and hypotheses are presented separately for each problem. Table 1 provides an overview of the measures associated with each of the following hypotheses.

Table 1. Overview of the Dependent Measures

First Engineering Problem	Second Engineering Problem
Building Measures (Hypothesis 1)	**Building Measures (Hypothesis 4)**
Number of Functional Triangles and Diagonal Braces	Number of Functional Triangles and Diagonal Braces
Sturdiness of the Structure	Sturdiness of the Structure
Conversation Measures	
Elaborative Talk (Hypothesis 2)	
Open-Ended Questions	
Responses	
Associations to the Demonstration	
Associations to Prior Experiences	
Associations Between Structures	
STEM Talk (Hypothesis 3)	
Science Process	
Technology	
Engineering	
Mathematics	

First engineering problem. The three following research questions and hypotheses pertain to families' engagement in the first problem-solving task, fixing either a wobbly skyscraper or a wobbly bridge.

Research question 1: Building outcomes. What types of instructions can best support children's abilities to transfer their knowledge across different informal learning experiences?

Hypothesis 1. It was hypothesized that families who received engineering instructions prior to working on the first engineering problem would be more successful at stabilizing the first wobbly structure than families who did not receive such instructions. In other words, those who received engineering instructions were expected to add a greater number of functional triangles and diagonal braces, and receive higher ratings of the overall sturdiness of their fixed structures, compared to families who did not receive engineering instructions. The transfer manipulation was not expected to affect building outcomes of first engineering problem.

Research question 2: Elaborative talk. Were families who received instructions talking in more elaborative ways while working on the first engineering problem than families who did not receive instructions?

Research hypothesis 2. Compared to parents who did not receive transfer instructions, those who did were expected to demonstrate more conversational techniques associated with an elaborative style. Specifically, it was hypothesized that parents who received transfer instructions would ask more open-ended questions (*"How can we make this sturdier?"*) and make more associations (*"This is like the Lego task where we built a bridge.")* than those who did not receive transfer instructions. This hypothesis was based on the idea that the transfer instructions could make transfer more salient, and thus encourage parents to make such connections across experiences, contexts, and time. Associations included making connections between the engineering demonstration and the engineering problems (*"What did the lady say about triangles?"*), between the first engineering problem and relevant prior experiences (*"This is like the marshmallow task where we built sturdy houses."),* and verbal comparisons across engineering problems

(*"The key to fixing both this skyscraper and that bridge is to use triangles, okay?"*). Also based on the notions of distancing discussed, the transfer instructions were hypothesized to support conversations that made individual object manipulation experiences part of a more integrative and cohesive representation that supported transfer. Given that *Wh-* questions may play an important role in constructing these representations, the transfer instructions were also expected to lead parents who received it to ask more *Wh-* questions than those who did not receive the transfer instructions.

Research question 3: STEM talk. Were there differences in the content of parent-child conversations depending on the type of instructions families received?

Hypothesis 3. Parents and children who received engineering instructions were expected to talk more about engineering concepts and principles while working on the first engineering problem than those who did not receive the engineering instructions. Moreover, parents and children who received transfer instructions were expected to talk more about the science process while working on the first engineering problem than those who did not receive transfer instructions. Science process talk encompassed modeling talk (e.g., *"Watch how I'm going to fix this."*), delegating work (e.g., *"You put the beam on and I'll tighten the nuts and bolts."*), hypothesis testing (e.g., *"What do you think will happen if we add this triangle here?"*), and planning ("*I think we should take care of the foundation first, and then move onto the next level." "What do you think we should do next?"*).

Furthermore, the combination of engineering and transfer instructions was expected to result in the most talk about science process, technology (e.g., *"What are the mending plates for?"*), engineering (e.g., *"We should add lots of triangles to make this sturdy."*), and mathematics (e.g., *"We need 4 more beams."*).

The following hypothesis pertains to the children's performance on the second problem-solving task in which they fixed the structure (bridge, skyscraper) that they did not fix with their parents.

***Research question 4: Building outcomes*.** What types of instructions would promote young children's ability to transfer their knowledge across engineering problems when working on their own, without the help of their parents?

Hypothesis 4. It was hypothesized that children from families who received both engineering and transfer instructions would add more cross braces and triangles when fixing the second structure and that their structures would receive higher sturdiness ratings than those from families who did not receive the engineering and transfer instructions.

CHAPTER TWO

METHODS

Participants

Participants were 128 parents and their 4- to 8-year-old children (M_{age} = 6.63, *SD* = 1.38). They were recruited from the *Skyline* exhibit at the Chicago Children's Museum (CCM). The criteria for inviting participants were that the children were (a) between the ages of 4- and 8-years and (b) accompanied by at least one of their parents. The sample consisted of 62.5% Caucasian, 10.2% African American, 8.6% Hispanic, 7.8% Asian, and 9.4% mixed race children; 1.6% of the families did not specify the children's race. The mean level of mothers' educational level was 16.72 years (*SD* = 1.89); the mean level of other parent's education was 16.44 years (*SD* = 2.30). The income level of the participating families was distributed as follows: 38.3% reported an income greater than $150, 000; 21.9% between $100,000 – $149, 999; 10.9% between $75,000 – $99,999; 10.9% between $50,000 – $74,999; 7.8% between $20,000 – $49,999; 3.9% reported less than $20,000; and 6.3% did not report this information.

Procedure

Materials and engineering problems. All families were observed in the Skyscraper Challenge building space in CCM's 2,500 square-foot Skyline exhibit (Figure 1). The Skyscraper Challenge features small-scale plastic building materials, including mending plates, beams, and girders.

Figure 1. Skyscraper Challenge Building Space

The building materials in the Skyscraper Challenge contrast with the building materials featured in the Wobbly Station (Figure 2) that was used for the engineering instructions. The Wobbly Station features large-scale wood struts and metal bolts, of the sort available in a second building area in the exhibit. The participating families were presented either with a wobbly skyscraper or a wobbly bridge (in a counterbalanced order) made out of the small-scale plastic building materials available in the Skyscraper Challenge building area (Figures 3a and 3b). All families were asked to “fix it and make it sturdier, stronger, so it doesn’t wobble anymore”.

The experimental manipulation was carried out in the Skyline exhibit right before the families were presented with the first engineering problem. Families either did or did not receive engineering instructions, and either did or did not receive transfer instructions. In combination, these two variables yielded a 2 (engineering instructions: yes, no) x 2 (transfer instructions: yes, no) experimental design; families were randomly assigned to one of the four cells in this 2 x 2 design. Child gender was balanced across cells (i.e., there were equal numbers of boys and girls in each cell).

Engineering instructions. Families who received engineering instructions were provided with the opportunity to experiment with a key engineering principle – cross-bracing – prior to solving the two engineering problems. Families were taken to a permanent exhibit display (the Wobbly Station, Figure 2), which features a wooden square with a middle piece that can be connected either horizontally or diagonally with a metal bolt. Children were first shown how wobbly the wooden square was and then asked where to connect its middle piece in order to stop it from wobbling. The researcher then connected the piece as the children suggested. Next families were shown that connecting the middle piece diagonally stopped the square from wobbling and were also explicitly told about the function of triangles.

Figure 2. Wobbly Station

Figure 3. Wobbly Skyscraper

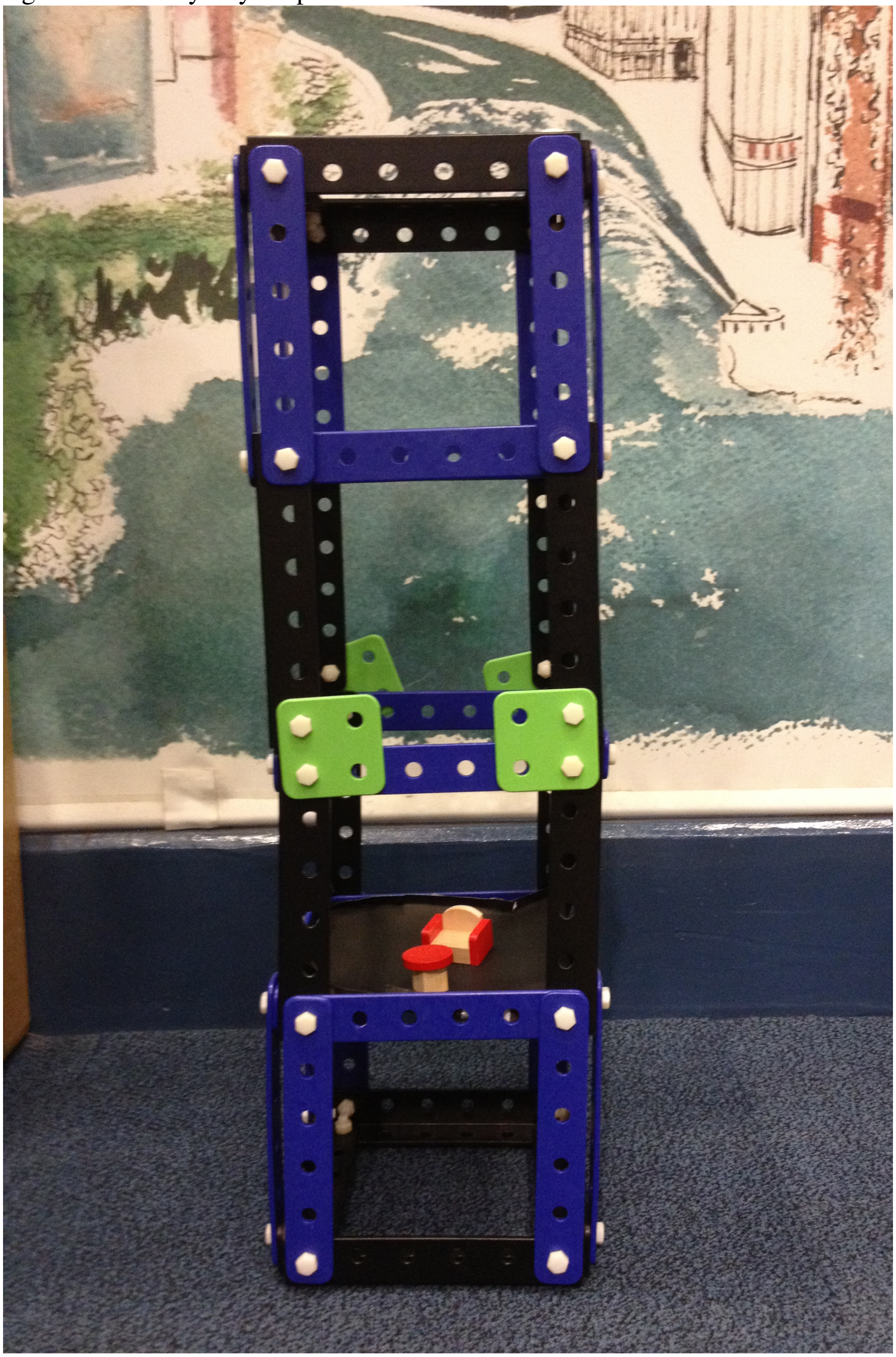


Figure 4. Wobbly Bridge

After connecting the piece diagonally and demonstrating that the square was not moving anymore, families were told: “My square is not moving anymore and that’s because I connected this piece diagonally like this [*pointed out the diagonal*]. When you connect the piece diagonally like this you create two triangles. There is a triangle over here and another triangle over here [*pointed out the two triangles formed by the diagonal brace*], and triangles are the strongest shape.”

Transfer instructions. The transfer instructions involved telling families that after they are done fixing the first wobbly structure, the children would have to fix another wobbly structure on their own; these families were also shown the second wobbly structure. More specifically, families were told: “And once you are done fixing my wobbly skyscraper/wobbly bridge, I have a special project just for the child/children.

I have this long bridge/tall skyscraper over here, but my long bridge/tall skyscraper is really wobbly. See how it's moving this way and this way? [*showed how wobbly it was*] I will need your help to fix this, to make it sturdier, stronger, so it doesn't wobble anymore. But you will have to work on this one without your parents' help."

All families were given 12 minutes plus an additional 3, if they wanted, for a total of 15 minutes per engineering problem. All families were video recorded as they worked on fixing the first wobbly structure and children were video recorded as they worked on fixing the second wobbly structure.

Parent questionnaire. While the children worked on the second engineering problem, a parent of the child filled out a questionnaire (see Appendix A). Parents provided demographic information, including level of education, ethnicity, race, and family household income. Additionally, parents rated their own and their children's prior knowledge and interest in building on a scale of 1 to 7 (1 = knew very little/very little interest, 7 = knew a great deal/very high interest). Lastly, they indicated how often their children played with 12 different types of toys on a scale of 1 to 7 (1 = almost never, 7 = daily). This information was used to determine whether random assignment had resulted in groups that were not different on any of the background characteristics.

Coding

The sturdiness of the final structures was scored from photographs that were taken at the museum. The video records of the conversations during the first engineering problem (masked for condition) were scored using Noldus ObserverPro software. The procedure for establishing inter-rater reliability was the same for all of the coding systems described below. Two researchers, blind to condition, independently coded 20% of the photos and video records. Once reliability was established, no single reliability estimate was below Cohen's Kappa (κ) = .70. The remainder of the data was coded by one reliable coder with checks by a second reliable coder.

Building Outcomes

Coders scored each of the two final structures and reliability was κ = 1.00 for each of the following:

A. Total number of pieces: the total number of building materials added to the structures, excluding nuts and bolts.
B. Total number of functional pieces: the total number of triangular shapes that served a structural function (i.e., were placed in such a way that restricted the movement of the structure in any given direction).
C. Total number of decorative triangles: the total number of triangular shapes that served a decorative function (i.e., did not restrict the movement of the structure).

To assess the sturdiness of each structure, a ratio of the total number of functional pieces to total number of pieces was computed.

Talk During the First Engineering Problem

The parent-child conversations during the first engineering problem were coded using a coding system adapted from Haden et al. (2014) and Marcus et al. (in press).

Table 2 provides an overview of the conversation codes.

Elaborative talk. The coding of the conversations during the first engineering problem focused on the:

A. Number of open-ended questions parents asked. Open-ended questions are questions of the *Wh*- type format (Who, What, Where, Why, When, How) that ask for new pieces of information (e.g., "Where should I attach this triangle?" "How do you connect these two pieces?").

B. Number of new pieces of information children provided in response to the open-ended questions.

Table 2. Parent-Child Conversation Codes

Conversation Code	Definition	Examples
Elaborative Talk		
Open-ended questions	These are questions of the *Wh-* type format (Who, What, Where, Why, When, How) that ask for new pieces of information	"How do we connect these two pieces?" "Why do we have to add triangles?"
Responses	Number of new pieces of information provided in response to the open-ended questions	Parent: "What shapes should we use?" *Child: "We should use triangles."*
Associations to the demonstration	Talk that involves making connections between the engineering problem and what they were shown and/or told by the researcher prior to working on solving the engineering problem	"What did the lady say about triangles?" "This is just like the square she showed us before and the key is to use triangles."
Associations to prior experiences	Talk that involves making connections between the engineering problem (the here-and-now) and what the child/parent already knows or has experience with	"This is like the marshmallow task we did where we built houses." "We should do Xs just like the ones on the John Hancock."
Associations between engineering problems	Verbal comparisons across the two engineering problems	"Do you see what I'm doing here? That's what you need to do when you work on that skyscraper by yourself." "The key to fixing both this skyscraper and that bridge is to use triangles, okay?"
STEM Talk		
Science Process	Talk about hypothesis testing, problem solving, delegating work, figuring something out, redoing based on something not working, planning how to building, or proposing an idea	"What do you think will happen if I add this piece here?" "Why don't you add this beam first, and then we'll move onto the next one?"
Technology	Talk that involves labeling building materials or talk about the function of building materials	"Give me a mending plate." "What are these braces for?"
Engineering	Talk about triangles and/or their function, how to make the structure sturdier, how to connect pieces, how to tighten nuts and bolts, as well as talk about parts of the building	"How can we make this bridge sturdier?" "Let's add a triangle here."
Mathematics	Talk about numbers, length, weight, and geometric shapes other than triangles	"We need 3 more light blue pieces." "The light blue piece does not fit here, we need a shorter one."

C. Associations to the demonstration: talk that involved making connections between the engineering problem and what they were shown and/or told by the researcher prior to working on the engineering problem (e.g., “What did the lady say about triangles?” “This is just like the square she showed us before and the key is to use triangles.”)

D. Associations to prior experiences: talk that involved making connections between the engineering problem (the here-and-now) and what the child/parent already knows or has experience with (e.g., “This is like the marshmallow task we did where we built houses.” “We should do Xs just like the ones on the John Hancock.”)

E. Associations between engineering problems: verbal comparisons across the two engineering problems (e.g., “Do you see what I’m doing here? That’s what you need to do when you work on that skyscraper by yourself.” “The key to fixing both this skyscraper and that bridge is to use triangles, okay?”).

Kappa's were κ. = .81, 1.00, 1.00, and 1.00, for parents’ open-ended questions, associations to the demonstration, associations to prior experiences, and associations between engineering problems, respectively; and κ = .78, .86, 1.00, and 1.00, for children's responses, associations to the demonstration, associations to prior knowledge, and associations between engineering problems, respectively.

STEM talk. Children’s and parents’ talk was also categorized in terms of content as follows:

A. Science process: talk about hypothesis testing, problem solving, delegating work, figuring something out, redoing based on something not working, planning how to build, or proposing an idea (e.g., "What do you think will happen if I add this piece here?" "Why don't you add this beam first, and then we'll move onto the next one?")

B. Technology: talk that involves labeling building materials or talk about the function of building materials (e.g., "Give me a mending plate." "What are these braces for?")

C. Engineering: talk about triangles and/or their function, how to make the structure sturdy, how to connect pieces, how to tighten nuts and bolts, as well as talk about parts of the building, such as floors and windows (e.g., "How can we make this bridge sturdier?" "Let's add a triangle here.")

D. Mathematics: talk about numbers, length, weight, and geometric shapes other than triangles (e.g., "We need 3 more light blue pieces." "The light blue piece does not fit here, we need a shorter one.")

Kappa's were κ. = .79, .70, .84, and .84, for parents' science process, technology, engineering, and mathematics talk, respectively, and κ = .91, .70, .80, and .92, for children's science process, technology, engineering and mathematics talk, respectively.

CHAPTER THREE

RESULTS

All research hypotheses were tested using analyses of variance (ANOVAs). For each dependent measure, a 4 (Instructional Condition: Engineering + Transfer Instructions, Engineering Instructions, Transfer Instructions, Control) x 2 (Type of Structure: Skyscraper, Bridge) ANOVA tested if the effects of instruction were different for families working on the two structures. Main effects were followed by pairwise tests with a Bonferroni adjustment for multiple comparisons (all *p*s $< .05$, unless otherwise noted).

Preliminary Analyses

Initial analyses examined whether there were differences by instructional condition and type of structure (skyscraper, bridge) on any of the background characteristics reported by the parents. These analyses of background characteristics were conducted with child gender as a third between group factor. The primary question here was whether random assignment had resulted in groups that did not differ on the background characteristics listed in Tables 3 and 4. A secondary question was whether there were gender differences on any of these characteristics, particularly child prior knowledge and interest in building. As shown in Table 5, there was a Condition x Type of Structure x Child Gender interaction for children's age, $F(3, 112) = 2.78$, $p < .05$.

Table 3. Means and Standard Deviations for Background Characteristics by Condition, Type of Structure, and Child Gender

	Instructional Condition								Type of Structure				Child Gender			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Boys		Girls	
Demographic Variable	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Child age (years)	6.40	(1.47)	6.52	(1.43)	6.57	(1.17)	7.03	(1.40)	6.55	(1.44)	6.71	(1.32)	6.74	(1.36)	6.52	(1.40)
Maternal education	17.20	(2.01)	16.71	(1.95)	16.41	(1.88)	16.56	(1.78)	16.62	(1.85)	16.82	(1.95)	16.67	(1.90)	16.78	(1.89)
Second parent's education	15.60	(2.59)	16.62	(2.17)	16.86	(2.21)	16.77	(2.05)	16.30	(2.28)	16.57	(2.34)	16.60	(2.10)	16.28	(2.49)
Parents' prior knowledge	3.22	(2.03)	3.44	(1.93)	3.47	(1.95)	3.53	(1.95)	3.53	(1.96)	3.30	(1.94)	3.59	(1.91)	3.23	(1.98)
Parents' interest in building	3.75	(1.76)	3.16	(1.85)	4.03	(1.82)	4.06	(1.70)	3.80	(1.84)	3.70	(1.78)	3.86	(1.74)	3.64	(1.86)
Children's prior knowledge	2.50	(1.44)	2.34	(1.43)	2.44	(1.32)	2.84	(1.57)	2.44	(1.37)	2.63	(1.51)	3.02	(1.52)	2.05	(1.17)
Children's interest in building	4.75	(1.80)	4.25	(2.16)	4.66	(1.82)	4.88	(1.79)	4.77	(2.02)	4.50	(1.75)	5.39	(1.66)	3.88	(1.81)

Note. Prior knowledge and interest were rated on a 1 to 7 scale.

Table 4. Summary of ANOVAs for Background Characteristics by Condition, Type of Structure, and Child Gender

	Instructional Condition			**Type of Structure**			**Child Gender**			**Condition x Type of Structure**			**Condition x Child Gender**			**Type of Structure x Child Gender**			**Condition x Type of Structure x Child Gender**		
Demographic	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Child age (years)	1.38	.25	.03	.51	.48	.00	.91	.34	.01	1.94	.13	.04	1.15	.33	.03	.42	.52	.00	2.78	.04	.06
Maternal education	1.03	.39	.01	.29	.59	.00	.07	.80	.00	.87	.46	.01	.99	.40	.01	1.60	.21	.00	1.02	.39	.01
Second parent's education	1.63	.19	.05	.16	.69	.00	.49	.49	.00	.09	.96	.00	1.02	.39	.03	.62	.44	.01	.17	.92	.00
Parents' prior knowledge	.16	.92	.00	.49	.49	.00	1.14	.29	.01	1.91	.13	.04	1.68	.18	.04	3.63	.06	.03	1.47	.23	.03
Parents' interest in building	1.75	.16	.04	.09	.77	.00	.47	.49	.00	.83	.48	.02	.35	.79	.01	5.58	.02	.04	.24	.87	.01
Children's prior knowledge	.79	.50	.02	.58	.45	.00	15.59	.00	.11	.27	.85	.01	.31	.82	.01	.41	.53	.00	1.09	.36	.02
Children's interest in building	.84	.48	.02	.81	.37	.00	26.21	.00	.16	.86	.46	.02	4.65	.00	.09	3.03	.08	.02	.23	.88	.00

Table 5. Means and Standard Deviations for Children's Play Preferences by Condition, Type of Structure, and Child Gender

	Instructional Condition								**Type of Structure**				**Child Gender**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Boy		Girl	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Puzzles	4.66	(1.54)	4.16	(1.69)	4.06	(1.68)	4.91	(1.42)	4.58	(1.61)	4.31	(1.60)	4.45	(1.55)	4.44	(1.67)
Puzzle Games	4.75	(1.44)	4.10	(1.78)	4.53	(1.63)	4.63	(1.56)	4.57	(1.65)	4.44	(1.56)	4.56	(1.72)	4.45	(1.49)
Legos	5.09	(1.99)	4.69	(1.99)	5.03	(1.80)	5.16	(2.10)	5.09	(2.00)	4.89	(1.93)	5.83	(1.59)	4.16	(1.95)
Construction	3.56	(1.92)	3.48	(2.15)	3.61	(1.78)	3.53	(1.80)	3.62	(1.92)	3.48	(1.88)	4.41	(1.77)	2.68	(1.60)
Art	6.03	(1.30)	6.34	(.94)	5.97	(1.45)	5.94	(1.32)	6.16	(1.17)	5.98	(1.35)	5.54	(1.49)	6.59	(.66)
Board and Card Games	5.03	(1.56)	4.16	(1.67)	4.81	(1.57)	4.50	(1.78)	4.55	(1.83)	4.70	(1.49)	4.60	(1.80)	4.64	(1.53)
Music	4.19	(2.02)	4.38	(1.76)	4.45	(1.81)	4.90	(1.99)	4.52	(1.91)	4.44	(1.89)	3.93	(1.79)	5.02	(1.85)
Math Games	4.07	(2.03)	4.22	(1.95)	4.59	(1.95)	5.03	(1.72)	4.38	(1.87)	4.57	(2.00)	4.76	(1.92)	4.20	(1.91)
Education-Oriented Computer/Internet Games	4.44	(1.93)	5.31	(1.96)	4.61	(2.09)	5.13	(1.78)	4.68	(2.00)	5.06	(1.91)	4.51	(1.99)	5.24	(1.86)
Video Games	3.39	(2.23)	4.00	(2.20)	4.16	(2.52)	3.39	(2.30)	3.66	(2.42)	3.81	(2.22)	4.13	(2.27)	3.36	(2.31)
Pretend Play/Fantasy	5.69	(1.45)	5.31	(1.75)	5.00	(1.57)	5.42	(1.84)	5.38	(1.75)	5.33	(1.56)	5.06	(1.73)	5.64	(1.54)
Toys for Moving Arms and Legs	5.81	(1.60)	5.59	(1.54)	5.50	(1.41)	5.90	(1.30)	5.87	(1.31)	5.53	(1.58)	5.97	(1.26)	5.44	(1.60)

Note. Play preference was rated on a scale of 1 to 7.

Follow up tests revealed that for those who worked on the skyscraper, there were no significant age differences among boys in the four instructional groups, $F(3, 28) = 1.11$, $p = .36$. Girls who received no instructions ($M = 8.06$, $SD = 1.10$) were older than girls who received both engineering and transfer instructions ($M = 5.85$, $SD = 1.36$), girls who received engineering instructions ($M = 5.76$, $SD = .79$), and girls who received transfer instructions ($M = 6.37$, $SD = 1.21$), $F(3, 28) = 7.13$, $p < .01$. For those who worked on the bridge, there were no differences in children's age by child gender and instructional condition, Fs ≤ 1.23, ps $\geq .27$.

With the exception of child age, ANOVAs confirmed that the instructional groups were not different on any other background characteristics, Fs ≤ 1.75, ps $\geq .16$. Moreover, families who worked on the skyscraper and families who worked on the bridge were not different on any background characteristics, Fs ≤ 81, ps $\geq .37$. As further illustrated in Table 6, only two main effects of child gender reached statistical significance. Compared to parents of girls, parents of boys rated their children as having the most prior knowledge about building (boys: $M = 3.02$, $SD = 1.52$; girls: $M = 2.05$, $SD = 1.17$), $F(1, 112) = 15.59$, $p < .001$, and interest in building (boys: $M = 5.39$, $SD = 1.66$; girls: $M = 3.88$, $SD = 1.81$), $F(1, 112) = 26.21$, $p < .001$. Whereas the interaction between condition and child gender was not statistically significant for children's prior engineering knowledge, $F(3, 112) = .31$, $p = 82$, there was a significant interaction between condition and child gender for child interest in building, $F(3, 112) = 4.65$, $p < .01$. Follow up tests revealed that across the instructional conditions, parents of boys rated their children similarly in their interest in building, $F(3, 60) = 1.26$, $p = .30$.

Table 6. Summary of ANOVAs for Children's Play Preferences by Condition, Type of Structure, and Child Gender

	Instructional Condition			**Type of Structure**			**Child Gender**			**Condition x Type of Structure**			**Condition x Child Gender**			**Type of Structure x Child Gender**			**Condition x Type of Structure x Child Gender**		
	F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Puzzles	2.11	.10	.05	.92	.34	.01	.00	.96	.00	.69	.56	.02	.83	.48	.02	.38	.54	.00	3.02	.03	.07
Puzzle Games	.97	.41	.02	.23	.63	.00	.14	.71	.00	2.19	.09	.05	1.25	.30	.03	2.73	.10	.02	1.34	.26	.03
Legos	.42	.74	.01	.40	.53	.00	27.05	.00	.18	1.16	.33	.02	.19	.90	.00	.29	.59	.00	.73	.53	.01
Construction	.03	.99	.00	.23	.63	.00	31.93	.00	.08	1.12	.34	.01	2.03	.11	.02	.01	.95	.00	.04	.99	.00
Art	.90	.45	.02	.91	.34	.01	27.99	.00	.18	1.78	.16	.03	1.26	.29	.02	2.47	.12	.02	.73	.54	.01
Board and Card Games	1.53	.21	.04	.24	.63	.00	.02	.90	.00	.31	.82	.01	.46	.71	.01	.06	.81	.00	.48	.70	.01
Music	.75	.52	.02	.07	.80	.00	10.96	.00	.08	.58	.63	.01	.47	.70	.01	.61	.44	.00	1.00	.39	.02
Math Games	1.60	.19	.04	.25	.62	.00	2.56	.11	.02	.30	.83	.01	.27	.85	.01	2.27	.13	.02	2.00	.12	.05
Education-Oriented Computer/Internet	1.45	.23	.03	1.28	.26	.01	4.80	.03	.04	.36	.78	.01	.67	.57	.01	6.56	.01	.05	1.15	.33	.03
Video Games	1.04	.38	.02	.18	.67	.00	3.32	.07	.03	.73	.54	.02	.33	.80	.01	3.61	.06	.03	2.59	.06	.06
Pretend Play/Fantasy	.93	.43	.02	.03	.86	.00	3.75	.06	.03	.89	.45	.02	.66	.58	.02	.32	.57	.00	.43	.73	.01
Toys for Moving Arms and Legs	.56	.64	.01	1.87	.17	.01	4.45	.04	.03	1.16	.33	.03	1.90	.13	.04	.73	.39	.01	1.14	.34	.03

However, parents of girls who received both engineering and transfer instructions rated their girls as having more interest in building ($M = 4.75$, $SD = 1.73$) than girls who received only the engineering instructions ($M = 2.69$, $SD = 1.58$), $F(3, 60) = 4.19$, $p < .01$. There was also one significant interaction between child gender and type of structure for parents' interest in building, $F(1, 112) = 5.58$, $p < .05$. Follow up tests showed that, among families who worked on the skyscraper, parents of boys ($M = 4.28$, $SD = 1.82$) reported having more interest in building than parents of girls ($M = 3.31$, $SD = 1.75$), $F(1, 62) = 4.72$, $p < .05$. For those who worked on the bridge, there were no significant differences in parents' interest in building by child gender, $F(1, 62) = 1.44$, $p = .24$.

Also by way of background characteristics, recall that parents indicated how often their children played with 12 different types of toys on a scale of 1 to 7 (1 = almost never, 7 = daily). Table 3 lists the means and standard deviations for children's play preferences by condition, type of structure, and child gender. A series of ANOVAs examined whether there were differences by instructional group, type of structure, and child gender in children's play preferences. These results are summarized in Table 5. As illustrated in the table, there were no significant differences by instructional group in children's play preferences as reported by parents, $F\text{s} \leq 2.11$, $p\text{s} \geq .10$. There were also no significant differences between those who worked on the skyscraper and those who worked on the bridge in children's play preferences, $F\text{s} \leq 1.87$, $p\text{s} \geq .17$. Six main effects of child gender reached statistical significance. Compared with parents of girls, parents of boys rated their children as playing more often with Legos, construction toys, and toys for moving arms and legs, $F\text{s} \leq 31.93$, $p\text{s} < .05$. Girls were rated as playing more often with art, musical toys, and education-oriented computer/Internet games than boys, *F*s $\leq$ 27.99, *p*s $<$ .05. There was only one significant interaction between type of structure and child gender, $F(1, 112) = 6.56$, $p < .05$. For those families who worked on the skyscraper, parents of girls ($M = 5.48$, $SD = 1.81$) rated their children as playing educational computer games more frequently than parents of boys ($M = 3.87$, $SD = 1.88$), $F(1, 60) = 11.91$, $p < .01$. There were no significant differences between boys and girls who worked on the bridge, $F(1, 62) = .07$, $p = .80$. Although there was a significant Condition x Type of Structure x Child Gender for children's puzzle play, $F(3, 112) = 3.02$, $p < .05$, follow up tests revealed that the Condition x Type of Structure interaction did not differ by child gender.

Preliminary correlational analyses also tested the association between parents' educational level, parents' and children's prior engineering knowledge, parents' and children's interest in building engineering and each measure of parents' and children's conversations during building, and the building outcomes for the two engineering problems. Mothers' education was significantly correlated with parents' talk about science process, $r = .25$, parents' open-ended questions, $r = .25$, children's responses, $r = .22$, and the sturdiness ratio of the first structure, $r = .23$ (all *p*s $\leq$ .05). The second parent's educational level, (*r*s $\leq$ .18, *p*s $\geq$ .06), parents' prior knowledge (*r*s $\leq$ .14; *p*s $\geq$ .11) and parents' interest in building (*r*s $\leq$ .14; *p*s $\geq$ .17) were not significantly correlated with any of the conversation or building outcomes. However, children's prior knowledge about building was significantly associated with parents' talk about technology, $r = -.22$,

p < 05. Children's interest in building was significantly associated with children's talk about science, $r = .27$, children's engineering talk, $r = .22$, adults' open-ended questions, $r = .18$, children's responses, $r = .21$, and the sturdiness ratio of the second task, $r = .23$ (all ps $\leq .05$). These background variables were included as covariates in the main analyses of the dependent measure to which the variables were significantly correlated. However, these covariates did not change the pattern of results, and so the results presented here are without the covariates.

Main Analyses

To test the hypotheses, I first examined whether the instructions and the type of structure families worked on were related to the sturdiness of the first wobbly structure. Then, I examined whether the engineering and transfer instructions might have fostered families' talk in the exhibit. Lastly, I examined whether group membership and type of structure were related to the sturdiness of the second structure that children fixed on their own, without their parents' help.

Child age effects were tested by running all of the main analyses as 4 (Condition) x 2 (Type of Structure) x 2 (Child Age: Younger, Older) ANOVAs. A median split on child age ($M = 6.63$, $SD = 1.38$, median = 6.69) was used to group children as younger or older. Because the results revealed very few main or interactive effects of child age, the main analyses reported here do not include child age as a factor. The results of these analyses are reported in Appendix B. Additionally, child gender effects were tested by running all of the main analyses as 4 (Condition) x 2 (Type of Structure) x 2 (Child

Gender: Male, Female) ANOVAs. Again, because very few main or interactive effects of child gender were found, the main analyses reported here do not include child gender as a factor. These analyses of child gender are reported in Appendix C. A mediational model was proposed, but the conditions for testing mediation were not met. The detailed results are presented in Appendix D.

First Engineering Problem

Children worked with their parents on the first engineering problem. Half the families worked on the wobbly skyscraper while the others worked on fixing the wobbly bridge.

Building outcomes. The first research hypothesis was that families who received engineering instructions would better stabilize the first wobbly structure through bracing than families who did not receive engineering instructions. To assess the stability of the wobbly structure, a ratio of the total number of functional pieces to total number of pieces was computed. The top portion of Table 7 lists the means and standard deviations for the ratio of functional-to-total-pieces. Consistent with this hypothesis, the main effect of condition was significant, $F(3, 120) = 10.24$, $p < .001$; families who received both engineering and transfer instructions ($M = .66$, $SD = .31$) or only engineering instructions ($M = .68$, $SD = .32$) had a significantly higher ratio of functional-to-total-pieces than families who received only transfer instructions ($M = .32$, $SD = .38$) and no instructions at all ($M = .38$, $SD = .35$). The main effect of type of structure was also significant, $F(1, 120) = 9.57$, $p < .01$; families who worked on the skyscraper ($M = .60$, $SD = .39$) had a higher ratio of functional pieces to total pieces than families who worked on the bridge (*M* = .42, *SD* = .35). The interaction of Condition x Type of Structure was not statistically significant, $F(3, 120) = 1.84$, $p = .14$.

Table 7. Means and Standard Deviations for the Building Outcomes by Condition and Type of Structure

	Instructional Condition								**Type of Structure**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
First Engineering Problem												
Total pieces	9.25	(4.81)	9.03	(4.84)	9.28	(4.07)	10.59	(6.45)	10.81	(5.31)	8.27	(5.56)
Braces	6.63	(5.01)	6.66	(4.40)	3.19	(4.06)	3.81	(4.16)	6.31	(4.85)	3.83	(4.13)
Sturdiness ratio	.66	(.31)	.68	(.32)	.32	(.38)	.38	(.35)	.60	(.39)	.42	(.35)
Second Engineering Problem												
Total pieces	6.16	(3.88)	6.06	(3.06)	6.06	(4.31)	5.53	(2.98)	5.70	(3.41)	6.20	(3.73)
Braces	3.56	(3.92)	1.91	(2.83)	.81	(1.65)	.81	(1.55)	1.56	(2.59)	1.98	(3.13)
Sturdiness ratio	.48	(.38)	.31	(.42)	.13	(.27)	.16	(.30)	.26	(.35)	.28	(.39)

Table 8. Summary of ANOVAs for the Building Outcomes by Condition and Type of Structure

	Instructional Condition			**Type of Structure**			**Condition x Type of Structure**		
	F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
First Engineering Problem									
Total pieces	.70	.56	.01	8.91	.00	.06	3.42	.02	.07
Total functional pieces	5.94	.00	.12	10.93	.00	.07	1.15	.33	.02
Sturdiness ratio	10.24	.00	.19	9.57	.00	.06	1.84	.14	.03
Second Engineering Problem									
Total pieces	.21	.89	.00	.63	.43	.00	2.15	.10	.05
Total functional pieces	7.58	.00	.15	.80	.37	.01	1.07	.36	.02
Sturdiness ratio	6.90	.00	.14	.08	.77	.00	1.65	.18	.03

Therefore, the engineering instructions led families to add greater stability to the wobbly structure regardless of whether their first engineering problem was the wobbly skyscraper or the wobbly bridge.

Elaborative talk: Parents' open-ended questions and children's responses. The second hypothesis was that families who received transfer instructions would engage in more elaborative conversations while working on the first engineering problem than families who did not receive transfer instructions. The analysis of elaborative talk included parents' open-ended questions and children's responding to those questions. The top portion of Table 9 displays the mean frequency of parents' open-ended questions. The main effects of condition, $F(3, 120) = .27$, $p = .84$, and of type of structure, $F(1, 120) = .01$, $p = .91$, were not statistically significant. However, there was a significant Condition x Type of Structure interaction, $F(3, 120) = 3.61$, $p < .05$. For those families who worked on the skyscraper, parents who received both engineering and transfer instructions ($M = 10.50$, $SD = 7.40$) asked more open-ended questions than parents who did not receive any such instructions/Control ($M = 3.69$, $SD = 3.48$), $F(3, 60) = 2.72$, $p = .05$. But, parents who received only one set of instructions (Engineering Instructions Only: $M = 7.88$, $SD = 9.17$; Transfer Instructions Only: $M = 7.00$, $SD = 5.92$) were not different from those who received both types of instructions or no instructions, on open-ended question asking. For those who worked on the bridge, there were no differences in parents' open-ended question asking across conditions, $F(3, 60) = 1.15$, $p = .34$.

With regard to children's responses to their parents' open-ended questions, both frequency and rate of children's responding was considered. Rate of responding was calculated as the number of child responses to parents' open-ended questions divided by the total number of parents' open-ended questions. Thus, rate of responding controlled for variation in the number of open-ended questions parents asked. Children's frequency of responding to adults' open-ended questions was relatively high across conditions (M = 3.34, SD = 3.62); only 21.9% of the children did not provide any response to parents' open-ended questions. Further, as illustrated in the bottom portion of Tables 9 and 10, there were no significant differences in children's frequency of responding across conditions or across the type of structure they worked on, Fs $\leq .52$, ps $\geq .48$. Moreover, although the Condition x Type of Structure interaction was significant, $F(3, 120) = 3.03$, $p < .05$, follow up tests indicated that the effects of condition on children's frequency of responding were not significantly different depending on the type of structure they worked on (Skyscraper: $F(3, 60) = 1.91$, $p = .14$; Bridge: $F(3, 60) = 1.15$, $p = .34$). Similarly, there were no significant main or interactive effects of condition on children's rate of responding, all Fs ≤ 1.59, ps $\geq .20$. Thus, although children who worked on the skyscraper and who received both engineering and transfer instructions were asked the most questions, and thus had the greatest opportunity to respond, the instructions did not affect the extent to which children responded to their parents' What, How, and Where type questions.

Table 9. Means and Standard Deviations for Families' Open-Ended Questions and Responses by Condition and Type of Structure

	Instructional Condition								Type of Structure			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Parents												
Open-ended questions	8.16	(6.22)	7.50	(7.73)	6.84	(6.48)	6.84	(7.36)	7.27	(7.09)	7.41	(6.78)
Responses	1.31	(1.35)	1.16	(1.37)	1.25	(1.57)	1.38	(1.41)	1.23	(1.37)	1.31	(1.47)
Rate of responding	.88	(.52)	.63	(.51)	.75	(.41)	.74	(.50)	.79	(.50)	.71	(.49)
Children												
Open-ended questions	1.72	(1.61)	1.91	(2.10)	1.84	(2.03)	2.19	(1.77)	1.75	(1.66)	2.08	(2.06)
Responses	3.72	(3.72)	3.28	(4.18)	3.31	(3.21)	3.03	(3.43)	3.56	(4.04)	3.11	(3.16)
Rate of responding	.52	(.30)	.44	(.32)	.61	(.28)	.50	(.34)	.52	(.30)	.52	(.32)

Table 10. Summary of ANOVAs for Families' Open-Ended Questions and Responses by Condition and Type of Structure

	Instructional Condition			**Type of Structure**			**Condition x Type of Structure**		
	F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Parents									
Open-ended questions	.27	.84	.01	.01	.91	.00	3.61	.02	.08
Responses	.14	.94	.00	.10	.76	.00	.78	.51	.02
Rate of responding	1.12	.35	.04	.65	.42	.01	.49	.69	.02
Children									
Open-ended questions	.36	.78	.01	.99	.32	.01	1.96	.12	.05
Responses	.20	.89	.00	.52	.48	.00	3.03	.03	.07
Rate of responding	1.59	.20	.04	.01	.93	.00	1.55	.21	.04

In summary, among parents who worked on the skyscraper, receiving both the engineering and transfer instructions led parents to ask more than twice as many open-ended questions compared with parents who did not receive any instructions. Parents who worked on the bridge did not differ in their open-ended question asking by instructional group or structure. There were also no differences in children's rate of responding across conditions.

Elaborative talk: Associations. Associations are also an element of elaborative talk. The hypothesis that the transfer instructions would lead parents to make the most associations was based on the idea that the transfer instructions would make transfer more salient, and would thus encourage parents to make connections across experiences, contexts, and time. Recall that the coding of the parent-child conversations focused on three types of associations: (1) associations to prior knowledge, (2) associations to the demonstration used to convey the engineering instructions, and (3) associations across the two engineering problems. Although all parents and children could have made associations to prior knowledge, only a subset of the families was expected to make the other two types of associations. Specifically, only families in the Engineering + Transfer Instructions and Engineering Instructions conditions were expected to make associations to the demonstration because only these families saw the engineering demonstration used to convey the engineering instructions ($n = 64$). Likewise, only families in the Engineering + Transfer Instructions and Transfer Instructions conditions were expected to make associations across engineering problems because only these families received information about the second engineering problem before beginning to work on the first ($n = 64$).

Overall, the frequency of all three types of associations was very low and so each of the three types of associations was scored for either presence or absence of such talk. A series of Chi-Square analyses were then conducted to examine whether there was an association between condition and associative talk and between type of structure and associative talk. Presentation of each of these analyses begins with parents' talk and is immediately followed by a discussion of children's talk.

Associations to prior knowledge involved making connections between the engineering problem and prior relevant experiences. These were very infrequent. Specifically, 76.6% of the parents and 86.7% of the children did not make any such associations. Results indicated no differences across conditions in whether or not prior knowledge associations were made. This was the case for parents, $\chi^2(3, N = 128) = 2.96$, $p = .40$, Cramer's $V = .15$, and for children , $\chi^2(3, N = 128) = 1.29$, $p = .73$, Cramer's $V = .10$. Moreover, there were no differences between those who fixed the skyscraper versus the bridge first in whether or not they made a prior knowledge association. This was so for parents, $\chi^2(1, N = 128) = .17$, $p = .68$, Cramer's $V = .04$, and for children, $\chi^2(1, N = 128) = 1.70$, $p = .19$, Cramer's $V = .12$.

Looking at families' associations to the demonstration, it was the case that 31.3% of the parents and 53.1% of children who receive engineering instructions (Engineering + Transfer Instructions, Engineering Instruction Only) made no associations to the demonstration. Furthermore, results revealed no significant differences across the two conditions (Engineering + Transfer Instructions, Engineering Instructions Only) in whether or not associations to the demonstration were made. This was true for parents, $\chi^2(1, N = 64) = .00$, $p = 1.00$, Cramer's $V = .00$, and for children, $\chi^2(1, N = 64) = .25$, $p = .62$, Cramer's $V = .06$. Also, there were no differences between those who fixed the skyscraper versus those who fixed the bridge first in whether or not they made an association to the demonstration. This was true for parents, $\chi^2(1, N = 64) = 1.16$, $p = .28$, Cramer's $V = .14$, and for children, $\chi^2(1, N = 64) = .00$, $p = 1.00$, Cramer's $V = .00$.

Lastly, families' associations across the two engineering problems were examined. Note that 75% of the parents and 98.4% of the children who received transfer instructions (Engineering + Transfer Instructions, Transfer Instructions Only) did not make an association across engineering problems. Moreover, parents' making of such associations did not differ across conditions, $\chi^2(1, N = 64) = .33$, $p = .56$, Cramer's $V = .07$; nor did it differ across type of structure, $\chi^2(1, N = 64) = .00$, $p = 1.00$, Cramer's $V = .00$. The one child who made an association across engineering problems was in the Engineering + Transfer Instructions condition and worked on the bridge.

In sum, parents' and children's associative talk was very infrequent and, in contrast to my hypothesis, there were no significant differences among families who received instructions and those who did not in their making of associations, nor among families who worked on the skyscraper or the bridge.

STEM talk. Parents and children who received engineering instructions were expected to talk more about engineering principles and concepts than those who did not receive the engineering instructions. Families who received transfer instructions were expected to talk more about science process than those who did not receive transfer instructions. The combination of engineering and transfer instructions was expected to result in the most talk about science process, technology, engineering, and mathematics.

The top portion of Table 11 displays the means and standard deviations for parents' talk about science process, technology, engineering, and mathematics. For parents' science talk, the main effects of condition, $F(3, 120) = .72$, $p = .54$, and of type of structure, $F(1, 120) = .33$, $p = .57$ were not significant. However, the Condition x Type of Structure interaction was significant, $F(3, 120) = 2.98$, $p < .05$. For those who worked on the skyscraper, parents who received both engineering and transfer instructions (M = 10.25, SD = 4.61) talked more about the science process than parents who received no instructions (M = 5.00, SD = 3.20), $F(3, 60) = 3.78$, $p < .05$. For those who worked on the bridge, there were no significant group differences in science talk, $F(3, 60) = .37$, $p = .78$.

With regard to parents' technology talk, the main effect of condition was not significant, $F(3, 120) = 1.45$, $p = .23$; nor was the main effect of type of structure, $F(1, 120) = .24$, $p = .63$. However, the Condition x Type of Structure was significant, $F(3, 120) = 4.96$, $p < .01$. For those who worked on the bridge, parents who received the transfer instructions (M = 13.94, SD = 10.79) talked significantly more about technology than parents who received both engineering and transfer instructions (M = 5.19, SD = 3.67), $F(3, 60) = 4.11$, $p < .05$. For those who worked on the skyscraper, there were no significant group differences in technology talk, $F(3, 60) = 2.17$, $p = .10$.

For parents' engineering talk, the main effect of condition was not significant, $F(3, 120) = .10$, $p = .96$; nor was the main effect of type of structure, $F(1, 120) = .17$, $p = .69$. The Condition x Type of Structure interaction was significant, $F(3, 120) = 2.91$, $p < .05$, although the follow up tests did not reveal any significant group differences in engineering talk for those who worked on the skyscraper, $F(3, 60) = 1.02$, $p = .39$, or for those who worked on the bridge, $F(3, 60) = 2.11$, $p = .11$.

Lastly, for parents' mathematics talk, the main effect of condition was not significant, $F(3, 120) = 1.65$, $p = .18$; nor was the main effect of type of structure, $F(1, 120) = 2.80$, $p = .10$. However, the Condition x Type of Structure interaction was significant, $F(3, 120) = 2.75$, $p < .05$. Among those who worked on the skyscraper, parents who received both engineering and transfer instructions ($M = 6.75$, $SD = 4.34$) talked significantly more about mathematics than parents who did not receive any instruction ($M = 2.44$, $SD = 2.83$), $F(3, 60) = 3.64$, $p < .05$. For those who worked on the bridge, there were no significant instructional group differences in parents' talk about mathematics, $F(3, 60) = .41$, $p = .75$.

The bottom portion of Table 11 lists the means and standard deviations for children's talk about science process, technology, engineering, and mathematics. As shown in the table, in contrast to my hypothesis, there were no significant main effects of condition on children's talk about science process, technology, engineering, and mathematics, all Fs ≤ 1.20, ps $\geq .31$. There were also no significant main effects of type of structure, Fs ≤ 2.01, ps $\geq .16$; and no significant interactions between conditions and the type of structure they worked on, Fs ≤ 2.23, ps $\geq .09$.

Table 11. Means and Standard Deviations for Families' STEM Talk by Condition and Type of Structure

	Instructional Condition								Type of Structure			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Parents												
Science Process	8.28	(4.98)	7.13	(4.77)	7.84	(5.70)	6.63	(4.61)	7.72	(4.89)	7.22	(5.17)
Technology	8.97	(7.53)	9.25	(6.07)	10.94	(9.32)	7.25	(6.20)	9.41	(7.03)	8.80	(7.85)
Engineering	18.47	(10.21)	19.50	(10.07)	19.75	(9.07)	19.47	(11.29)	19.66	(10.53)	18.94	(9.68)
Mathematics	5.34	(4.29)	4.53	(4.44)	4.44	(3.86)	3.25	(2.85)	4.95	(4.25)	3.83	(3.54)
Children												
Sciences Process	1.72	(2.28)	1.97	(2.15)	2.66	(2.65)	2.06	(2.00)	2.05	(2.31)	2.16	(2.27)
Technology	3.78	(3.54)	4.41	(5.72)	4.19	(4.39)	4.84	(5.65)	4.92	(5.55)	3.69	(4.02)
Engineering	5.66	(3.88)	7.53	(7.54)	6.38	(4.53)	5.94	(4.00)	6.72	(5.94)	6.03	(4.35)
Mathematics	3.28	(3.80)	2.47	(2.58)	2.38	(2.06)	2.00	(2.26)	2.73	(2.66)	2.33	(2.87)

Table 12. Summary of ANOVAs for Families' STEM Talk by Condition and Type of Structure

	Instructional Condition			Type of Structure			Condition x Type of Structure		
	F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
Parents									
Science Process	.72	.54	.02	.33	.57	.00	2.98	.03	.07
Technology	1.45	.23	.03	.24	.63	.00	4.96	.00	.11
Engineering	.10	.96	.00	.17	.69	.00	2.91	.04	.07
Mathematics	1.65	.18	.04	2.80	.10	.02	2.75	.04	.06
Children									
Sciences Process	.99	.40	.02	.08	.78	.00	2.23	.09	.05
Technology	.26	.86	.01	2.01	.16	.02	.46	.71	.01
Engineering	.80	.50	.02	.55	.46	.00	.79	.50	.02
Mathematics	1.20	.31	.03	.68	.41	.01	.25	.86	.01

Taken the results indicate that the effects of the instructions on parents' STEM talk varied depending on the type of structure they worked on. Consistent with my hypothesis, parents who received both engineering and transfer instructions talked more about science and mathematics than parents who received no instructions, but this difference was only apparent for families who worked on the skyscraper. There were no group differences for science and mathematics talk for those who worked on the bridge. Also contrary to my hypothesis, among those who worked on the bridge, parents who received only transfer instructions talked more about technology than parents who received both engineering and transfer instructions. The engineering and transfer instructions did not lead to differences in the frequency of parents' engineering talk. Furthermore, the children in the four instructional conditions talked similarly about STEM while working on the first engineering problem regardless of whether the problem was the wobbly skyscraper or bridge.

Second Engineering Problem

The children performed the second engineering problem without their parents. The second engineering problem was the bridge for those who had worked on the skyscraper with their parents, and the skyscraper for those who had worked on the bridge first with their parents.

Building outcomes. The fourth hypothesis was that children who received both engineering and transfer instructions would be more successful at fixing the second wobbly structure than children who did not receive engineering and transfer instructions. As hypothesized, the main effect of condition was significant, $F(1, 120) = 6.90$, $p < .001$; children who received both engineering and transfer instructions ($M = .48$, $SD = .38$) had a significantly higher ratio of functional-to-total-pieces than those who received engineering instructions ($M = .31$, $SD = .42$), transfer instructions ($M = .13$, $SD = .27$), and no instructions ($M = .16$, $SD = .30$). The main effect of type of structure was not significant, $F(1, 120) = .08$, $p = .77$; nor was the Condition x Type of Structure interaction, $F(3, 120) = 1.65$, $p = .18$. Therefore, the children who received the combination of engineering and transfer instructions were best able to fix the wobbly structure on their own regardless of whether the second engineering problem was the wobbly skyscraper or the wobbly bridge.

CHAPTER FOUR

DISCUSSION

This study investigated ways to support young children's STEM learning and ability to generalize their knowledge across situations. Taken together, the findings provide important information about how to foster children's learning in museums in ways that this learning may be usable in different situations. The following discussion of the results is organized according to the four research hypotheses, the implications of the work for informal educational environments and their visitors, and future directions for research in this field.

In this study, an experimental methodology was adapted to examine the impact of specific instructions on parent-child conversations and building outcomes. The experimental manipulation involved providing parents and their children with engineering instructions, transfer instructions, both engineering and transfer instructions, or neither. Families were then observed working to solve one engineering problem together, and immediately afterward, the children were invited to solve a second engineering problem on their own, without the help of their parents.

Observations of how the instructions provided to families influenced the building outcomes and conversations led to several important findings about learning and transfer. First, the engineering and transfer instructions did facilitate families' efforts to stabilize the first wobbly structure, and this was true regardless of the type of structure they worked on – skyscraper or bridge. As predicted, families who received engineering instructions – either alone or in combination with the transfer instructions - had a higher ratio of functional-to-total-pieces when solving the first engineering problem, compared to families who received only transfer instructions or no instructions at all. Second, the engineering and transfer instructions influenced parents' use of a key conversational technique associated with an elaborative style while working on the first engineering problem. Among families whose first engineering problem was the skyscraper, those who received the engineering and transfer instructions asked the most open-ended questions. Open-ended questions may play an important role in focusing children's attention to the problem, and their understanding of it. Effects on the content of parents' talk were also observed among families for whom the wobbly skyscraper was the first engineering problem performed. Specifically, among the families who worked on the skyscraper, it was the parents who received both the engineering and transfer instructions who talked more about science and mathematics than those who received no instructions at all. Fourth, when working on their own, children who received both engineering and transfer instructions were better at stabilizing the second wobbly structure than those who received only engineering instructions, only transfer instructions, or no instructions. With regard to the first engineering problem, the differences by type of structure were confined to the conversational analyses; building outcomes did not vary by type of structure.

Building Outcomes

The first research hypothesis focused on families' ability to use the information presented during the engineering demonstration while working to stabilize the first wobbly structure. The engineering demonstration involved experimenting with a key engineering principle – cross-bracing – and it took place right before working on the first engineering problem. The demonstration involved a wobbly station that is component of the Skyline exhibit. The wobbly station (see Figure 2) is made out of large-scale wood materials and metal bolts, the materials that are featured in the large-scale building area in the exhibit. Thus, although the exhibit also includes a building area with the same materials being used in the demonstration, the research question here asks if families can take what they learn from this demonstration and apply it to fixing a skyscraper or bridge structure built from smaller, plastic, colorful materials that include some analogous pieces (struts, bolts), and in a slightly different context – the small-scale building area of the exhibit called Skyscraper Challenge.

Answering this question is important because it will provide important information about how to facilitate children's ability to transfer their knowledge across different informal learning experiences. Young children can acquire knowledge through manipulating objects (Auslander, 2001; Bruner, 1966; Piaget, 1970; Tall, 2004), but past work has pointed out that children do not always transfer what they learn through object manipulation to new situations (Kaminski, Sloutsky, & Heckler, 2009; McNeil, Uttal, Jarvin, Sternberg, 2009; Uttal, Liu, & DeLoache, 2006; Uttal, Scudder, & DeLoache, 1997). Often what children learn in one setting remains “welded” to that setting, and unfortunately, it is not remembered in new situations and applied to new problems (Brown, Bransford, Ferrara, & Campione, 1983; Jant et al., 2014; Tulving & Thomson, 1973).

Researchers distinguish between different types of transfer tasks, such as near and far transfer tasks, with far transfer tasks being more difficult than near transfer tasks (e.g., Barnett & Ceci, 2002; Klahr & Chen, 2011). Klahr and Chen (2011), for example, proposed a three-dimensional model of transfer. Considering their conceptualization of transfer, the engineering problem used in this study could be classified as a “farther” transfer task. Specifically, this study focused on how task and context similarity, two main dimensions of transfer, influenced children’s knowledge transfer. As described previously, the format of the task and the building materials were different. The demonstration involved large-scale wood materials whereas the engineering problems required participants to work with small-scale, colorful, plastic building materials. The physical context was also different – families were provided with engineering instructions in the large-scale area of the Skyline exhibit, and had to transfer this learning to the Skyscraper Challenge space. What could facilitate such transfer?

Previous work reported that simply seeing physical models of sturdy structures or being exposed to signs with information about how to build sturdy structures did not promote transfer of learning (e.g., Benjamin et al., 2010; Haden et al., 2014). Moreover, observing that models of skyscrapers that included triangular braces were sturdier than models of skyscrapers that did not include triangular braces was also not sufficient to promote transfer of knowledge across contexts and materials (Marcus et al., in press). Marcus and colleagues conveyed the engineering information through a demonstration that involved skyscrapers made out of drinking straws and a leaf blower that simulated the wind. The researchers found that seeing which skyscrapers were able to withstand the "wind" was not sufficient; only families who were also explicitly told about the function of triangles incorporated them into their own structure and thus made their structures sturdier.

One challenge, however, lies in finding ways to promote learning and transfer such that it would be organic to the museum experience and thus sustainable for museums. The current study aimed to address this issue by using the Wobbly Station – a permanent exhibit display that is a component of the Skyline exhibit. Based on the past research findings reviewed above, it was hypothesized that explicitly telling families about the function of triangular braces would promote children's learning and ability to apply, or transfer, their learning when working to stabilize the first wobbly structure. Confirming this hypothesis, and consistent with the results of previous work, the results revealed that families who received engineering instructions – either alone or in combination with transfer instructions - added a greater number of pieces that functioned to brace the structure relative to the total number of pieces added. In other words, engaging families in a demonstration of the engineering principle that involved bracing a wobbly frame structure did set the stage for transfer.

These findings are encouraging considering that the demonstration and the engineering problem involved structures that were perceptually dissimilar. Gentner and colleagues (2016), for instance, found that the similarity of structures influenced children's learning and ability to transfer their learning. The researchers used analogical comparison training to foster children's transfer abilities. More specifically, the researchers presented children with model buildings to compare and then observed them repair a one-story building on their own. They found that children who were presented with highly similar buildings that showed high alignment performed better on the repair task than children who were exposed to different-looking buildings that showed low alignment. In the present study the demonstration involved one frame structure, whereas the engineering problem involved a complete structure – a skyscraper or a bridge. The sides of the skyscraper and the bridge are made up of squares - there are four squares on each side of the skyscraper, for example. But there are size differences; the square involved in the demonstration is almost double the size of each of the squares that make up the skyscraper or the bridge.

Elaborative Talk

The second research hypothesis focused on the type of conversations families had while working on the first engineering problem. It was anticipated that families who received transfer instructions would talk in more elaborative ways than families who did not receive such instructions. This hypothesis was based on the idea that the transfer instructions would make transfer more salient and would thus encourage parents to prepare their children to transfer their knowledge to the second engineering problem.

Examining parents' conversational style is important as past work has revealed that parents who engage in more elaborative conversations as an experience unfolds have children who better understand and remember the experience (Boland et al., 2003; Hedrick et al., 2010; see Ornstein et al., 2004, for a review). This study focused on two components of an elaborative style that were identified by prior research to be especially beneficial, namely open-ended questions and associative talk. Open-ended questions can foster children's understanding, learning, and retention of information in informal educational environments (Benjamin et al., 2010; Jant et al., 2014). These questions can help parents gauge what their children know and do not know, call attention to important aspects of an event, and also encourage children to participate in the conversation and talk about the event they are experiencing. Similarly, by making associations across experiences, contexts, and time parents can make transfer the subject of discussion. Associations involve relating what is being experienced to what they have experienced before and this is what transfer requires – that children connect what they are currently doing to relevant prior knowledge and experiences.

As predicted, parents who received both engineering and transfer instructions asked more open-ended questions than parents who did not receive any such instructions. This finding is important given the crucial role that open-ended questions play in fostering children's understanding and learning about science (Callanan & Jipson, 2001; Crowley et al., 2001; Falk & Dierking, 1992). Furthermore, such questions can also promote children's sustained engagement in museum exhibits (e.g., Humphrey & Gutwill, 2005).

It is important to acknowledge that the combination of engineering and transfer instructions fostered question asking but only among parents who worked on the skyscraper. Why the instructions did not lead parents who worked on the bridge to also ask more open-ended questions is not very clear. Although the skyscraper and the bridge looked superficially different, they were essentially the same structure. The bridge was the skyscraper placed on its side – the only difference was that it had "legs". Moreover, from an engineering point of view, the two structures share similar design principles and both types of structures use triangular bracing to provide stability (Sorby, personal communication). Additionally, families did not perform differently with respect to bracing the structures when comparing those who worked on the skyscraper to those who worked on the bridge first.

In thinking about why the bridge did not lead to increases in parents' open-ended questions, it might be that the bridge was a more challenging task. Also, the exhibit focuses on skyscrapers and the models available in the exhibit are all skyscrapers. Therefore, it may have been easier for families to ask questions about and otherwise explicate the knowledge through elaborative conversation about the skyscraper – to prepare the children for transfer – when they were working on the skyscraper. Further, this difference might also be the result of the fact that skyscrapers are more similar to who we are as humans. That is, we are part of a flat world with gravity and we have an upright posture and some researchers argue that young children's learning and use of spatial terms is highly influenced by these facts (e.g., Clark, 1973). Extrapolating from this work, it might be that the effect of gravity is clearer with the skyscraper than with the bridge and so that might facilitate parents' talk while working on the skyscraper.

Importantly, past work has revealed that it is not necessarily the sheer number of open-ended questions asked by parents that facilitate children's learning and retention of information, but rather the number of questions asked by the parents and answered by children (Benjamin et al., 2010; Haden et al., 2001; Hedrick et al., 2009; Jant et al., 2014; Tessler & Nelson, 1994). In this study, the engineering and transfer instructions did not influence children's responding to their parents' open-ended questions. Even though the children who received both engineering and transfer instructions were asked the most open-ended questions, and thus had the greatest opportunity to respond, they did not. Haden and colleagues (2014) reported similar results; in their study, the facilitated educational program did not facilitate children's responding to parents' questions.

In the present study it may be that children were not verbally responding, but perhaps they were providing nonverbal responses. For example, when asked where to place a piece or what to do next, perhaps the children were physically showing the parent where to place the piece or what to do next. The coding system did not capture nonverbal responses, but it might be fruitful to examine whether this was the case. Yet finding ways to increase children's verbal responding is essential. Research on parent-child conversations as events unfold indicates that joint talk is a strong predictor of children's understanding and retention of information (Haden et al., 2001; Tessler & Nelson, 1994). For example, Haden and colleagues (2001) found that objects that were handled and discussed by both the mother and the child during a staged activity were better recalled than those that were jointly handled but only talked about by the mother, which were better recalled than those that were not discussed at all. Given such findings, future work should focus on ways to not only increase question asking, but also children's verbal responding.

In addition to focusing on parents' open-ended questions and children's responding, the study examined families' associative talk, which is another key component of an elaborative conversational style. Families who received transfer instructions were expected to make more associations than families who did not receive transfer instructions. Three types of associations were considered: associations to relevant prior experiences, associations to the demonstration, and associations across engineering problems. In contrast to this hypothesis, there were no differences between families who received instructions and those who did not in their making of associations. Other studies that have explicitly trained parents to make associations (e.g., Benjamin et al., 2010; Boland et al., 2003) were able to increase use of this kind of connecting talk, but in general, it is the case that associations occur fairly infrequently. The instructions provided in this study, even those making transfer across problems salient, did not lead to higher levels of associative talk. Transfer of knowledge requires that children connect what they are currently doing to what they already know (e.g., Bransford & Schwartz, 1999), and so by using associations parents could have explicitly helped children make such connections.

STEM Talk

The third research hypothesis focused on the content of families' conversations while working on the first engineering problem. Families who received both engineering and transfer instructions were expected to talk the most about science, technology, engineering, and mathematics, and this hypothesis was supported among families who worked on the skyscraper. Counter to what was expected, parents who received only transfer instructions talked more about technology than parents who received both engineering and transfer instructions, but this was true only among families who worked on the bridge. Also unexpectedly, there were no differences in the STEM content of talk among the children in the different instructional groups.

Research work focusing on parent-child conversations during ongoing events suggests that the more adults talk about STEM, the more children might learn about STEM (e.g., Gentner et al., 2016; Gunderson & Levine, 2011; Loewenstein & Gentner, 2005; Pruden et al., 2011). Gentner and colleagues (2016), for example, found that parents who talked about diagonal braces during a construction project had children who were better able to repair a wobbly building than children whose parents did not talk about diagonal braces. Against this backdrop of findings, the fact that the combination of engineering and transfer instructions led to increases in talk about science and mathematics is promising.

It is unclear why the engineering and transfer instructions promoted talk about science and mathematics only for those who worked on the skyscraper. As discussed previously, it may be that the museum's focus on skyscrapers and the availability of so many different examples of skyscrapers interacted with the instructions to influence families' talk about the science process and mathematics. Science process talk, in particular, involved talking about planning how to fix the structure, hypothesis testing, and problem solving. Talk about numbers, quantity, and equality of length was classified as mathematics talk. Perhaps when faced with an engineering problem that was difficult - the bridge - the parents focused more on actually fixing the structure and not on engaging their children in conversations.

Also unexpected was the finding regarding parents' talk about technology. It may be that presented with a difficult task, such as fixing a bridge, and yet aware that their children would have to work by themselves to fix another wobbly structure might have led parents to focus on the information available to them, such as the labels present in the exhibit naming the building materials. Labeling building materials and talking about the function of building materials was coded as technology (e.g., "What are the mending plates for?").

All parents engaged in considerable talk about engineering and there were no differences among parents in the four instructional groups. This finding is similar to the results from a previous study conducted in the Skyline exhibit (Marcus et al., in press). Although in that study families had a different task – to build a sturdy skyscraper – those families who received engineering information did not talk more about engineering than those who did not receive such information. And just like in that study, parents in this study engaged in considerable talk about engineering when compared to another study that took place in the same area of the Skyline exhibit (Haden et al., 2014).

As to why there were no differences in children's STEM talk among the different instructional groups, this is consistent with the results of a previous study in the same exhibit (Marcus et al., in press). As suggested by Haden and colleagues (2014), given that there was a time limit, it is possible that children were more focused on fixing the structure "now" and talking later. This appeared to be the case in Haden et al.'s (2014) study. Although the facilitated educational program did not foster children's responding to parents' open-ended questions during the building activity, the children who received building information prior to working on the building activity talked more about STEM than those who did not receive such information when telling narratives about their building experiences immediately after building.

Second Engineering Problem: Building Outcomes

The last hypothesis focused on children's performance on the second engineering problem when working on their own. It was hypothesized that the combination of engineering and transfer instructions would result in children's better ability to fix the second wobbly structure on their own, without the help of their parents. As hypothesized, children who received both engineering and transfer instructions were more successful in stabilizing the second wobbly structure than children in the other three groups. This finding is important as it indicates that providing children with engineering and transfer instructions fostered their ability to transfer the information they learned during the demonstration and apply it when working on their own with different materials and in a different context.

Based on Klahr and Chen's (2011) three-dimensional model introduced previously, this engineering problem would be considered an even "farther" transfer task than the first. In addition to focusing on how task and physical context similarity influenced children's knowledge transfer, this second engineering problem also focused on social context. Specifically, the social context was different – children had their parents during the demonstration and again when working on the first engineering problem, but they were by themselves when working on their own to stabilize the second wobbly structure. Yet the combination of engineering and transfer instructions promoted children's ability to apply their knowledge when working on this task.

Implications for Museums

The current study offers important information that educators and other professionals at Chicago Children's Museum may find particularly useful about ways to promote learning and transfer of knowledge in informal educational environments. First, the findings highlight the benefits of having the Wobbly Station in the Skyline exhibit. In this study, families who were provided with information about the role of triangular braces and were shown at the Wobbly Station that triangular braces stopped the wobbly frame from moving were more successful in stabilizing the first wobbly structure. More generally, the findings point out that providing families with simple but actionable information can help support their learning in museums. Second, the findings suggest that informing families that the knowledge they gain in one exhibit could be used in other situations might be especially beneficial. In this study, children who received *both* engineering and transfer instructions were better able to transfer the engineering principle when working on their own to stabilize a second wobbly structure. The transfer instructions involved telling families that the children would have to work on a second engineering problem on their own without the help of their parents right after they were done fixing the first engineering problem as a family. With this in mind, in the case of CCM it might be useful to point out that the engineering principle of cross-bracing can be used not only when building in the large-scale area that features the same materials as the Wobbly Station, but also when building in the Skyscraper Challenge area and in Tinkering Lab.

In the present study, a researcher engaged families in experimentation with the Wobbly Station. Therefore, it might be a good idea for the museum to encourage their on-the-floor facilitators to do the same. Although the Wobbly Station has a sign with information about cross braces, it is not clear whether families actually pay attention to it and whether they can benefit from it. As discussed in the previous section, past work has found that simply exposing families to signs that contain information about how to build sturdy structures was not sufficient to foster their ability to build sturdy structures (Haden et al., 2014). The engineering and transfer instructions we provided to families were very short, simple, and engaging, and incorporating them into the routine of on-the-floor facilitators would not require intensive training.

Extending our transfer instructions, it might be helpful if the facilitators could briefly mention to families that the same principle used to stabilize the wobbly frame could be used to stabilize a variety of structures made of different materials. There is a photo of the John Hancock building on the wall across from the Wobbly Station, so they might want to point out the cross braces on the Hancock building. Moreover, they could also add a photo of a real bridge that features triangular braces. Our previous work in the Skyline exhibit revealed that pointing out connections between the information provided in the exhibit and the real world fostered young children's transfer of knowledge both within and beyond the museum (Marcus et al., in press). In that study, children who were told about the function of triangular braces and were shown a photo of the John Hancock building built sturdier structures in the museum and talked more about science and engineering when reminiscing about their museum experience 2 weeks later. Therefore, there is reason to believe that incorporating these suggestions has the potential to foster visitors' learning and memories of the museum experience.

Limitations

Importantly, the literature that focuses on parent-child conversational interactions emphasizes that there is considerable ethnic variability among parents in their conversational style (e.g., Bell et al, 2009; Fivush & Haden, 2003; Miller et al. 2012) and explanatory conversations during science activities (e.g., Gaskins, 2008; Tenenbaum &

Callanan, 2008). The majority of the families in this sample, however, were Caucasian and highly educated, more because of the timing of the data collection (primarily on weekends) than because of the demographics of the Chicago Children's Museum's visitorship, which is rather diverse. Future work should examine how providing families with instructions might interact with ethnicity and parents' educational level to influence the results (e.g., Gonzalez, Moll, & Amanti, 2013; Moll et al., 1992; Tenenbaum & Callanan, 2008). Past work suggests that parents' educational level and prior visits to museums influence how they approach learning in museums. Tenenbaum and Callanan (2008), for example, found that parents with higher levels of education incorporated more scientific principle explanations in their conversations than parents with lower levels of education. Moreover, parents who had visited museums before used more explanations in the museum than those who had not. Other work pointed out that families' "funds of knowledge", or the prior knowledge rooted in cultural activities that they bring to the museum, has the potential to facilitate learning and transfer of knowledge across contexts (e.g., Gonzalez, Moll, & Amanti, 2013). For example, a family that earns a living in urban occupations related to construction could provide the foundation for engineering knowledge that could support children's STEM learning in informal settings. Previous work in this same exhibit – the Skyline exhibit - found that providing families with exhibit-related information prior to building in the context of a facilitated educational program was equally beneficial for families of diverse backgrounds (Haden et al., 2014).

Yet an important question remains regarding variations not only across ethnic groups but also within ethnic groups.

Conclusions and Future Directions

Overall, the results of this study revealed that providing families with engineering and transfer instructions fostered their ability to stabilize the wobbly structures, as well as the style and content of their conversations. Therefore, these results suggest that by providing families with simple demonstrations to illustrate key concepts verbally and physically (i.e., hands-on activities) museums could foster families' interactions and their learning in ways that this learning could be used in new situations. Although the instructions facilitated transfer of knowledge across contexts and building materials, the instructions influenced families' conversations differently depending on the type of structure they worked on. The instructions supported conversations among parents who worked on the skyscraper, but this effect did not extend to the bridge. Finding ways to support families' conversations regardless of the type of engineering problem they have to solve is important. Research suggests that children might learn more about STEM if they engage in conversations richer in STEM content during an ongoing experience (e.g., Gunderson & Levine, 2011; Pruden et al., 2011). Therefore, future research should examine ways to promote talk that is rich in STEM content in different situations. It is plausible that providing families with concrete and diverse examples would be beneficial. In this study, children were told that, "triangles make structures sturdy." Perhaps providing concrete examples of types of structures that use triangular braces would have been helpful. Indeed, past work suggested that highlighting similarities among contexts has the potential to promote transfer of knowledge (Engle, 2006).

Furthermore, it is important to acknowledge that the engineering and transfer instructions did not foster children's responding to parents' open-ended questions or their STEM talk. Future work should investigate what types of instructions or activities could support children's participation in conversations in informal educational environments. As suggested previously, it may be that encouraging families to incorporate conversational techniques such as open-ended questions and associations would be sufficient. However, one issue lies in finding ways to promote conversations using practices that would be sustainable for informal educational environments. Future work could investigate whether using interactive devices would be effective. For instance, having a touch screen next to the Wobbly Station that would prompt children to engage in hypothesis testing by asking open-ended questions and then summarizing the solution by making associations to real world situations might promote children's participation in conversations, their learning, and their ability to transfer their learning across situations.

Importantly, the literature that focuses on parent-child conversational interactions emphasizes that there is considerable ethnic variability among parents in their conversational style (e.g., Bell et al, 2009; Fivush & Haden, 2003; Miller et al. 2012) and explanatory conversations during science activities (e.g., Gaskins, 2008; Tenenbaum & Callanan, 2008). The majority of the families in this sample, however, were Caucasian and highly educated, more because of the timing of the data collection (primarily on weekends) than because of the demographics of the Chicago Children's Museum's visitorship, which is rather diverse. Future work should examine how providing families with instructions might interact with ethnicity and parents' educational level to influence the results (e.g., Gonzalez, Moll, & Amanti, 2013; Moll et al., 1992; Tenenbaum & Callanan, 2008). Past work suggests that parents' educational level and prior visits to museums influence how they approach learning in museums. Tenenbaum and Callanan (2008), for example, found that parents with higher levels of education incorporated more scientific principle explanations in their conversations than parents with lower levels of education. Moreover, parents who had visited museums before used more explanations in the museum than those who had not. Other work pointed out that families' "funds of knowledge", or the prior knowledge rooted in cultural activities that they bring to the museum, has the potential to facilitate learning and transfer of knowledge across contexts (e.g., Gonzalez, Moll, & Amanti, 2013). For example, a family that earns a living in urban occupations related to construction could provide the foundation for engineering knowledge that could support children's STEM learning in informal settings. Previous work in this same exhibit – the Skyline exhibit - found that providing families with exhibit-related information prior to building in the context of a facilitated educational program was equally beneficial for families of diverse backgrounds (Haden et al., 2014). Yet an important question remains regarding variations not only across ethnic groups but also within ethnic groups.

APPENDIX A

PARENT QUESTIONNAIRE

1. Not counting today's visit, how many times have you visited **this exhibit** ***Skyline***?

____

2. **Within the past TWO years,** have you been members of the Chicago Children's Museum?

☐ Yes, Became Members Today! ☐ Yes ☐ No

3. **In a typical year,** how many visits to museums (including art, history, natural history museums, as well as historic sites, botanical gardens, science centers, zoos, and children's museums) do you make with your child?

☐	☐	☐	☐	☐	☐
Once a week	Once or twice a month at least 12 times per year)	Every other month (6 times per year)	4-5 times per year	2-3 times per year	Once per year or less

Please **circle a number** to answer the following questions:

4. How much did **you** know about building before your museum visit today?

Knew Very Little 1 2 3 4 5 6 7 Knew A Great Deal

5. How much did **your child** know about building before your museum visit today?

Knew Very Little 1 2 3 4 5 6 7 Knew A Great Deal

6. How much did **you** learn about building during your museum visit today?

Learned Very Little 1 2 3 4 5 6 7 Learned a Great Deal

7. How much did **your child** learn about building during your museum visit today?

Learned Very Little 1 2 3 4 5 6 7 Learned a Great Deal

8. Before your museum visit today, how interested in building were **you**?

Very Little Interest 1 2 3 4 5 6 7 Very High Interest

9. Before your museum visit today, how interested in building was **your child**?

Very Little Interest 1 2 3 4 5 6 7 Very High Interest

10. **Gender** of parent/guardian completing the survey: ☐ Female ☐ Male

11. Current **Marital Status**

☐ Married ☐ Partnered

☐ Single (including never married, widowed, separated, or divorced) ☐ Other, please specify: ______________________________

12. Please list the **age and gender** of each child in your household:

1) **Child participating** in the study today : Age: ________years old ☐ Female ☐ Male

Other children in your household:

2) Age: ________years old ☐ Female ☐ Male
3) Age: ________years old ☐ Female ☐ Male
4) Age: ________years old ☐ Female ☐ Male
5) Age: ________years old ☐ Female ☐ Male
6) Age: ________years old ☐ Female ☐ Male

13. **Education** (check highest level completed)

	You	Child's Other Parent/Guardian
• Some High School	☐	☐
• High School Graduate	☐	☐
• Some college/Vocational or Technical School Graduate	☐	☐
• College Graduate	☐	☐
• Master's Degree	☐	☐
• Doctoral/Professional Degree (PhD, MD, JD)	☐	☐

Parent Occupation

You: ______________________________

Child's Other Parent/Guardian: ______________________________

14. **Ethnicity, Race**

	Participating Child	You
• Hispanic/Latino ethnicity (one or more races)	☐	☐
• Non-Hispanic		
Caucasian or White	☐	☐
African American or Black	☐	☐
Asian	☐	☐
American Indian or Alaska Native, Native North, Central, or South Americans	☐	☐
Native Hawaiian or Other Pacific Islander	☐	☐
More than one race (non-Hispanic/Latino)	☐	☐

• Other (please write in) ____________________

15. **<u>Family Household Income (check one)</u>**

☐ Less than $20,000

☐ $20,000 – $49,999

☐ $50,000 – $74,999

☐ $75,000 – $99,999

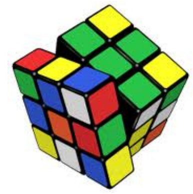
☐ $100,000 to $149,999

☐ >$150,000

How often does your child play with the following kinds of toys? Pictures are just examples of types of toys. (Circle number)

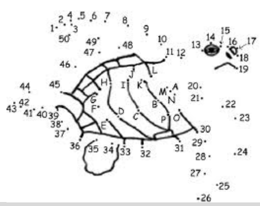
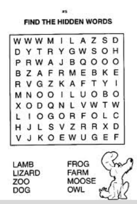
1. Puzzles

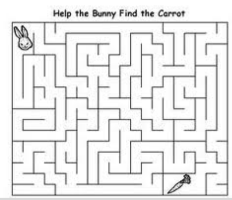




Almost Never 1 2 3 4 5 6 7 Daily

2. Puzzle Games



	2	4	
1			3
4			2
	1	3	

Almost Never 1 2 3 4 5 6 7 Daily

3. Legos



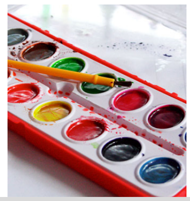
Almost Never 1 2 3 4 5 6 7 Daily

4. Construction (not Lego)



Almost Never 1 2 3 4 5 6 7 Daily

5. Art



Almost Never 1 2 3 4 5 6 7 Daily

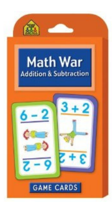
6. Board and Card Games

Almost Never 1 2 3 4 5 6 7 Daily

7. Music

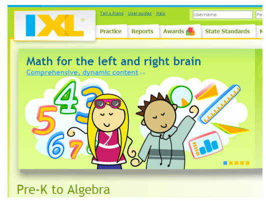
Almost Never 1 2 3 4 5 6 7 Daily

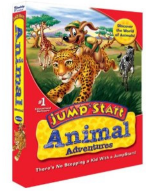
8. Math Games

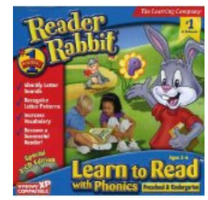


Almost Never 1 2 3 4 5 6 7 Daily

9. Education-Oriented Computer/Internet Games







Almost Never 1 2 3 4 5 6 7 Daily

10. Video Games




Almost Never 1 2 3 4 5 6 7 Daily

11. Pretend Play/Fantasy





Almost Never 1 2 3 4 5 6 7 Daily

12. Toys for Moving Arms and Legs









Almost Never 1 2 3 4 5 6 7 Daily

APPENDIX B

CHILD AGE

Analyses also examined whether the effects on building outcomes and parent-child conversations were different for younger and older children. A median split on child age (*M* = 6.63, *SD* = 1.38, median = 6.69) was used to group children as younger or older. A series of 4 (Condition) x 2 (Type of Structure) x 2 (Child Age) ANOVAs were conducted for each dependent measure.

Building Outcomes: Table 13 and 14 display the results of the analyses with child age as a third between subject factor for families' building outcomes. As shown in the top portion of the table, the main effect of child age for the sturdiness ratio of the first wobbly structure was not significant, $F(1, 112) = .57$, $p = .45$. However, there was a significant Condition x Child Age interaction, $F(3, 112) = 3.59$, $p < .05$. Follow up analyses revealed that for younger children, the main effect of condition was not significant, $F(3, 60) = 2.53$, $p = .07$. However, for older children, the main effect of condition was significant, $F(3, 60) = 9.24$, $p < .001$. For families with older children, those who received both engineering and transfer instructions (*M* = .62, *SD* = .38) or just engineering instructions (*M* = .75, *SD* = .22) had a significantly higher ratio of functional-to-total-pieces than families who received just transfer instructions (*M* = .26, *SD* = .38) or no instructions (*M* = .28, *SD* = .34). There were no other significant interactive effects with child age, all *F*s $\leq$ 1.50, *p*s $\geq$ .22.

Table 13. Means and Standard Deviations for Building Outcomes by Condition, Type of Structure, and Child Age

	Instructional Condition								**Type of Structure**				**Child Age**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Younger		Older	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
First Engineering Problem																
Total Pieces	9.25	(4.81)	9.03	(4.84)	9.28	(4.07)	10.59	(6.45)	10.81	(5.31)	8.27	(4.56)	7.95	(3.64)	11.13	(5.82)
Total functional pieces	6.63	(5.01)	6.66	(4.40)	3.19	(4.06)	3.81	(4.16)	6.31	(4.85)	3.83	(4.13)	4.86	(4.17)	5.28	(5.11)
Sturdiness Ratio	.66	(.31)	.68	(.32)	.32	(.38)	.38	(.35)	.60	(.39)	.42	(.35)	.55	(.36)	.47	(.39)
Second Engineering Problem																
Total Pieces	6.16	(3.88)	6.06	(3.06)	6.06	(4.31)	5.53	(2.98)	5.70	(3.41)	6.20	(3.73)	4.98	(3.40)	6.92	(3.49)
Total functional pieces	3.56	(3.92)	1.91	(2.83)	.81	(1.65)	.81	(1.55)	1.56	(2.59)	1.98	(3.13)	1.06	(1.73)	2.48	(3.55)
Sturdiness Ratio	.48	(.38)	.31	(.42)	.13	(.27)	.16	(.30)	.26	(.35)	.28	(.39)	.21	(.32)	.33	(.40)

Table 14. Summary of ANOVAs for Building Outcomes by Condition, Type of Structure, and Child Age

	Instructional Condition			Type of Structure			Child Age			Condition x Type of Structure			Condition x Child Age			Type of Structure x Child Age			Condition x Type of Structure x Child Age		
	F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
First Engineering Problem																					
Total pieces	.46	.71	.01	9.32	.00	.06	11.57	.00	.08	2.28	.08	.05	.13	.94	.00	.33	.57	.00	.51	.68	.01
Total functional pieces	5.08	.00	.10	12.73	.00	.08	1.03	.31	.01	1.40	.25	.03	1.69	.17	.03	.14	.71	.00	.36	.78	.01
Sturdiness ratio	8.69	.00	.15	11.71	.00	.07	.57	.45	.00	2.40	.07	.04	3.59	.02	.06	.04	.84	.00	1.50	.22	.03
Second Engineering Problem																					
Total pieces	.37	.77	.01	.12	.73	.00	7.94	.01	.06	1.37	.26	.03	1.29	.28	.03	.83	.36	.01	.06	.98	.00
Total functional pieces	10.84	.00	.18	.14	.71	.00	14.40	.00	.08	1.10	.35	.02	4.05	.01	.07	.76	.39	.00	2.19	.09	.04
Sturdiness ratio	7.12	.00	.13	.50	.48	.00	6.33	.01	.04	1.19	.32	.02	4.51	.01	.08	1.21	.27	.01	2.43	.07	.04

As shown in the bottom portion of the table, the main effect of child age for the sturdiness ratio of the second structure was significant, $F(1, 112) = 6.33$, $p < .05$. However, this was qualified by a significant Condition x Child Age interaction, $F(3, 112) = 4.51$, $p < .05$. Follow up analyses revealed that for younger children, the main effect of condition was significant, $F(3, 60) = 7.63$, $p < .001$. Younger children who received both engineering and transfer instructions ($M = .45$, $SD = .37$) had a significantly higher ratio of functional-to-total-pieces than younger children who received only engineering instructions ($M = .06$, $SD = .13$) or only transfer instructions ($M = .06$, $SD = .13$); those in the Control group ($M = .25$, $SD = .38$) were not significantly different from the children in the other three groups. The main effect of condition was also significant for older children, $F(3, 60) = 5.97$, $p < .01$; older children who received both engineering and transfer instructions ($M = .53$, $SD = .40$) or just engineering instructions ($M = .53$, $SD = .46$) had significantly higher ratio of functional-to-total-pieces than children who received no instructions ($M = .11$, $SD = .22$). Older children who received just transfer instructions ($M = .21$, $SD = .36$) were no significantly different from older children in the other three groups. There were no other interactive effects, all Fs ≤ 2.43, ps $\geq .07$.

Elaborative Talk. Tables 15 and 16 display the results of the analyses with child age as a third between subject factor for families' elaborative talk. As shown in the top portion of the table, for parents' open-ended questions, neither the main effect of child age, $F(1, 112) = 2.04$, $p = .16$, nor the interactions with child age were significant, all Fs $\leq .79$, ps $\geq .50$. Similarly, as shown in the bottom portion of the table, there were no significant main effects of child age for children's frequency of responding or rate of responding, all *F*s ≤ .37, *p*s ≥ .55; nor were there any interactive effects, all *F*s ≤ 1.48, *p*s ≥ .22.

STEM Talk. Tables 17 and 18 display the results of the analyses with child age as a third between subject factor for families' STEM talk. As shown in the top portion of the table, parents of younger children talked more about science process, technology, and engineering than parents of older children, all *F*s ≤ 10.67, *p*s ≤ .05; the main effect of child age for parents' talk about mathematics was not significant, $F(1, 112) = .004$, $p = .95$. There were no significant interactive effects of child age, *F*s ≤ 1.02, *p*s ≥ .39.

As can be seen in the bottom portion of the table, the main effect of child age was not significant for children's talk about science, technology, or engineering, all *F*s ≤ .3.17, *p*s ≥ .08. However, there was a significant main effect of child age for children's talk about mathematics; older children ($M = 3.03$, SD = 3.23) talked more about mathematics than younger children ($M = 2.03$, $SD = 2.12$), $F(1, 112) = 5.26$, $p < .05$. However, there were no significant interactive effects of child age, all *F*s ≤ 2.23, *p*s ≥ .09.

Table 15. Means and Standard Deviations for Families' Open-Ended Questions and Responses by Condition, Type of Structure, and Child Age

	Instructional Condition								**Type of Structure**				**Child Age**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Younger		Older	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Parents																
Open-ended question	8.16	(6.22)	7.50	(7.73)	6.84	(6.48)	6.84	(7.36)	7.27	(7.09)	7.41	(6.78)	8.61	(7.03)	6.06	(6.60)
Responses	1.31	(1.35)	1.16	(1.37)	1.25	(1.57)	1.38	(1.41)	1.23	(1.37)	1.31	(1.47)	1.38	(1.49)	1.17	(1.34)
Rate of responding	.88	(.52)	.63	(.51)	.75	(.41)	.74	(.50)	.79	(.50)	.71	(.49)	.78	(.56)	.72	(.42)
Children																
Open-ended question	1.72	(1.61)	1.91	(2.10)	1.84	(2.03)	2.19	(1.75)	1.75	(1.66)	2.08	(2.06)	1.94	(1.95)	1.89	(1.81)
Responses	3.72	(3.72)	3.28	(4.18)	3.31	(3.21)	3.03	(3.43)	3.56	(4.04)	3.11	(3.16)	3.75	(3.38)	2.92	(3.82)
Rate of responding	.52	(.30)	.44	(.32)	.61	(.28)	.50	(.34)	.52	(.30)	.52	(.32)	.52	(.29)	.52	(.34)

Table 16. Summary of ANOVAs for Families' Open-Ended Questions and Responses by Condition, Type of Structure, and Child Age

	Instructional Condition			**Type of Structure**			**Child Age**			**Condition x Type of Structure**			**Condition x Child Age**			**Type of Structure x Child Age**			**Condition x Type of Structure x Child Age**		
	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2
Parents																					
Open-ended questions	.27	.85	.01	.04	.84	.00	2.04	.16	.02	2.86	.04	.07	.79	.50	.02	.32	.57	.00	.14	.94	.00
Responses	.09	.97	.00	.26	.61	.00	.86	.36	.01	.89	.45	.02	.70	.55	.02	2.53	.12	.02	1.05	.37	.03
Rate of responding	1.07	.37	.04	.43	.51	.00	.14	.71	.00	.47	.70	.01	.34	.80	.02	1.70	.20	.02	.72	.54	.02
Children																					
Open-ended questions	.32	.81	.01	.844	.36	.01	.42	.52	.00	2.21	.09	.05	.50	.69	.01	.32	.57	.00	.58	.63	.01
Responses	.14	.94	.00	.32	.57	.00	.37	.55	.00	2.42	.07	.06	.54	.66	.01	.33	.57	.00	.34	.79	.01
Rate of responding	1.48	.22	.04	.00	.96	.00	.21	.65	.00	1.29	.28	.03	.10	.96	.00	.03	.86	.00	1.48	.22	.04

Table 17. Means and Standard Deviations for Families' STEM Talk By Condition, Type of Structure, and Child Age

	Instructional Condition								**Type of Structure**				**Child Age**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Younger		Older	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Parents																
Science Process	8.28	(4.98)	7.13	(4.77)	7.84	(5.70)	6.63	(4.61)	7.72	(4.89)	7.22	(5.17)	8.78	(5.17)	6.16	(4.52)
Technology	8.97	(7.53)	9.25	(6.07)	10.94	(9.32)	7.25	(6.20)	9.41	(7.03)	8.80	(7.85)	11.44	(8.01)	6.77	(5.99)
Engineering	18.47	(10.21)	19.50	(10.07)	19.75	(9.07)	19.47	(11.29)	19.66	(10.53)	18.94	(9.68)	22.48	(10.97)	16.11	(7.99)
Mathematics	5.34	(4.29)	4.53	(4.44)	4.44	(3.86)	3.25	(2.85)	4.95	(4.25)	3.83	(3.54)	4.73	(4.07)	4.05	(3.80)
Children																
Sciences Process	1.72	(2.28)	1.97	(2.15)	2.66	(2.65)	2.06	(2.00)	2.05	(2.31)	2.16	(2.27)	1.94	(2.08)	2.27	(2.46)
Technology	3.78	(3.54)	4.41	(5.72)	4.19	(4.39)	4.84	(5.65)	4.92	(5.55)	3.69	(4.02)	3.58	(3.57)	5.03	(5.83)
Engineering	5.66	(3.88)	7.53	(7.54)	6.38	(4.53)	5.94	(4.00)	6.72	(5.94)	6.03	(4.35)	5.44	(3.89)	7.31	(6.12)
Mathematics	3.28	(3.80)	2.47	(2.58)	2.38	(2.06)	2.00	(2.26)	2.73	(2.66)	2.33	(2.87)	2.03	(2.12)	3.03	(3.23)

Table 18. Summary of ANOVAs for Families' STEM Talk by Condition, Type of Structure, and Child Age

	Instructional Condition			**Type of Structure**			**Child Age**			**Condition x Type of Structure**			**Condition x Child Age**			**Type of Structure x Child Age**			**Condition x Type of Structure x Child Age**		
	F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Parents																					
Science Process	.37	.77	.01	.28	.60	.00	5.36	.02	.04	1.97	.12	.05	1.02	.39	.02	.27	.60	.00	.10	.96	.00
Technology	1.14	.34	.02	.07	.80	.00	10.31	.00	.07	4.12	.01	.09	.13	.94	.00	.02	.88	.00	.17	.92	.00
Engineering	.25	.86	.01	.05	.82	.00	10.67	.00	.08	1.78	.16	.04	.37	.78	.01	.02	.90	.00	.11	.96	.00
Mathematics	1.42	.24	.03	2.88	.09	.02	.00	.95	.00	2.50	.06	.06	.45	.72	.01	.10	.75	.00	.46	.71	.01
Children																					
Sciences Process	1.34	.27	.03	.18	.67	.00	.90	.35	.01	2.42	.07	.06	.28	.84	.01	.01	.94	.00	1.49	.22	.03
Technology	.17	.92	.00	1.96	.16	.02	2.67	.11	.02	.15	.93	.00	.92	.43	.02	1.14	.29	.01	1.17	.33	.03
Engineering	1.28	.29	.03	.59	.44	.00	3.17	.08	.02	.65	.59	.01	.62	.61	.01	1.53	.22	.01	2.17	.10	.05
Mathematics	.91	.44	.02	1.33	.25	.01	5.26	.02	.04	.22	.88	.01	.73	.53	.02	.17	.68	.00	2.23	.09	.05

APPENDIX C

CHILD GENDER

Analyses also examined whether the effects on building outcomes and parent-child conversations were different for boys and girls. Specifically, a series of 4 (Condition) x 2 (Type of Structure) x 2 (Child Gender) ANOVAs were conducted for each dependent measure.

Building Outcomes. For the sturdiness ratio of the first structure, neither the main effect of child gender nor the interactions were significant, all Fs $\leq .83$, ps $\geq .37$. Therefore, the instructions provided helped families with boys and girls equally.
There was a significant main effect of child gender for the sturdiness ratio of the second structure, $F(1, 112) = 6.58$, $p < .05$. Boys ($M = .35$, $SD = .40$) had a higher sturdiness ratio than girls ($M = .19$, $SD = .32$). However, the interactions between child gender, instructional condition, and type of structure were not statistically significant, all Fs $\leq .62$, ps $\geq .61$.

Elaborative Talk. As illustrated in Tables 21 and 22, there was a main effect of child gender for parents' open-ended questions, $F(1, 112) = 4.01$, $p < .05$. Parents of boys ($M = 8.55$, $SD = 7.53$) asked significantly more open-ended questions than parents of girls ($M = 6.13$, $SD = 6.05$). However, there were no significant interactive effects of child gender on parents' open-ended questions, all Fs $\leq .50$, ps $\geq .68$. There was also a main effect of child gender for children's frequency of responding, $F(1, 112) = 5.26$, $p < .05$. Boys ($M = 4.06$, $SD = 4.14$) provided significantly more responses to their parents' questions than girls ($M = 2.61$, $SD = 2.86$). However, the main effect of child gender for children's rate of responding was not significant, $F(1, 112) = .91$, $p = .34$, and there were no significant interactive effects of child gender for children's frequency of responding or rate of responding, all *F*s $\leq$ 1.06, *p*s $\geq$ .31.

STEM Talk. Tables 23 and 24 display the results of the analyses with child gender as a third between subject factor for families' STEM talk. As shown in the top portion of the table, for parents' talk about science process, technology, engineering, and mathematics, neither the main effects of child gender, *F*s $\leq$ 2.00, *p*s $\geq$ .16, nor the interactions with child gender were significant, all *F*s $\leq$ 2.62, *p*s $\geq$ .11.

The bottom portion of Tables 23 and 24 display the results for children's STEM talk. As illustrated in the tables, there was a significant Condition x Type of Structure x Child Gender interaction for children's talk about technology, $F(3, 112) = 3.39$, $p < .05$. Follow up tests revealed that for those who worked on the skyscraper, girls who received no instructions ($M = 10.00$, $SD = 7.37$) talked more about technology than girls who received transfer instructions ($M = 2.13$, $SD = 2.47$) and girls who received engineering instructions ($M = 2.88$, $SD = 2.64$); those who received both engineering and transfer instructions ($M = 5.25$, $SD = 3.85$) were not significantly different compared to girls in any of the other conditions. There were no differences by instructional group among girls who worked on fixing the bridge.

There was also a significant main effect of child gender for children's talk about engineering, $F(1, 112) = 4.91$, $p < .05$. However, this was qualified by a significant Condition x Child Gender interaction, $F(3, 112) = 3.28$, $p < .05$. Follow up tests revealed only one marginally significant difference. Boys who received engineering instructions ($M = 10.56$, $SD = 1.43$) tended to talk more about engineering than boys who received both engineering and transfer instructions (*M* = 5.25, *SD* = 1.43). There were no group differences in girls' talk about engineering. The Condition x Type of Structure x Child Gender was not statistically significant, $F(3, 112) = 1.07$, $p = .36$.

Table 19. Means and Standard Deviations for Building Outcomes by Condition, Type of Structure, and Child Gender

	Instructional Condition								**Type of Structure**				**Child Gender**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Boys		Girls	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
First Engineering Problem																
Total Pieces	9.25	(4.81)	9.03	(4.84)	9.28	(4.07)	10.59	(6.45)	10.81	(5.31)	8.27	(5.56)	9.94	(4.88)	9.14	(5.30)
Total functional pieces	6.63	(5.01)	6.66	(4.40)	3.19	(4.06)	3.81	(4.16)	6.31	(4.85)	3.83	(4.13)	5.61	(4.86)	4.53	(4.41)
Sturdiness Ratio	.66	(.31)	.68	(.32)	.32	(.38)	.38	(.35)	.60	(.39)	.42	(.35)	.54	(.37)	.48	(.38)
Second Engineering Problem																
Total Pieces	6.16	(3.88)	6.06	(3.06)	6.06	(4.31)	5.53	(2.98)	5.70	(3.41)	6.20	(3.73)	5.72	(3.43)	6.19	(3.71)
Total functional pieces	3.56	(3.92)	1.91	(2.83)	.81	(1.65)	.81	(1.55)	1.56	(2.59)	1.98	(3.13)	2.17	(3.14)	1.38	(2.54)
Sturdiness Ratio	.48	(.38)	.31	(.42)	.13	(.27)	.16	(.30)	.26	(.35)	.28	(.39)	.35	(.40)	.19	(.32)

Table 20. Summary of ANOVAs for the Building Outcomes by Condition, Type of Structure, and Child Gender

	Instructional Condition			Type of Structure			Child Gender			Condition x Type of Structure			Condition x Child Gender			Type of Structure x Child Gender			Condition x Type of Structure x Child Gender		
	F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
First Engineering Problem																					
Total pieces	.23	.87	.01	12.63	.00	.06	.41	.52	.01	2.39	.07	.07	2.14	.10	.06	1.55	.22	.01	1.32	.27	.01
Total functional pieces	5.89	.00	.12	10.84	.00	.07	2.04	.16	.01	1.14	.34	.02	1.04	.38	.02	.02	.89	.00	.61	.61	.01
Sturdiness ratio	9.84	.00	.18	9.20	.00	.06	.83	.37	.01	1.77	.16	.03	.09	.97	.00	.60	.44	.00	.55	.65	.01
Second Engineering Problem																					
Total pieces	.21	.89	.00	.64	.43	.00	.57	.45	.00	2.18	.09	.05	.68	.57	.02	1.45	.23	.01	1.95	.13	.05
Total functional pieces	7.62	.00	.15	.80	.37	.01	2.87	.09	.02	1.08	.36	.02	.45	.72	.01	.03	.87	.00	1.47	.23	.03
Sturdiness ratio	7.02	.00	.14	.09	.77	.00	6.58	.01	.04	1.68	.18	.03	.55	.65	.01	.02	.89	.00	.62	.61	.01

Table 21. Means and Standard Deviations for Families' Open-Ended Questions and Responses by Condition, Type of Structure, and Child Gender

	Instructional Condition								Type of Structure				Child Gender			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Boys		Girls	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Parents																
Open-ended questions	8.16	(6.22)	7.50	(7.73)	6.84	(6.48)	6.84	(7.36)	7.27	(7.09)	7.41	(6.78)	8.55	(7.53)	6.13	(6.05)
Responses	1.31	(1.35)	1.16	(1.37)	1.25	(1.57)	1.38	(1.41)	1.23	(1.37)	1.31	(1.47)	1.14	(1.34)	1.41	(1.48)
Rate of responding	.88	(.52)	.63	(.51)	.75	(.41)	.74	(.50)	.79	(.50)	.71	(.49)	.72	(.49)	.78	(.50)
Children																
Open-ended questions	1.72	(1.61)	1.91	(2.10)	1.84	(2.03)	2.19	(1.77)	1.75	(1.66)	2.08	(2.06)	1.84	(1.78)	1.98	(1.97)
Responses	3.72	(3.72)	3.28	(4.18)	3.31	(3.21)	3.03	(3.43)	3.56	(4.04)	3.11	(3.16)	4.06	(4.14)	2.61	(2.86)
Rate of responding	.52	(.30)	.44	(.32)	.61	(.28)	.50	(.34)	.52	(.30)	.52	(.32)	.55	(.31)	.49	(.31)

Table 22. Summary of ANOVAs for Families' Open-Ended Questions and Responses by Condition, Type of Structure, and Child Gender

	Instructional Condition			**Type of Structure**			**Child Gender**			**Condition x Type of Structure**			**Condition x Child Gender**			**Type of Structure x Child Gender**			**Condition x Type of Structure x Child Gender**		
	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2
Parents																					
Open-ended questions	.27	.85	.01	.01	.91	.00	4.01	.05	.03	3.55	.02	.08	.18	.91	.00	.04	.85	.00	.50	.68	.01
Responses	.14	.94	.00	.10	.75	.00	1.14	.29	.01	.81	.49	.02	1.81	.15	.04	2.87	.09	.02	1.13	.34	.03
Rate of responding	.58	.63	.02	.35	.55	.00	.38	.54	.00	.18	.91	.01	1.79	.16	.06	7.07	.01	.07	.50	.68	.02
Children																					
Open-ended questions	.36	.78	.01	.997	.32	.01	.18	.67	.00	1.98	.12	.05	1.94	.13	.05	.06	.81	.00	.99	.40	.02
Responses	.20	.90	.00	.51	.48	.00	5.26	.02	.04	3.01	.03	.07	.30	.83	.01	.03	.86	.00	.40	.76	.01
Rate of responding	1.47	.23	.04	.02	.90	.00	.91	.34	.01	1.47	.23	.04	.94	.42	.02	1.06	.31	.01	.48	.70	.01

Table 23. Means and Standard Deviations for Families' STEM Talk By Condition, Type of Structure, and Child Gender

	Instructional Condition								**Type of Structure**				**Child Gender**			
	Engineering + Transfer Instructions		Engineering Instructions		Transfer Instructions		Control		Skyscraper		Bridge		Boys		Girls	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Parents																
Science Process	8.28	(4.98)	7.13	(4.77)	7.84	(5.70)	6.63	(4.61)	7.72	(4.89)	7.22	(5.17)	7.95	(4.75)	6.98	(5.26)
Technology	8.97	(7.53)	9.25	(6.07)	10.94	(9.32)	7.25	(6.20)	9.41	(7.03)	8.80	(7.85)	9.22	(7.61)	8.98	(7.30)
Engineering	18.47	(10.21)	19.50	(10.07)	19.75	(9.07)	19.47	(11.29)	19.66	(10.53)	18.94	(9.68)	20.14	(10.40)	18.45	(9.77)
Mathematics	5.34	(4.29)	4.53	(4.44)	4.44	(3.86)	3.25	(2.85)	4.95	(4.25)	3.83	(3.54)	4.64	(3.90)	4.14	(3.98)
Children																
Sciences Process	1.72	(2.28)	1.97	(2.15)	2.66	(2.65)	2.06	(2.00)	2.05	(2.31)	2.16	(2.27)	2.41	(2.51)	1.80	(1.99)
Technology	3.78	(3.54)	4.41	(5.72)	4.19	(4.39)	4.84	(5.65)	4.92	(5.55)	3.69	(4.02)	4.52	(5.21)	4.09	(4.53)
Engineering	5.66	(3.88)	7.53	(7.54)	6.38	(4.53)	5.94	(4.00)	6.72	(5.94)	6.03	(4.35)	7.36	(5.98)	5.39	(4.08)
Mathematics	3.28	(3.80)	2.47	(2.58)	2.38	(2.06)	2.00	(2.26)	2.73	(2.66)	2.33	(2.87)	2.80	(2.84)	2.27	(2.68)

Table 24. Summary of ANOVAs for Families' STEM Talk by Condition, Type of Structure, and Child Gender

	Instructional Condition			Type of Structure			Child Gender			Condition x Type of Structure			Condition x Child Gender			Type of Structure x Child Gender			Condition x Type of Structure x Child Gender		
	F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Parents																					
Science Process	.39	.76	.02	.15	.70	.00	2.00	.16	.01	1.85	.14	.07	1.09	.36	.02	2.19	.14	.02	.44	.73	.01
Technology	1.45	.23	.03	.24	.63	.00	.04	.85	.00	4.94	.00	.11	.86	.46	.02	1.71	.19	.01	1.06	.37	.02
Engineering	.46	.71	.00	.02	.89	.00	1.93	.17	.01	1.50	.22	.07	.22	.88	.00	2.62	.11	.02	.24	.87	.01
Mathematics	1.65	.18	.04	2.81	.10	.02	.56	.46	.00	2.76	.05	.06	1.11	.35	.02	1.82	.18	.01	.87	.46	.02
Children																					
Sciences Process	1.04	.38	.02	.08	.78	.00	2.45	.12	.02	2.34	.08	.05	2.14	.10	.05	.00	.97	.00	1.69	.17	.04
Technology	.29	.83	.01	2.24	.14	.02	.26	.61	.00	.51	.68	.01	3.48	.02	.08	.73	.40	.01	3.39	.02	.07
Engineering	.86	.46	.02	.60	.44	.00	4.91	.03	.04	.86	.47	.02	3.28	.02	.07	.03	.86	.00	1.07	.36	.02
Mathematics	1.19	.32	.03	.67	.41	.01	1.15	.29	.01	.25	.86	.01	.70	.56	.02	.14	.71	.00	1.14	.34	.03

APPENDIX D

EXPLORATORY ANALYSES

With regard to the second engineering problem that children solved on their own, it was anticipated that the combination of the transfer instructions and elaborative talk would result in the sturdiest structures. Families who received the transfer instructions were expected to have more elaborative conversations than families who did not receive the transfer instructions. These elaborative conversations, in turn, were expected to boost children's abilities to successfully fix the second wobbly structure on their own.

According to Baron and Kenny (1986), in order to be able to conduct mediational analyses, four conditions must be met: (1) the main effect of transfer instructions on parents' elaborative talk must be significant, (2) the main effect of transfer instructions on the sturdiness ratio of the second structure must also be significant, (3) elaborative talk must be significantly associated with the sturdiness ratio of the second structure, and (4) the impact of the main effect of transfer on the sturdiness ratio of the second structure has to be less after controlling for the mediator – that is, for elaborative talk. But most importantly, if the main effect of transfer instructions on the sturdiness ratio of the second structure is not significant, there is no significant effect to mediate.

As summarized in the previous section, these conditions are not met. Recall that parents who received both engineering and transfer instructions asked significantly more open-ended questions than parents who did not receive any instructions, but this group difference was only evident for those who worked on the skyscraper. Therefore, it was the combination of engineering and transfer instructions that fostered parents' elaborative talk, not just the transfer instructions, and it depended on the type of structure families worked on. Similarly, children who received both engineering and transfer instructions were more successful at stabilizing the second wobbly structure on their own than children who received only one set of instructions or no instructions. Also, parents' open-ended questions were not significantly associated with the sturdiness ratio of the second structure, $r = .09$, $p = .33$. Moreover, as discussed in the previous section, distancing talk was very infrequent (75% of the parents did not make any associations across engineering problems) and parents' distancing talk was also not significantly associated with the sturdiness ratio of the second structure, $r = .06$, $p = .47$.

Correlational analyses were conducted to determine which measures of building and conversations during the first engineering problem were related to the sturdiness ratio of the second structure. Only two correlations were significant (all *p*s $< .05$): children's mathematics talk during the first engineering problem, $r = .18$, and the sturdiness ratio of the first structure, $r = .41$. These results suggest that the more successful families were in stabilizing the first engineering problem and the more children talked about mathematics, the more successful children were when working to stabilize the second structure on their own.

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Following completion of her B.S. degree, Dr. Marcus entered the Developmental Psychology Ph.D. program at Loyola University Chicago. Since starting graduate school at Loyola, she has been working with Dr. Catherine Haden and her Co-PI Dr. David Uttal to conduct a research project at the Chicago Children's Museum. The project has been funded by the National Science Foundation and it focuses on how parent-child conversational interactions during hands-on activities impact children's STEM learning. Her master's thesis investigated how learning in a museum could be extended beyond its walls through social interactions with others. Dr. Marcus's research work has resulted in numerous poster presentations, as well as several book chapters and manuscripts.