Effects of Instruction and Parent-Child Conversation on Children's Stem Learning and Transfer

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EFFECTS OF INSTRUCTION AND PARENT-CHILD CONVERSATION ON CHILDREN’S STEM LEARNING AND TRANSFER

A THESIS SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL IN CANDIDACY FOR THE DEGREE OF MASTER OF ARTS

PROGRAM IN DEVELOPMENTAL PSYCHOLOGY

BY MARIA MARCUS CHICAGO, ILLINOIS AUGUST 2014
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### TABLE OF CONTENTS

ACKNOWLEDGMENTS iii  
LIST OF TABLES vi  
LIST OF FIGURES vii  
ABSTRACT viii  

#### CHAPTER ONE: INTRODUCTION 1
- Theoretical Framework 3
- Engineering 5
- Transfer of Learning 8
- Parent-Child Conversations During Events 17
- Parent-Child Conversations After Events 21
- Current Study 26
- Hypotheses 29
  - Hypothesis 1 29
  - Hypothesis 2 29
  - Hypothesis 3 30
  - Hypothesis 4 30
  - Hypothesis 5 30

#### CHAPTER TWO: METHODS 32
- Participants 32
- Procedure 33
  - Pre-exhibit Experience 33
  - Skyscraper Challenge Interaction 34
  - Paired-Comparison Task 34
  - Memory Conversations 34
- Coding 35
  - Prior Engineering Knowledge: Brief Interview 35
  - Prior Engineering Knowledge: Paired-Comparison Picture Task 36
  - Conversations in the Exhibit 37
  - Final Structures 39
  - Immediate Assessment of Learning and Transfer 40
  - Memory Conversations 40

#### CHAPTER THREE: RESULTS 44
- Preliminary Analyses 44
- Analyses of Demographic Characteristics by Condition and Child Gender 45
- Main Analyses 47
  - Prior Engineering Knowledge 47
<table>
<thead>
<tr>
<th>Chapter/Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Structures</td>
<td>51</td>
</tr>
<tr>
<td>Conversations in the Exhibit</td>
<td>52</td>
</tr>
<tr>
<td>Immediate Assessment of Learning and Transfer</td>
<td>56</td>
</tr>
<tr>
<td>Memory Conversations</td>
<td>57</td>
</tr>
<tr>
<td>Associations Between Talk in the Exhibit and Children’s Recall</td>
<td>75</td>
</tr>
<tr>
<td>CHAPTER FOUR: DISCUSSION</td>
<td>80</td>
</tr>
<tr>
<td>Prior Engineering Knowledge</td>
<td>81</td>
</tr>
<tr>
<td>Building Behaviors</td>
<td>82</td>
</tr>
<tr>
<td>Parent-Child Conversations in the Exhibit</td>
<td>83</td>
</tr>
<tr>
<td>Knowledge Transfer</td>
<td>85</td>
</tr>
<tr>
<td>Memory Conversations</td>
<td>87</td>
</tr>
<tr>
<td>One-day Delay</td>
<td>87</td>
</tr>
<tr>
<td>Two-week Delay</td>
<td>88</td>
</tr>
<tr>
<td>Memory Reporting Over Time</td>
<td>89</td>
</tr>
<tr>
<td>Associations Between Talk in the Exhibit and Children’s Memory Reports</td>
<td>89</td>
</tr>
<tr>
<td>Limitations</td>
<td>91</td>
</tr>
<tr>
<td>Conclusions and Implications for Museum Practice</td>
<td>93</td>
</tr>
<tr>
<td>APPENDIX A: INSTRUCTIONS FOR THE REMINISCING CONVERSATIONS</td>
<td>96</td>
</tr>
<tr>
<td>APPENDIX B: DYADS’ ELABORATIVE TALK IN THE BUILDING EXHIBIT</td>
<td>99</td>
</tr>
<tr>
<td>REFERENCE LIST</td>
<td>101</td>
</tr>
<tr>
<td>VITA</td>
<td>108</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1. Means for Children's Age, Parental Education Level, Prior Engineering Knowledge, and Interest in Building by Experimental Condition 46

Table 2. Means for Total Pieces, Number of Stories, Number of Decorative Pieces, Number of Functional Pieces and Sturdiness of Final Structures by Experimental Condition 52

Table 3. Summary of the ANOVAs for Mothers' Talk in the Exhibit 54

Table 4. Summary of the ANOVAs for Children's Talk in the Exhibit 55

Table 5. Families who Recorded a Memory Conversation at the 1-day Delay Compared to Those who did not: Demographics 58

Table 6. Families who Recorded a Memory Conversation at the 1-day Delay Compared to Those who did not: Children's Talk in the Exhibit 59

Table 7. Families who Recorded a Memory Conversation at the 1-day Delay Compared to Those who did not: Mothers' Talk in the Exhibit 60

Table 8. Families who Recorded a Memory Conversation at the 1-Day Delay Compared to Those who did not: Final Structures 61

Table 9. Summary of the ANOVAs for Mothers' Recall at the 1-Day Delay 63

Table 10. Summary of the ANOVAs for Children's Recall at the 1-Day Delay 64

Table 11. Summary of the ANOVAs for Mothers' Recall at the 2-Week Delay 66

Table 12. Summary of the ANOVAs for Children's Recall at the 2-Week Delay 67

Table 13. Summary of the Repeated Measures ANOVAs for Children's Recall 71

Table 14. Summary of the Repeated Measures ANOVAs for Mothers' Recall 73
LIST OF FIGURES

Figure 1. Skyscraper choice selection 49
Figure 2. Explanations of sturdy and wobbly choice selections 50
Figure 3. Children’s technology talk over time 69
Figure 4. Children’s engineering talk over time 70
Figure 5. Mothers’ engineering talk over time 73
ABSTRACT

This study examined the effects of direct instruction and parent-child conversation on children’s STEM learning, transfer abilities, and remembering. A total of forty mothers and their 5- to 6-year-old children (M = 5.87) participated in this study. Mother-child dyads were randomly assigned to one of two conditions that differed in the amount of engineering information they received prior to engaging in a building activity in a museum exhibit. The provision of engineering information fostered dyads building activities and their long-term recall of the museum visit. Implications for museum research and practice are discussed.
CHAPTER ONE

INTRODUCTION

The number of U.S. students pursuing a career in science, technology, engineering, and mathematics (STEM) fields has decreased in recent years (Kuenzi, Matthews, & Mangan, 2006; Mayo, 2009; Sanders, 2009). Furthermore, international studies of academic achievement indicate that U.S. students perform worse on standardized math and science assessments than students from other leading nations (Martin, Mullis, & Foy, 2008; Mullis, Martin, & Foy, 2008; Programme for International Student Assessment, 2005). In an effort to address these critical issues, policy makers have focused primarily on strengthening teacher preparation in these areas (Sanders, 2009). Concentrating on better educating more teachers, however, should not be the only effort put forth to increase the number of children choosing science education and career paths, particularly because a substantial number of children become uninterested in STEM subjects in early grades (Sanders, 2009). Indeed, there is a growing sense that sustained interest in STEM is born out of early experiences even before - and not exclusively in - school (Carlson & Sullivan, 2004; Sullivan, 2006). Many of children’s first experiences engaging in scientific discovery and science learning occur in informal settings – including gardens, aquariums, and museums – making it imperative to explore how to boost children’s interest and understanding of STEM concepts and principles in
such contexts. Moreover, because children often engage in early science experiences in informal settings with their parents, as we look to increase teachers’ skills in classrooms, it is also important to look at ways to best support parents’ efforts to expose their children to STEM (for reviews, see Leinhardt, Crowley & Knutson, 2002; Haden, 2010). The current research focused on linking parent-child interactions in a science-oriented museum exhibit to children’s learning and transfer of STEM-related principles.

The current project intersects with previous examinations of children’s memory that have focused on parent-child conversations during and after events (for reviews, see Fivush, Haden, & Reese, 2006; Ornstein, Haden, & Hedrick, 2004) and more specifically with studies of children’s science learning in museums that focused on parent-child verbal interactions (e.g., Crowley et al., 2001; Crowley & Jacobs, 2002; Falk & Dierking, 1992; Tenenbaum, Snow, Roach, & Kurland, 2005; Valle & Callanan, 2006). The project aims to contribute to the literature information about which elements of maternal conversational style are most effective for promoting learning and transfer of STEM-related principles. At the core of the study is an examination of the impact of instruction about simple engineering principles on parent-child conversations and on children’s ability to transfer those principles in new circumstances and on their long-term recall, and in this way, the study also overlaps with the work on children’s engineering learning (e.g., Benjamin, Haden, & Wilkerson, 2010; Davis, Ginns, & McRobbie, 2002). This is essential because while sizable literatures exists in which the linkages between mothers’ style of talk during and after events and their children’s recall have been investigated, few studies have focused on the actual event that the parent-child dyads talked about.

The current study also connects with the literature on children’s transfer (for a review,
see Klahr & Chen, 2011). Given that elaborative conversations during ongoing events have been shown to enhance children’s understanding and subsequent remembering of those experiences (e.g., Boland, Haden, & Ornstein, 2003) it is essential to know whether such conversations could also enhance children’s ability to generalize learned STEM principles from one situation to a different one, as well as their later recall of such principles. Lastly, this project investigated whether the effects of instruction and parental style of talk were additive, such that those dyads who had more knowledge about engineering and richer conversations while engaging in a building activity would talk more about STEM-related information one day and two weeks after the museum visit.

In providing a backdrop for this study, the literature review that follows first discusses theoretical underpinnings supporting the role of social interactions for children’s learning. Then, given the focus on children’s STEM learning, previous research on children’s knowledge of engineering is addressed. This is followed by a treatment of research that has focused on children’s transfer of learning. Next, an overview of the empirical work on mother-child conversations during events is examined in order to provide a clearer picture as to the role such conversations play in children’s understanding and subsequent recall. Finally, previous research regarding the role of mother-child reminiscing is evaluated.

**Theoretical Framework**

Research focusing on parent-child conversational interactions in museums, as well as other contexts, has been guided primarily by the sociocultural theory, which highlights that children learn through social interactions (e.g., Rogoff, 1990; Vygotsky, 1978). In particular, Vygotsky (1978) argued that children come to master important
mental activities, such as problem solving, through joint interactions with more mature and skilled members of their society who scaffold them. The Vygotskian notion of “zone of proximal development,” defined as the range of activities that a child cannot do on his or her own but can do with the help of a more knowledgeable partner, illustrates how adults can promote children’s cognitive development (Berk, 2008). When children work on a task that they cannot accomplish without assistance, parents can offer guidance and support that fit the child’s needs (i.e., scaffold them). By doing so, parents can transfer the mental strategies to their children and thus may enhance their children’s learning.

Building upon Vygotsky’s notion of scaffolding is Rogoff’s (1998, 2003) concept of guided participation. Whereas scaffolding is a form of teaching that adults employ mainly when helping children with school-like tasks, guided participation also considers the support provided by adults in everyday activities. Although school-like activities are important for promoting children’s cognitive development, they are not the only ones. As Rogoff suggested, the everyday verbal exchanges between adults and children are also essential for children’s learning.

A museum context represents a natural setting in which parents can scaffold and guide their children’s learning using language as a means of increasing their children’s understanding and interest. More specifically, engaging in a building activity in a museum context provides parents with a great opportunity to engage in scaffolding. For instance, they can determine what their children do and do not understand by asking open-ended questions. Their use of questions can also encourage children to actively participate in the conversational interaction. Additionally, caregivers can encourage talk about aspects of the events in which their children seem interested and provide more
details about those aspects. Furthermore, parents can positively evaluate their children’s responses in order to sustain the conversation. Parents can use these conversational techniques both during a building activity and during a reminiscing conversation. Indeed, as it is pointed out in the following literature review, past work that focused on parent-child conversations during and after events found that parents differ in how they scaffold conversational interactions. Most importantly, differences in maternal styles of talk have been found to influence children’s understanding and remembering. What is not known, however, is whether maternal styles of talk impact children’s STEM learning and transfer abilities. Given that a major goal of the current research is to pinpoint the factors that promote children’s engineering learning, the work on children’s engineering knowledge is reviewed next.

**Engineering**

Research on children’s knowledge about engineering has focused primarily on assessing their understanding of what engineering is and what engineers do (e.g., Cunningham, 2009; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Knight & Cunningham, 2004). Interestingly, even though the products of engineering are ubiquitous in our lives, findings have shown that a large number of students have a narrow and often inaccurate view of what an engineering job entails (Cunningham et al., 2005; Knight & Cunningham, 2004). Research has shown, for example, that students fail to identify design as a feature of engineering. When asked to choose the types of work performed by engineers from a set of 16 pictures that depicted people at work (e.g., make pizza, repair cars), less than a third of the students in grades 1 through 5 recognized that engineers design things (Cunningham et al., 2005).
In addition to examining children’s engineering literacy, a smaller body of work has explored the factors that promote interest and learning of engineering. Sadler and colleagues (2000), for instance, have reported that providing middle school students with clear and precise goals of an engineering design challenge increases their engagement with the task. With regard to learning, research has shown that teacher scaffolding can facilitate children’s ability to solve engineering problems (Kahn & Bers, 2005). In a study conducted by Kahn and Bers (2005) 5- and 7-year-old children participated in five 1-hour workshops that introduced them to a robotic construction kit. The children’s task was to build an object using the computer programming software. Although all of the projects were children’s creations, the researchers noted that children learned more and were more likely to apply their knowledge when assisted by teachers. To illustrate, consider a participant who was interested in building a nutcracker, but could not figure out how to make the “mouth” of the nutcracker to open and close. Even though the child learned in a previous session that gears move in opposite directions, she was not able to apply that knowledge on her own. When the teacher hinted that gears have special properties, the girl not only recalled the information, but also applied it to her project. Therefore, it appears that teacher scaffolding can boost children’s ability to apply previously gained knowledge to new situations. Teachers, however, are not the only adults who can scaffold students. Given that parents are children’s first teachers, it interesting to consider how parents may scaffold early engineering learning even before they encounter this topic in school.

Not only is there a need for research on how parents enhance their children’s engineering learning, but also on what children already know about engineering.
principles (e.g., structural integrity and cross-bracing). Indeed, it has been suggested that boosting students’ understanding of the relationships between the properties of materials, stability, and bracing is essential because all three properties need to be taken into account when constructing an artifact (National Association of Advisers and Inspectors in Design and Technology, 1994). Even though the importance of knowing about these concepts has been acknowledged, only one study has investigated children’s understanding of these concepts (Davis, Ginns, & McRobbie, 2002). Davis et al. (2002) asked 6- to 13-year-olds to provide suggestions of how to make a wood bridge more stable. Findings revealed that compared to the younger participants, older children provided more complex suggestions. Specifically, whereas younger children tended to suggest that hammering the nails of the bridge would make it more stable older children proposed that external and internal bracing would make the structure more stable.

More germane to the focus of the current research, previous work has shown that young children can be taught to build sturdy buildings (Benjamin, Haden, & Wilkerson, 2010). In a study conducted by Benjamin et al. (2010) parent-child dyads were provided with information about building engineering principles. Specifically, dyads in the building instruction condition were informed that triangular cross braces make buildings sturdier. Results indicated that families who received such building instructions built stronger buildings (i.e., included more triangular cross braces) than those who did not and also talked more about engineering. What is not known from this study is how much prior knowledge children came with about these principles, and whether or not children were able to apply the information learned with one set of materials when building with a different set. These questions are addressed in the current study.
Overall, previous research on children’s understanding of engineering indicates that although they have a narrow view of engineering and engineering related concepts, they can easily learn such concepts. Furthermore, past research points out that adults can facilitate children’s engineering learning through scaffolding. What is lacking, however, is information regarding children’s ability to generalize their knowledge to new tasks and experiences. The current research attempts to fill in that gap. Given the focus in the current study on children’s transfer of learning to different materials and to a different context, it is appropriate now to turn to the literature that has focused on children’s transfer of learning.

**Transfer of Learning**

How can we enhance children’s ability to transfer the knowledge they acquire in one setting to different situations and tasks? Knowledge transfer, or the ability to recall and apply previously learned information in novel circumstances, has been the subject of extensive research over the past century (Barnett & Ceci, 2002; Klahr & Chen, 2011). The results of past work, however, are inconclusive; whereas some studies have indicated that even children can transfer (e.g., Brown & Kane, 1988; Brown, Kane, & Echols, 1986; Chen & Siegler, 2000), a substantial number of laboratory experiments have shown that both children and adults have difficulty applying their knowledge in new situations (e.g., Bransford, Brown, & Cocking, 1999; Lave, 1988). Yet, as some researchers have highlighted, cognitive development would not take place if children could not be able to generalize across contexts (e.g., Dunbar, 2001; Klahr & Chen, 2011). Therefore, identifying the mechanisms that facilitate young children’s ability to transfer is essential and is an important aim of the current project.
Past research that has focused on pinpointing the factors that boost transfer performance has indicated that task goals play an important role (e.g., Bransford & Franks, 1976; Holyoak, Junn, & Billman, 1984; Lung & Dominowski, 1985; Weisberg, DiCamillo, & Phillips, 1978). More specifically, findings suggest that children and young adults are more likely to demonstrate transfer if the goals of the learning and transfer tasks are similar (i.e., the goals require individuals to perform the same type of action). To illustrate, consider a study conducted by Weisberg et al. (1978). In their study undergraduate students were first asked to learn a series of paired associates, among which there was the “box-candle” pair, and were then presented with Duncker’s (1945) candle problem, which requires finding a way to mount a candle to a wall using a box of matches and thumbtacks. Although the solution to the transfer problem was suggested by one of the pairs that the students memorized, the majority of them failed to solve the problem. The researchers speculated that the undergraduates failed to transfer because they used the goal of the task (i.e., “Find a way to mount the candle to the wall.”) to search their memory for possible solutions and not the elements of the problem (i.e., the box and the candle).

Research by Holyoak, Junn, and Billman (1984) provides further support for the importance of goal similarity to transfer and extends the findings to young children. In their second experiment, kindergarteners and first graders were first presented with one of three stories that served as base analogs: (1) Magic Staff story, (2) Extra-Character story, or (3) Altered-Goal story. All three stories were about a genie who was planning to move his home from one bottle to another and who used his magic staff to pull the new bottle up next to his old one in order to be able to drop his precious jewels from the old
bottle into the new one. In two of the stories (the Magic Staff and Extra-Character), the genie’s primary goal was to safely transfer his precious jewels from one bottle to another. In the Altered-goal version of the story, however, the primary goal of the genie was to move into a new bottle large enough to share with his friend and the transfer of the jewels was depicted as a peripheral goal. After hearing one of the three stories, depending on the condition they were in, participants were asked to solve the ball problem, which entailed transferring some balls from one bowl to another given certain materials (e.g., coffee scoop, long dowel with a slit at one end) without leaving their seat. Findings revealed that those children who were presented with the Altered-Goal story, in which the genie’s main goal was to find a big enough home that he could share with a friend, hindered their performance on the transfer task. That is, when the character of the base analog (i.e., the genie) had a different goal than the children, 5- to 7-year-olds did not use the story suggested strategy to solve the transfer problem.

Presenting children with similar goals and with opportunities to abstract generalized rules was found to promote uninformed transfer (i.e., transfer of previously learned knowledge without being hinted to do so). In real-world situations children are rarely, if ever, told or hinted what specific lesson they need to apply in order to solve a problem. Instead, they are presented with the problem and have to search their memory for relevant information and then apply that information to the problem at hand. Studies that have explored the issue of uninformed transfer have shown that it occurs less frequently than informed transfer and that not only young children, but even college students fail to use story analogues to solve transfer problems without being hinted to do so by the experimenter (e.g., Gick & Holyoak, 1980; 1987; Holyoak et al., 1984;
Weisberg et al., 1978). Under certain conditions, however, college students were found to be able to apply their knowledge of earlier stories in solving a transfer problem. One such condition involves exposure to story analogues that foster abstraction of a generalized schema that can be applied to the transfer task (e.g., Gick & Holyoak, 1983). Gick and Holyoak (1983), for instance, asked college students to read and compare two story analogues – the fortress story and the fire-fighting story, and then to solve Duncker’s radiation problem (1945). The radiation problem involves finding a way to destroy a malignant stomach tumor using a type of ray that at high intensity can destroy both the tumor and the healthy tissues, while at lower intensities will not affect the tissues or the tumor. The solution to this problem, the convergence solution, is indicated by the story analogues. The fortress problem involves sending small groups of soldiers down multiple roads to converge simultaneously on a fortress that had to be captured and the fire-fighting story involves the use of multiple hoses in order to extinguish a fire. The investigators found that asking college students to compare the two stories allowed them to derive a generalized schema for convergence problems, which in turn facilitated unprompted transfer to the radiation problem. An important question is how young children might fare on uninformed transfer tasks, and particularly whether they benefit from being presented with opportunities to extract generalized rules. This study addresses this question.

Providing individuals with opportunities to abstract generalized rules is not the only factor that can increase children’s transfer success. Research indicates that presenting children with examples during the learning task is also beneficial (e.g., Brown & Kane, 1988; Gick & Holyoak, 1983). To illustrate, Brown and Kane (1988; Study 4)
exposed 4-year-old children to either: (a) rules and examples of animal defense mechanisms or biological deterrents, (b) rules only, (c) examples only, or (d) no rules or examples. Those in the Rule and Example condition were told that there are animals who mimic more scary animals as a way of protecting themselves from enemies (animal defense mechanism) or that there are animals who are liked by humans because they eat pests (biological deterrents); they were then shown a picture of an animal and told what the animal looked like or what the animal ate (e.g., hawkmoth caterpillar mimics a snake; the ladybug eats aphids on farmers’ crops). Those in the Rule Only condition were only told the general rule and those in the Example Only condition were only given an example of the rule. The control group was presented with an irrelevant story. Children were then presented with two transfer problems that could be solved by analogy. Results revealed that those 4-year-olds who were presented with examples (Rule and Example or Example Only) were more likely to solve the transfer problems than children in the other groups. In fact children in the Rule and Example and Example Only conditions performed extremely well on the transfer problems (i.e., the proportion of correct solutions to the first transfer problem was 1.00 and .94 for those in the Rule and Example condition and Example Only condition, respectively). Given the excellent performance of the 4-year-olds in Study 4, the researchers conducted a subsequent experiment in which they increased the level of difficulty by adding more irrelevant facts to the analogy stories and providing 4-year-olds with only two examples (i.e., one example and the transfer problem). Although the transfer task was more difficult, the results were similar to those obtained in Study 4. That is, children who were provided with examples (Rules
and Examples or Examples Only) performed better on the transfer tasks than those who were provided with Rules Only or an irrelevant story.

Therefore, Brown and Kane (1988) demonstrated that presenting preschoolers with examples is better than presenting them only with rules (Studies 4 and 5). It should be noted, however, that although participants in their Example Only condition were not provided with the general rule (i.e., mimicking), they were given the solution (i.e., they were shown a picture of an animal and told what it looked like). In the current study, parent-child dyads in the No Instruction condition were only presented with three straw skyscrapers, a sturdier one that included diagonal cross braces throughout, a wobblier one without any diagonal cross braces, and one with diagonal braces only at the bottom. Unlike Brown and Kane’s (1988) study, in which children were shown a picture of an animal and told what the animal looked like, in this study dyads in the No Engineering Information/Control condition were not told that the diagonal braces kept the straw building from falling over; they had to figure that out on their own. Thus, this task might have been more difficult than the analogy problems used by Brown and Kane (1988) and so examples might not have been sufficient. The current study addresses this suggestion. Specifically, it investigates whether examples illustrating that triangular cross braces prevent buildings from falling down are sufficient in promoting transfer or whether providing parents and children with examples and instruction about specific engineering principles along with their participation in elaborative conversations, interact to boost learning and transfer of knowledge.

Although only presenting children with examples might not enhance transfer performance, children’s transfer could have been facilitated by the fact that the goal of
the learning task was the same as the goal of the transfer task; dyads were first informed that triangular cross braces prevent buildings from falling down and then were asked to build a building that would not fall down. The materials, however, were different. The model buildings used for the demonstration and instruction were made out of straws. Children had to build a sturdier building out of plastic building materials. There is research showing that preschool children can transfer a newly learned strategy to new materials under certain circumstances (Blote, Resing, Mazer, & Van Noort, 1999). For example, Blote et al. (1999) trained 4-year-old children to use “matching” to solve a same-different task, which required them to decide whether two sets of toys were the same or different. Participants were then presented with another same-different task that involved building blocks of different geometric forms. Results revealed that children applied the matching strategy to the new set of objects. As the researchers suggested, however, children’s performance on the transfer task might have been facilitated by their prolonged experience with the task. The children first participated in a microgenetic study that involved six sessions and then in three more training sessions before being exposed to the transfer task. Given that in reality children do not spend as much time working on one single task, it is essential to determine whether they can generalize to new materials without extensively engaging in a task. Pinpointing the mechanisms that facilitate transfer irrespective of the specific characteristics of materials is also very important.

In addition to learning more about transfer to new materials, determining whether context similarity affects children’s transfer abilities is also important. Indeed, researchers have called for more research that explores the effects of physical context on
children’s abilities to transfer (Klahr & Chen, 2011). The few studies that have examined the links between physical context and transfer performance have focused mainly on college students, infants, and toddlers (e.g., DeLoache, 2004; Rovee-Collier, 1999; Spencer & Weisberg, 1986). Findings from this small body of work have shown that when the transfer context is different from the learning context, performance is hindered. For instance, Spencer and Weisberg (1986) instructed college students to read two stories analogous to Duncker’s (1945) radiation problem and then asked them to solve the radiation problem. The researchers manipulated the social context and the timing between the story analysis and the problem solving phases. That is, some participants were introduced to the stories and the radiation problem by an experimenter without any delay in between the phases or with a six-minute delay. The other participants were introduced to the stories by the experimenter and to the radiation problem by a recitation leader, again with or without delay in between phases. Spencer and Weisberg (1986) found that when there was a delay between the presentation of the stories and the introduction of the radiation problem, students in the different-context condition did not apply their knowledge of the earlier stories in solving the radiation problem. Thus, this study points out that the temporal interval between tasks and context similarity interacted to affect college students’ ability to transfer. Little is known, however, about the effects of physical context on children’s transfer performance (Klahr & Chen, 2011). The current study addresses this issue by examining whether 5- to 6-year-olds can transfer the knowledge they acquire in a room adjacent to the museum exhibit to the building space in the Skyline exhibit. Furthermore, the study considers whether conversations assist such transfer.
Using traditional conceptualizations of the degree of transfer, which distinguish between near and far transfer, the task used in this study could be considered to be an example of a far transfer task. Researchers, however, have recently suggested that transfer is a multi-dimensional concept (Barnett & Ceci, 2002; Klahr & Chen, 2011). Indeed, Klahr and Chen (2011) proposed a three-dimensional model of thinking about transfer. Based on their model, the transfer task in the current study addresses whether and how two of the dimensions - task and context similarity, - affect children’s transfer of learning. Although, the source and the target tasks involve the same domain (i.e., engineering) and cover story (i.e., building sturdy buildings), the problem format and the materials are different. All participants were first exposed to a demonstration of how diagonal braces prevent buildings from falling down – the model buildings were made out of straws; then half of the participants received further specific information about the function of diagonal cross braces. The transfer task involved building a model skyscraper using a different set of materials (i.e., plastic building materials). Moreover, the physical context was also different – participants received information about the function of diagonal cross braces in a room adjacent to the museum exhibit, but had to apply it in the building space that is part of the Skyline exhibit. The temporal interval was small, ranging from 2 to 3 minutes.

As reviewed in this section, successful transfer of knowledge depends both on the amount of initial learning and on the ability to recall previously learned information. By providing hints that scaffold children’s making of connections between the demonstration and the transfer task, caregivers might transform the uninformed transfer task into an informed one, thus enhancing children’s transfer performance. Given that parent-child
conversations during events have been found to facilitate children’s understanding and recall of those events, it is essential to consider their impact on children’s transfer performance. This review turns now to a discussion of the literature on parent-child conversational interactions during events.

**Parent-Child Conversations During Events**

A relatively small but strong body of research indicates that the way in which parents talk to their children during an ongoing event influences children’s understanding and subsequent recall of that event (e.g., Boland, Haden, & Ornstein, 2003; Haden, Ornstein, Eckerman, & Didow, 2001; Tessler & Nelson, 1994). Illustrating this is a study by Tessler and Nelson (1994), who observed mothers and their 3-year-old children as they visited a museum. The investigators found that only those objects that have been talked about by both the mother and the child were recalled a week later. Importantly, none of the three-year-olds mentioned objects that they have seen in the museum but not talked about.

Additionally, the researchers noted that there are specific types of verbal interactions that can boost children’s comprehension of an ongoing event and subsequent recall. Specifically, associative talk was found to play an important role (Tessler & Nelson, 1994). In the second study of Tessler and Nelson (1994) mothers and their 4-year-old children were observed as they went on a picture-taking task through an unfamiliar neighborhood. Children’s picture recognition and memory of the walk were assessed three weeks later. Tessler and Nelson (1994) found that children whose mothers related aspects of the walk to familiar things recalled more photographs and more information about the walk than children whose mothers did not make associations.
Moreover, associative talk has been shown to also promote children’s science learning (e.g., Crowley et al., 2001). Crowley and Jacobs (2002), for instance, found that children of parents who explained fossils by connecting them to previous experiences recalled more fossils than children of parents who did not make such connections.

Importantly, the effectiveness of associative talk during events, as well as other elaborative conversational techniques, in enhancing children’s recall was confirmed by an experimental study conducted by Boland and colleagues (2003). In their study, mothers in the training group were instructed to use four techniques associated with an elaborative conversational style while engaging in a camping activity in their homes: (1) Wh- questions, (2) associations, (3) follow-ins, and (4) positive evaluations. The results revealed that mothers who were asked to use the elaborative conversational techniques did indeed use them more frequently than untrained mothers. Moreover, Boland et al. (2003) demonstrated that elaborative parent-child conversations during events positively impacted children’s recall. Specifically, the findings indicated that, 1 day and 3 weeks after participating in the camping event, children of trained mothers recalled more details about the event than children of untrained mothers, suggesting a causal relationship between maternal style of talk and children’s remembering.

More recent experimental evidence bolsters the importance of elaborative talk for children’s memory performance. To illustrate, McGuigan and Salmon (2006) have shown that 5-year-olds who experienced elaborative talk during a novel zoo event recalled more correct information than their peers who experienced empty talk. Not only did elaborative talk boost children’s verbal recall, but also their nonverbal recall. McGuigan and Salmon (2006) reported that children exposed to elaborative talk re-
enacted the zoo event more accurately than those exposed to empty talk. In a further examination into the effects of elaborative talk on children’s remembering Hedrick, Haden, and Ornstein (2009) experimentally manipulated the level of elaborative talk that an experimenter used with 3- to 6-year-old children both during and after a specially constructed camping event. Findings showed that children engaged in highly elaborative talk as the event unfolded recalled more descriptive information than those engaged in low-elaborative talk both 1 day after the event and 3 weeks later. Most importantly, results suggested that engaging children in elaborative talk both during and after events might be beneficial. Children who reported the most information were those who experienced elaborative talk during and after the camping event. Therefore, the effects of elaborative talk during and after events appear to be additive.

It should be noted that although a large number of studies that have explored the impact of elaborative talk during events on children’s remembering have been conducted either in the home or the school environment, research in museums has also focused on the links between elaborative conversations and children’s remembering (e.g., Benjamin et al., 2010; Crowley & Callanan, 1998; Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001). Crowley and Callanan (1998; Crowley, Callanan, Jipson, et al., 2001), for instance, have examined the content of parent-child conversations in a museum. The investigators found that parents used three types of elaborative explanations when talking about a zoetrope, which is an animation device, with their 4- to 8-year-olds. Specifically, they provided causal explanations for the observed events, made connections between the exhibit and children’s prior knowledge, and discussed abstract principles.
In a more recent study, researchers have investigated the links between parent-child elaborative talk in a museum exhibit and children’s subsequent recall of the exhibit experience (Benjamin et al., 2010; introduced in the Transfer section). In their study, some caregiver-child dyads were provided with building instruction, while other dyads received only conversational instructions. That is, they were instructed to use elaborative Wh- questions and associations. Indeed, Benjamin et al. (2010) found that caregivers who received conversational instructions asked more Wh- question and made more associations than those who only received building instruction. Children of parents who only received conversational instruction, however, recalled less during reminiscing conversations than those of parents who received both building and conversational instructions.

Taken together, the findings reviewed in this section indicate that parent-child conversations as events unfold boost children’s comprehension and recall. Moreover, they suggest that elaborative conversations have the potential to foster learning and transfer. Specifically, given that elaborative joint verbal exchanges were shown to enhance children’s understanding and recall of events, they might also facilitate children’s learning and transfer of STEM-related concepts. Furthermore, since effective transfer of learning depends on children’s ability to connect the task at hand to appropriate prior experiences, parents’ use of associations might be especially important for promoting transfer. The current research explores these possibilities.

Caregiver-child discussions about a museum experience, however, do not end when they leave the museum (Leinhardt & Knutson, 2004). Importantly, there is evidence suggesting that parents differ in their reminiscing styles and that elaborative
reminiscing conversations can foster children’s memory performance. Focusing on such conversations can reveal not only what children recall about the museum visit, but also how parents support their children’s learning and transfer of knowledge. The literature review turns to work on parent-child reminiscing conversations.

**Parent-Child Conversations After Events**

Previous research focusing on mother-child conversations about past events has demonstrated that mothers vary in their reminiscing styles (Engel, 1986; Fivush & Fromhoff, 1988; McCabe & Peterson, 1991; Reese, Haden, & Fivush, 1993). In contrast to mothers typified as *low elaborative* or *repetitive*, mothers characterized as *high elaborative* or *topic extending* tend to engage in long conversations during which they provide rich and elaborate descriptions of past events. These mothers ask many open-ended questions, confirm their children’s responses, and make many associations to other experiences that are relevant to the event they are discussing. Mothers characterized as being *low elaborative* or *repetitive* tend to provide little descriptive information and to have shorter conversations about past events. These mothers ask fewer and redundant questions and probe their children for specific pieces of information.

Furthermore, these differences in mothers’ approaches to the task of discussing past events with their children have been shown to be consistent over time (Reese et al., 1993; 1996). To illustrate, Reese et al. (1993) assessed mother-child reminiscing four times over a 2 ½ year period, – when children were 40, 46, 58, and 70 months of age, - and found that mothers used more elaborations and fewer repetitions over time. Moreover, mothers’ use of elaborations at the early time points of children’s development were found to be significantly related to the their use of elaborations at the later time
points, and their use of repetitions early on significantly related to their repetitions at later times. In addition, the results revealed that although children increased in their memory responding, mothers were consistent in their use of elaborations and repetitions over time. That is, high-elaborative mothers were more elaborative than low-elaborative mothers even when their children became better narrators (i.e., provided more memory responses). Most importantly, the findings highlighted that high elaborative mothers provided new information even when their children did not.

Not only were mothers shown to be consistent in their reminiscing style with the same child over time, but also across different-age children (Haden, 1998). Haden (1998), for instance, observed mothers as they separately talked to their younger and older children about shared past events. The results revealed that mothers were consistent in how they talked about past events with their two different-age children. Moreover, mothers were consistent in their use of the three stylistic dimensions (i.e., elaborative, repetitive, and declarative) across siblings. Therefore, these findings suggest that children who grow up in the same family are provided with similar opportunities for acquiring reminiscing skills.

Studies examining parent child reminiscing across mothers and fathers provide further support for the suggestion that children are exposed to similar linguistic environments when it comes to reminiscing (Reese & Fivush, 1993; Reese, Haden, & Fivush, 1996). In particular, Reese and Fivush (1993) observed mothers and fathers as they separately reminisced with their 3-year old children and found that mothers and fathers did not differ in their level of elaborativeness with their children. It should be noted, however, that both mothers and fathers were more elaborative when talking to
their daughters than when reminiscing with their sons. Reese, Haden, and Fivush (1996) replicated these initial findings and extended them to 5-year-old children and by pointing out that parents use more evaluations when discussing past events with their daughters than with their sons.

In addition to indicating that parents vary in how they discuss past events with their daughters and sons, previous research also illustrated that children differ in how they narrate with their mothers and fathers (Haden, Haine, & Fivush, 1997). Haden et al. (1997) longitudinally assessed the linkages between parents’ and children’s provision of narrative structure in conversations about past experiences. Parents and their children were observed talking about shared past events when the children were 40 months old and again when they were 70 months old. The researchers found that both boys and girls provided more narrative structure, include more action information, and more spatial-temporal orientations when talking to their fathers than when talking to their mothers.

Most importantly, however, longitudinal research that has focused primarily on mother-child conversations about past experiences has shown that mothers’ reminiscing styles influence children’s memory performance as well as their reminiscing skills (Fivush, Haden, & Reese, 1996; Reese, Haden, Fivush, 1993). Reese et al. (1993), for example, found that children whose mothers were characterized as high elaborative when they were 40 months old recalled more memory information in later conversations at 58 and 70 months of age. Highly elaborative mothers ask many open-ended questions and provide new information about past experiences even when their children do not recall anything else. Therefore, these mothers are helping their children retrieve more information.
Extending this initial work, Harley and Reese (1999) investigated the impact of maternal reminiscing style on younger children’s verbal recall. Mothers and their children reminisced about past events when the children were 19, 25, and 32 months of age. The findings showed that, even after controlling for children’s language skills, maternal reminiscing style was a strong predictor of children’s memory responding over time. Highly elaborative mothers had children who provided more unique information across time than low elaborative mothers. Thus, this study illustrated that mothers’ style of talk about shared past events influence children’s remembering starting early on in development.

Notably, in a more recent extension of the early work looking at maternal reminiscing styles, Haden et al. (2009) examined individual differences among mothers in their use of elaborative open-ended questions and statements. Mother-child dyads were observed while reminiscing across a 1 ½ year period, from when children were 18 months old until they were 30 months old. Haden et al. (2009) found that mothers could be categorized based on their use of elaborative open-ended questions and statements in conversations with their 18-month-old children. That is, compared to mothers classified as low-eliciting, high-eliciting mothers asked more elaborative open-ended questions and elaborative yes-no questions, made more confirmations and fewer elaborative statements. Furthermore, mothers were consistent in their style of talk over the one-and-a-half year period. Also, children of high-eliciting mothers recalled more information than children of low-eliciting mothers at each age point (i.e., at 18, 24, and 30 months of age). Most importantly, the findings demonstrated that mothers who used a high-eliciting style when
talking about the past with their 18-year-olds had children who recalled more memory information in mother-child conversations at 30 months of age.

The linkages between maternal reminiscing styles and children’s subsequent remembering are validated by a number of experimental studies (Peterson, Jesso, & McCabe, 1999; Reese & Newcombe, 2007). In one, Peterson et al. (1999) trained mothers to use three specific conversational techniques: (1) open-ended Wh- questions, (2) encourage children’s participation in the conversations, and (2) follow children’s lead in the conversations. In contrast to mothers in the control group, who did not receive any training, trained mothers did use more open-ended questions and made more confirmations while reminiscing. Importantly, children of trained mothers had higher receptive skills and told longer and more embellished narratives than children of untrained mothers one year after the intervention.

A more recent maternal training study demonstrated that an elaborative reminiscing style facilitates children’s memory contributions and participation in conversations about past events. Reese and Newcombe (2007) randomly assigned mothers to a training or no-training condition. The researchers gave mothers in the training group an instruction sheet that listed a number of elaborative techniques they could use while discussing shared past events with their 2½ year olds. Families were visited multiple times over the course of 15 months from when the children were 19 months old to when they were 44 months old. The results of this work replicated those of Peterson et al. (1999) by showing that mothers can be trained to become more elaborative. Specifically, trained mothers became more elaborative in their reminiscing styles than untrained mothers both 2.5 months and 15 months after the intervention.
Furthermore, compared to children of untrained mothers, children of trained mothers recalled richer and more accurate memory reports 15 months after the final training session.

The work reviewed in this section indicates that high elaborative parents use conversational techniques that can enhance children’s recall and transfer of knowledge. Engaging in high elaborative reminiscing conversations has the potential to boost STEM learning and transfer, because they require children to recall and abstract what they learned from instruction and from actively engaging in a building task. Furthermore, the dyads can reflect and elaborate on the museum experience during reminiscing and so they can gain a better understanding and grasp of the acquired information, which in turn could facilitate their ability to apply it in different contexts.

**Current Study**

The current study extends prior work on the role that direct instruction and parent-child conversational interactions in informal settings – specifically museums – can play in enhancing children’s learning and transfer of STEM-related concepts and principles. In particular, this project demonstrates empirically how providing families with information about engineering principles impacts their conversations during a building activity, their ability to generalize across tasks and contexts, as well as their subsequent memory reports regarding their museum experience. Parent-child conversations in the exhibit reveal not only how children best learn specific engineering principles, but also how they acquire general approaches to problem solving.

This study focuses on parent-child interactions in the Skyscraper Challenge building space within the Skyline exhibit at Chicago Children’s Museum. Mothers with
5- to 6-year-old children were recruited to participate in the study. Using an experimental design, mother-child dyads were randomly assigned to one of two conditions that differed in the amount of engineering information they received prior to engaging in a building activity in the exhibit. A key feature of the manipulation was the provision of information about ways to build a strong building. Although dyads in both conditions were exposed to a demonstration, which illustrated that diagonal cross braces prevented buildings from falling down, those in the Engineering Information condition received further specific engineering instruction. That is, they were specifically told that triangular cross braces prevent buildings from falling down. Those in the No Engineering Information condition heard empty non-STEM related comments (e.g., “This was so interesting, wasn’t it?”).

Children’s understanding and learning of the fundamental engineering principles was assessed in a number of ways. Families were video recorded during the pre-exhibit demonstration and while they engaged in the building activity. The pre-exhibit recordings provided information about 5- to 6-year-olds’ knowledge of engineering. The exhibit recordings allowed an assessment of the effectiveness of engineering information in stimulating discussion about engineering and in enhancing children’s ability to build a strong building. Specifically, the amount and type of discussions between mothers and children were used to determine the impact of direct instruction. Children’s ability to transfer was assessed based on their inclusion of triangular cross braces and on their verbal comparisons between the two activities. Learning and remembering was also assessed upon completion of the building activity as well as one day and two weeks after
the museum visit. Parent-child dyads were asked to discuss about the museum experience within 24 hours and again 2 weeks later.

The study has several goals. The first is to explore the effectiveness of providing engineering information to families prior to engaging in a building activity in enhancing parent-child conversations about STEM. In other words, would informing mother-child dyads that triangular cross braces prevent buildings from falling down lead to conversations richer in STEM-related content? In turn, were those families that had richer conversations in the exhibit building stronger structures than families who had less elaborative conversations? The effect of building instruction on mother-child talk was assessed based on the amount and type of conversations mothers and their children had in the exhibit. The effect of building instruction on the strength of the buildings was assessed based on the number of cross braces included in the final structures and overall sturdiness of the structures.

Examinations of the parent-child conversations in the exhibit and the sturdiness of their final structures also answer questions regarding children’s ability to transfer and the conditions that facilitate transfer. That is, this project examines whether children could generalize what they learned in one context (the room adjacent to the museum exhibit) to a different context (the Skyscraper Challenge building space in the Skyline exhibit) and whether they could transfer from one type of materials (straws) to different ones (plastic building materials). There is evidence indicating that both infants’ and young adults’ learning is influenced by the context of learning such that they perform better on memory and problem solving tasks when the context of transfer is the same as the context of learning (e.g., DeLoache, 2004; Rovee-Collier, 1999; Spencer & Weisberg, 1986). These
findings raise a critical question: how can we enhance children’s ability to generalize across contexts? One avenue might be through conversations. Therefore, this study examines whether the provision of engineering instruction determines parents and children to have more elaborative conversations both during and after the museum visit and to build stronger buildings.

Lastly, this study investigates the potentially additive effects of engineering instruction and elaborative conversations during the building activity on children’s learning and memory reports. More specifically, this project examines whether reminiscing conversations in the days and weeks after the museum visit are richer for those families who were provided with engineering information and had elaborative conversations in the exhibit than those who either had less elaborative conversations or received no engineering information.

**Hypotheses**

Based on the previous research reviewed here, the following hypotheses are advanced.

**Hypothesis 1**

It was hypothesized that children in the Engineering Information and No Engineering Information conditions would not differ in prior engineering knowledge. That is, it was anticipated that children in the two conditions would not differ in their abilities to choose the sturdiest and wobbliest straw structures, their explanations of their choice selections, their suggestions for how to fix the wobbly skyscraper, or their ability to pick the stronger structure from pairs of photographs.

**Hypothesis 2**

It was predicted that children who would receive engineering information would
build sturdier buildings than those who would not receive such information. Specifically, it was anticipated that children who would be told that diagonal cross braces keep structures from falling down would include more functional triangles and cross braces in their skyscrapers than those who would not receive such information.

**Hypothesis 3**

Moreover, it was hypothesized that parent-child conversations in the exhibit would be richer in STEM-related content for those in the Engineering Information condition than for those in the No Engineering Information/Control condition. Specifically, providing mother-child dyads with information about how to build sturdy buildings was expected to determine them to talk more about STEM-related concepts and principles.

**Hypothesis 4**

It was also hypothesized that children who would receive engineering information would demonstrate a greater level of knowledge transfer in comparison to those who would not receive such instruction. That is, children who were informed that triangular shapes keep structures from falling down were expected to make more associations and connections between their pre-exhibit and exhibit experiences, to include more triangular cross braces in their structures, and to be better able to pick the stronger bridge from pairs of photographs.

**Hypothesis 5**

Finally, it was predicted that children who would have a better understanding of how to build strong buildings and who would have richer conversations in the exhibit would recall more pieces of new information during reminiscing at the two time points (1
day and 2 weeks later) than those who would have a poorer understanding of how to build sturdy buildings and less developed conversations. In other words, it was predicted that the effects of direct instruction and elaborative conversations on children’s learning and transfer would be additive.
CHAPTER TWO

METHODS

Participants

A total of forty mothers and their 5- to 6-year-old children ($M = 5.87, SD = .59$) participated in this study. The sample consisted of 45% Caucasian, 25% Asian, 12.5% African American, 7.5% Hispanic, 2.5% Middle East, and 7.5% mixed race children. Participants were recruited from the Skyline exhibit at the Chicago Children’s Museum (CCM). The criteria for inviting participants were that the child was (a) between the ages of 5- and 6-years and (b) accompanied by his or her mother. The mother-child dyads were randomly assigned to one of two conditions, Engineering or No Engineering Information, each with twenty pairs. Child gender was balanced across groups (i.e., there were 10 boys and 10 girls in each group). The sample size for this study has been determined through a power analysis using Haden’s prior work at Chicago Children’s Museum to estimate effect sizes. With a medium effect size of Cohen’s (1992) $f = .33$, and a sample size of $n = 18$ per condition, I had an 85% chance of detecting main effects and simple interactions. All participants received a small thank you gift for their participation.
Procedure

Pre-exhibit Experience

The pre-exhibit experience took place in a room adjacent to the Skyscraper Challenge where there was a large bank of windows looking out over the Chicago skyline. Each dyad was seen separately. The study began with a demonstration of how diagonal cross braces prevent skyscrapers from falling down. More specifically, to assess children’s prior knowledge about building engineering all participants were first asked to select the stronger structure from pairs of photographs depicting structures made out of wood. They were then asked to respond to several questions about skyscrapers. For example, the researcher presented all families with three models of skyscrapers made of straws and wrapped in plastic “skin.” The skyscrapers were of equal height and made of the same number of straws, but only one featured diagonal cross braces. All children were asked to select the skyscraper they thought was going to be able to withstand a strong wind and not fall over and to explain why they selected that skyscraper. Next, they were asked to select the skyscraper they thought was most likely to fall down and to explain their choice selection. Lastly, children were invited to provide suggestions for how to fix the wobbly skyscraper. Once the children explained their answers and provided suggestions, the researcher used a leaf blower to create “wind” and families saw that the skyscraper without diagonal cross braces fell straight to the floor (quite dramatically!), whereas the one including triangular shapes did not. Then, half of the families received further information about how diagonal cross braces squeeze structures together and keep them from falling down. Specifically, they were told: “On very windy days, tall buildings sway, just like trees. That is, the tops of the skyscrapers bend over
their base a little. A lot of swaying, however, is dangerous – like when a branch falls off of a tree. So, engineers need to build buildings that do not sway too much. One way they do that is by using cross braces in their buildings. These cross braces can look like triangles. They help skyscrapers hold up against the wind and not flop over. An excellent example of a skyscraper that has cross braces is the John Hancock Center” (Johmann, 2001). It should be noted that children were shown a photograph of the John Hancock Center and the cross braces were pointed out. Children in the No Engineering Information condition heard empty, non-STEM related comments. Thus, the key manipulation was the provision of the specific engineering information about cross bracing.

**Skyscraper Challenge Interaction**

Right after the pre-exhibit experience, each parent-child dyad was escorted to the Skyscraper Challenge building space that is located in CCM’s 2,500 square-foot Skyline exhibit. Small-scale plastic building materials, such as girders, nuts, bolts, are available in that building space. All parent-child dyads were instructed to build a skyscraper that would not fall over. Families were video recorded while building.

**Paired-Comparison Task**

After they were done building, children were asked to complete a second paired-comparison task. Specifically, they were shown photographs of bridges made out of wood and asked to choose the photograph depicting the stronger bridge.

**Memory Conversations**

All dyads were then asked to participate in an in-home assessment of the children’s memory for the museum visit. Caregivers were asked to audio record two
reminiscing conversations, one 24-hours and the other 2 weeks after the museum visit, during which to discuss their experience in the Skyscraper Challenge building space (see Appendix A for the Home Instructions page). Each family was given a digital voice recorder, an instruction sheet, and a postage-paid flat rate box that they could use to return the recorder to the laboratory.

**Coding**

Videotape records of the pre-exhibit demonstration and of the conversations during the building activity (masked for condition) were scored using Noldus Observer Pro software. The memory conversations (also masked for condition) were coded in CLAN from verbatim transcripts of the audio records. The procedures for establishing reliability were the same for all coding systems. Specifically, two researchers independently coded 25% of the records. Once reliability was established, no single reliability estimate was below 85% agreement. The author coded the remainder of the data with checks by the second coder.

**Prior Engineering Knowledge: Brief Interview**

Children’s responses to the five questions posed during the pre-exhibit demonstration focused on assessing their prior knowledge about building engineering. Children were first asked to choose the sturdiest skyscraper out of three skyscrapers made out of straws. Their choice of the sturdy straw skyscraper was scored as (a) correct, if they chose the skyscraper with triangular braces throughout or (b) incorrect, if they chose the skyscraper with triangular braces only at the bottom or the skyscraper with no triangular braces. Children’s explanations of their sturdy skyscraper selection were also classified as either (a) correct, if they mentioned the presence of triangles (e.g., “It has crosses.” “I think this
one because of these angled ones.”), or (b) incorrect, if they did not mention the triangles (e.g., “I like this one better.” “You set the tape really well.”).

They were then asked to pick the wobbliest straw skyscraper. Children’s choice of the wobbly straw skyscraper was scored as (a) correct, if they chose the skyscraper with no triangular braces, or (b) incorrect if they chose the skyscraper with braces throughout or the one with braces at the bottom. Their explanations of their wobbly skyscraper selection were also classified as (a) correct, if they mentioned that there were no triangles (e.g., “Because it has different shapes, rectangles” “There are no triangles here.”), or (b) incorrect, if they did not refer to triangles (e.g., “Because straws don’t stay together.” “The tape looks like it’s not strong enough.”).

Lastly, children’s answers to the question about how to fix the wobbliest skyscraper were scored as (a) correct, if they suggested adding triangles to the skyscraper (e.g., “Put more straws crossed.” “Add Xs.”), or (b) incorrect, if they did not suggest adding triangles (e.g., “Add big antennas.” “Add more horizontal lines.”). Two coders viewed the masked video records and established reliability by independently coding 25% of the video records. Overall percent agreement was 98% (range 90% - 100%).

Prior Engineering Knowledge: Paired-Comparison Picture Task

Children’s choices of the stronger structure from pairs of photographs were scored as (a) correct, if they chose the photograph depicting a structure with triangles or diagonal cross-braces, or (b) incorrect, if they chose the photograph depicting a structure with no triangles or diagonal cross-braces. Each correct choice received 1 point. The correct scores were summed to obtain an index of prior engineering knowledge. Agreement in scoring the performance on the paired-comparison task was 100%.
Conversations in the Exhibit

Parent-child conversations in the Skyscraper Challenge building space were coded using a coding system adapted from Haden et al. (2013). The same coding system was used for both mothers and children. First mothers’ and children’s utterances were categorized as (1) open-ended questions, (2) yes-no questions, or (3) statements. Open-ended questions were those that used a Wh- format (Who, What, Where, When, Why, How) to inquire information (e.g., “Why aren’t you adding this triangle first?”). Yes-No Questions were those that required the mother or the child to confirm or deny a piece of information (e.g., “Is this piece long enough?”). Declarative comments made by the mother or the child that provided information about the event were categorized as statements (e.g., “I’ll tighten this nut.”). Appendix B list the F-values, p-values, means, and standard deviations for children’s and mothers’ open-ended questions, yes-no questions, and statements, respectively. However, these categories were not the focus of this project and will not be discussed further.

All open-ended questions, yes-no questions, and statements were further classified in terms of content as follows:

A. Scientific Method: talk that referred to planning how to build, hypothesis testing, redoing based on something not working, proposing an idea, or problem solving (e.g., “Let’s take care of the foundation first, and then we’ll do the floor.” “I have an idea mom, we should put this piece here.”).

B. Technology: talk that involved labeling the building materials and/or discussing their function (e.g., “Where are the nuts and bolts?” “What are these mending plates for?”).
C. Engineering: talk about triangles and/or their function, how to make the skyscraper sturdy, parts of a building, and connecting or attaching pieces (e.g., “Do you want to put another triangle there?” “How do we build a strong foundation?”).

D. Mathematics: talk about numbers, amount, length, height, or geometric shapes (e.g., “We need another square.” “We need a longer stick, we need these longer ones.”).

E. Time: talk about the amount of time they had (e.g., “How many minutes do we have left?” “Are you worried about our time running out?”).

F. Associations to demonstration: comments that linked what was learned from the demonstration to what was done during the building activity (e.g., “What did the lady say about triangles?” “We’re going to build it like the sturdy one you saw in the room.”).

G. Associations to general knowledge: talk that linked their previous real-world experiences and knowledge to the building activity (e.g., “Remember it’s like when we do Lincoln Logs.” “This is going to be a window.”).

H. Directing physical actions: talk that directed the child or the mother to perform a specific action (e.g., “Go get another black piece Jack.” “Do you want to put one of the blue ones under here?”).

I. Evaluations: talk that involved evaluating the task or their building skills (e.g., “This is hard mommy.” “You should do this with your daddy.”).

J. Help/Engagement: any requests by the child for help (e.g., “Mommy will you help me with this one?”) or requests by the mother to work on the task (e.g., “Come over here.” “Common! We need to finish this.”).

K. Repetitions: talk that involved repeating what was previously said (e.g., mother said,
“This side is not sturdy” and the child said “That side is not sturdy” – in this case, the child’s utterance was coded as a repetition).

L. Confirmations: comments that confirmed a piece of information (e.g., “Yes.” “Right.”).

M. Negations: comments that denied a piece of information (e.g., “No.” “Nope.”)

N. Placeholders: talk that involved taking a conversational turn, but not providing any new information (e.g., “I don’t know.” “I don’t remember.”).

O. Off topic: talk that was not related to the building activity (e.g., “Maybe you should take a picture.” “My back hurts.”).

Inter-rater agreement for these codes averaged 89% (range 85% - 93%). It should be noted that confirmations, negations, placeholders, and off topic comments made by mothers and children were included in the total talk variable that was computed, but they are not considered individually in the reporting of the results.

**Final Structures**

The final structures were rated both in the museum and again in the laboratory from pictures using the following criteria:

A. Total number of pieces: the total number of building materials used in the building structure, not including nuts and bolts.

B. Total number of functional pieces: the total number of triangular shapes that served a structural purpose (i.e., were placed in such a way that restricted the movement of the structure in any direction).

C. Number of decorative triangles: the total number of triangular shapes that served a decorative function and did not restrict the movement of the structure.
D. Number of stories: four long pieces (blue, speckled, or black) extended vertically counted as one story.

To assess the sturdiness of the final structures a ratio of the total number of functional pieces to total pieces was computed. Agreement in scoring the final structures was 100%.

**Immediate Assessment of Learning and Transfer**

Children’s performance on the second paired-comparison task was scored as (a) correct, if they chose the photograph depicting a bridge with triangular shapes, or (b) incorrect, if they chose the photograph depicting a bridge with no triangular shapes. For each correct choice, the children received 1 point. The correct answers were summed to obtain a total that indexed their immediate learning and ability to transfer their knowledge. Agreement in scoring the paired-comparison task was 100%.

**Memory Conversations**

Lastly, similar to previous work (Benjamin et al., 2010), dyads were asked to talk about the museum visit one day and two weeks later. Each dyad was given a digital voice recorder and a postage paid box so they could send their recorded reminiscing conversations back to the laboratory. The recordings of the conversations about the building activity were transcribed verbatim and coded using a reliable coding system adapted from previous work (e.g., Benjamin et al., 2010; Boland et al., 2003; Haden et al., 1998; Haden et al., 2001). The memory conversations provided information not only about children’s learning in the museum, but also about the impact of time on their learning.

Mothers’ comments were first categorized as (a) general memory questions, (b)
yes-no questions, or (c) statements. General memory questions were open-ended questions of the *Wh*—type (Who, What, Why, Where, When, How) that required the child to provide memory information about their museum experience. Yes-No questions were questions that asked the child to confirm or deny a piece of memory information provided by the mother. Statements were declarative comments made by the mother that provided information about the museum experience.

Next, all general memory questions, yes-no questions, and statements were categorized as (a) elaborations or (b) repetitions. Elaborations were memory questions that asked for new, not previously mentioned memory information about the museum experience or declarative comments that provided new memory information. Repetitions consisted of memory questions or statements that repeated the same content or gist of information requested or provided in a previous question or statement.

Importantly, all elaborations were subcoded for STEM content, associations to the demonstrations, and associations to general knowledge as outlined in the Exhibit Conversations section, as well as for content related to the pre-exhibit demonstration, building activity, affect, and time.

A. **Scientific Method** (e.g., “When we were building our skyscraper why do you think we were having problems?” “What did we build first?”).

B. **Technology** (e.g., “Do you remember what the building parts looked like?” “The nuts went on the bolts, right?”).

C. **Engineering** (e.g., “What did we have to do to get those pieces to connect?” “We only had enough time to do one cross like an X.”).

D. **Mathematics** (e.g., “Was our building very tall?” “How many squares did we add?”).
E. Associations to demonstration (“The skyscraper I built was like the middle one the lady had.” “When we went and built our own building we tried to make an X too, didn’t we?”).

F. Associations to general knowledge (“A skyscraper is a large building that could fit a million of you in there.” “The one piece at the top was like an antenna.”).

G. Demonstration - Triangles: talk about the information they received regarding the function of triangles (e.g., “That first skyscraper that was really sturdy, do you remember how the straws were angled?” “Do you remember what the lady said about triangles?”).

H. Demonstration - General: talk about the pre-exhibit experience (e.g., “Do you remember talking to the lady in the room with big windows?” “Do you remember that she showed us some skyscrapers made out of straws?”).

I. Building activity: talk about building in the Skyline exhibit that did not contain STEM content (e.g., “Do you remember what color we did on the bottom?”).

J. Affect: affective types of talk, such as about their feelings towards the building activity (e.g., “Did you have fun working with me?” “It was a pretty difficult task.”).

K. Time (e.g., “We had to go fast, so we didn’t run out of time.”).

Children’s comments were classified as (a) memory questions, (b) memory elaborations, or (c) memory repetitions. Memory questions were open-ended questions spontaneously asked by the child (e.g., “Why didn’t we have enough time?”). Memory elaborations were provisions of new pieces of information about the past event under discussion (e.g., “We used nuts and bolts to put the pieces together.”). Memory repetitions were provision of information that was already mentioned by either the
mother or the child (e.g., mother: “We included lots of triangles to make the building sturdy.”; child: “Yeah, we used lots of triangles and made a strong building.”). Next, children’s memory questions and memory elaborations were further subcoded for content in the same fashion as mothers’ reminiscing talk. Agreement in scoring the memory conversations averaged 90% (range 85% - 95%).
CHAPTER THREE

RESULTS

Preliminary Analyses

In order to determine what, if any, covariates should be included in the main analyses preliminary correlational analyses were conducted. The correlations examined whether mother characteristics (education, marital status, prior engineering knowledge, interest) and child characteristics (age, prior engineering knowledge, interest) were correlated with the measures of the mothers’ and children’s building behaviors, conversations in the exhibit, and the two reminiscing conversations.

Maternal education was correlated with seven of the continuous measures of conversation in the exhibit (significant $r$s = .30-.50, $p$s < .05), but not with any measures of building or remembering ($p$s ≥ .14). Maternal education was retained as a covariate in the analyses of variance (ANOVAs) reported below that involved the variables with which it was correlated. Marital status was found to be significantly correlated with: mothers’ open-ended questions ($r = -.38, p < .05$), mothers’ yes-no questions ($r = -.35, p < .05$), children’s total statements ($r = -.46, p < .01$), and children’s mathematics talk ($r = -.33, p < .05$) in the exhibit. Therefore, marital status was retained as a covariate in the ANOVAs that involved the variables with which it was correlated. Child age was significantly correlated with mothers’ mathematics talk ($r = -.39, p < .05$), mothers’ use of evaluations ($r = -.32, p = .05$), and mothers’ talk about time ($r = .38, p < .02$) in the
exhibit. Child age was thus selected as the covariate for inclusion in the analysis reported below that involved the three aforementioned variables.

Three of the four correlations between mothers’ and children’s prior engineering knowledge and interest in building were significant \((rs = .37-.58, ps < .05)\); mothers’ interest in building and children’s prior engineering knowledge were not correlated \((r = .21, p = .20)\). Children’s interest was correlated with mothers’ talk about technology at the 2-week delay \((r = .42, p = .05)\), but not with any measures of building, talk in the exhibit, or the other reminiscing measures \((ps \geq .10)\). Child interest was retained as a covariate in the ANOVA analysis that involved mothers’ technology talk at the 2-week delay. Mother interest was only significantly related to children’s mathematics talk \((r = .48, p < .05)\) in the exhibit. Mother interest was thus retained as a covariate in the analysis involving children’s mathematics talk. Children’s prior knowledge was significantly associated with mothers’ talk about mathematics \((r = .32, p < .05)\) and mothers’ use of associative comments \((r = .40, p < .05)\). Therefore, child prior knowledge was included in the analyses that involved these two types of talk. Mothers’ prior knowledge was not significantly associated with any of the variables in the study \((rs = .00 - .38, ps \geq .06)\), and it was thus not included as a covariate in the main analyses.

**Analyses of Demographic Characteristics by Condition and Child Gender**

Table 1 lists the average age of the children at the time of the museum visit, their parents’ reported educational level, children’s and their mothers’ prior engineering knowledge, and children’s and mothers’ interest in building. There were no main effects of condition for maternal educational levels \(F(1, 37) = .46, p = .50\), or paternal
educational levels, $F(1, 27) = .82, p = .37$. Mothers’ prior engineering knowledge and interest in building also did not vary by condition, $Fs(1, 38) < .50, p \geq .50$. Male children ($M = 2.20, SD = 1.32$), however, were rated by their mothers as having higher prior engineering knowledge than female children ($M = 1.50, SD = .69$), $F(1, 38) = 4.41, p < .05$. Boys ($M = 4.20, SD = 1.58$) were also rated by their mothers as having higher interest in building than girls ($M = 3.15, SD = 1.53$), $F(1, 38) = 4.57, p < .05$. The Condition x Child Gender interactive effects for child prior engineering knowledge and child interest in building were not statistically significant ($Fs < 2.40, ps \geq .14$).

Table 1. Means for Children's Age, Parental Education Level, Prior Engineering Knowledge, and Interest in Building by Experimental Condition

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Engineering Information</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>5.83 (.67)</td>
<td>5.91 (.51)</td>
</tr>
<tr>
<td>Maternal education (years)</td>
<td>16.50 (1.57)</td>
<td>16.11 (2.05)</td>
</tr>
<tr>
<td>Other parent's education</td>
<td>17.47 (2.67)</td>
<td>16.57 (2.65)</td>
</tr>
<tr>
<td>Mothers' prior knowledge</td>
<td>2.45 (1.36)</td>
<td>2.15 (1.42)</td>
</tr>
<tr>
<td>Children's prior knowledge</td>
<td>1.70 (.73)</td>
<td>2.00 (1.38)</td>
</tr>
<tr>
<td>Mothers' interest</td>
<td>2.70 (1.63)</td>
<td>2.50 (1.50)</td>
</tr>
<tr>
<td>Children's interest</td>
<td>3.60 (1.60)</td>
<td>3.75 (1.71)</td>
</tr>
</tbody>
</table>

*Note. Standard deviations are in parentheses.*

There were no main effects of condition or child gender for the children’s age, $Fs(1, 36) < 3.00, ps > .10$. However, there was a significant Condition x Child Gender interaction predicting children’s age at the time of the museum visit, $F(1, 36) = 6.30, p < .05$. Simple effects tests were conducted to determine the nature of the significant
interaction. More specifically, two one-way ANOVAs were conducted comparing the age of children in the Engineering Information and Control conditions based on their gender. In the Engineering Information condition, there was not a significant simple main effect of gender predicting children’s age, $F(1, 18) = .23, p = .63$. Specifically, there was not a significant age difference between female children ($M = 5.90, SD = .58$) and male children ($M = 5.76, SD = .78$) in the Engineering Information condition. However, in the Control condition, there was a significant simple main effect of gender predicting child age, $F(1, 18) = 20.38, p < .001$. This suggested that, in the Control condition, male children ($M = 6.27, SD = .30$) were significantly older than the female children ($M = 5.55, SD = .41$).

**Main Analyses**

**Prior Engineering Knowledge**

**Hypothesis 1: Brief interview.** The first research hypothesis predicted no differences in prior engineering knowledge between children in the Engineering Information and No Engineering Information/Control conditions. To test this hypothesis, a series of Chi-Square analyses were run. These analyses focused on children’s: (a) choice of sturdiest skyscraper, (b) explanation of their sturdy selection, (c) choice of wobbliest skyscraper, (d) explanation of their wobbly selection, and (e) suggestions for how to fix the wobbliest skyscraper.

The first step in these analyses involved evaluating whether or not the number of correct and incorrect choices, explanations, and suggestions differed from chance. Findings revealed that the number of incorrect ($n = 23$) and correct ($n = 16$) choices of the sturdiest skyscraper was not statistically different from chance, $\chi^2(1, N = 39) = 1.26, p$
The number of correct and incorrect explanations for the sturdy choice selection, however, differed from chance, $\chi^2 (1, N = 39) = 18.69, p < .001$. Specifically, children provided significantly more incorrect explanations ($n = 33$) than correct explanations ($n = 6$). Regarding the choice of the wobbliest skyscraper, findings indicated that the number of correct ($n = 16$) and incorrect choices ($n = 24$) was not significantly different from chance, $\chi^2 (1, N = 39) = 1.60, p = .21$. However, similar to the sturdy choice selection, the number of correct and incorrect explanations for the wobbly choice selection differed from chance, $\chi^2 (1, N = 39) = 31.41, p < .001$. Again, children provided significantly more incorrect ($n = 37$) than correct ($n = 2$) explanations. Lastly, a chi-square focusing on the number of correct and incorrect suggestions for how to fix the wobbliest structure revealed that it differed from chance, $\chi^2 (1, N = 39) = 27.92, p < .001$. Children provided significantly more incorrect ($n = 36$) than correct suggestions ($n = 3$) for how to fix the wobbliest skyscraper.

Next, a series of chi-square analyses examined whether there was an association between experimental condition and children’s prior engineering knowledge. Figure 1 illustrates the percentage of children in each condition who chose the incorrect sturdiest and wobbliest structures. The chi-square test indicated that children’s choice of the sturdiest structure prior to the demonstration was not significantly different by condition, $\chi^2 (1, N = 39) = .02, p = .89$. Likewise, their choice of the wobbliest structure when asked prior to the demonstration was not significantly different by condition, $\chi^2 (1, N = 39) = .42, p = .52$. 
Figure 1. Skyscraper choice selection. This figure illustrates the proportion of children in each condition who chose the incorrect sturdiest and wobbliest skyscrapers.

With regard to children’s explanations of their sturdiest choice selection, Figure 2 shows the statistical trend, $\chi^2 (1, N = 39) = 2.92, p = .088$, such that more children in the Control condition than in the Engineering Information condition provided a correct explanation for their sturdiest selection. Furthermore, as shown in Figure 2, results indicated that there was no association between condition and whether children provided a correct or incorrect explanation for their wobbliest choice selection, $\chi^2 (1, N = 39) = 2.00, p = .16$. Children's suggestions for how to fix the wobbliest skyscraper were also analyzed. The proportion of children in each condition who provided a correct suggestion for how to fix the wobbliest skyscraper was compared with the proportion of children who provided an incorrect suggestion. There was a marginally significant association between condition and whether children provided a correct or incorrect suggestion for how to fix the wobbliest skyscraper, $\chi^2 (1, N = 39) = 3.09, p = .079$. This effect was based on the fact that none of the children in the Engineering Information condition provided a correct suggestion, but 15% of the children in the Control condition provided a correct suggestion.
Figure 2. Explanations of sturdy and wobbly choice selections. This figure illustrated the proportion of children in each condition who provided an incorrect explanation for their choice selection.

**Hypothesis 1: Paired-comparison picture task.** Children's abilities to choose the stronger structure from pairs of photographs were also assessed prior to the demonstration. Overall, the children averaged 2.53 (SD = 1.32) out of 6 pairs correct. A one-sample t-test was used to compare the sample’s mean score with chance performance of 0.50. The results indicate that the sample’s mean was significantly different from chance in making correct selections, $t(39) = 9.70, p < .001$. A one-way ANOVA, however, revealed that there were no significant differences between children in the Engineering Information and Control conditions in their ability to choose the correct photograph, $F(1, 38) = 1.77, p = .19$. Specifically, children in the Engineering Information condition ($M = 2.80, SD = 1.24$) did not differ significantly from those in the Control condition ($M = 2.25, SD = 1.37$) in their ability to identify strong structures. There were no main or interactive effects of gender ($F$s < .36, $ps \geq .56$).
In sum, there were no differences between the two conditions with regard to children’s choice of the wobbliest and sturdiest structures, their explanations for their wobbliest selection, or their ability to choose the stronger structure from pairs of photographs. Children in the Control group tended to give more correct explanations for their sturdiest selections and tended to give more correct suggestions for how to fix the wobbliest skyscraper. Nevertheless, random assignment generally worked to balance any differences in prior knowledge across conditions.

**Final Structures**

**Hypothesis 2: Building behaviors.** The second hypothesis concerned how the provision of engineering information prior to engaging in the building activity influenced dyads’ building behaviors. Specifically, it was expected that mother-child dyads in the Engineering Information condition would build sturdier structures than those in the Control condition. A series of one-way analyses of variance (ANOVAs) were conducted to test this hypothesis. As shown in Table 2, results revealed that children in the Engineering Information condition \( M = 2.35, SD = 1.95 \) constructed sturdier structures with more functional pieces than those in the Control condition \( M = 1.00, SD = 1.81 \), \( F(1, 38) = 5.15, p < .05 \). Additionally, the Engineering Information group \( M = .13, SD = .11 \) had a higher ratio of functional-to-total-pieces than the Control group \( M = .05, SD = .10 \), \( F(1, 38) = 5.02, p < .05 \). Moreover, families in the Control condition \( M = .85, SD = 1.35 \) included more decorative triangles than those in the Engineering Information condition \( M = .15, SD = .49 \), \( F(1, 38) = 4.76, p < .05 \). As also shown in Table 2, dyads in the two conditions did not differ in the total number of building materials used, \( F(1, 38) = .62, p = .44 \); nor did they differ in the number of stories built, \( F(1, 38) = .00, p = .
1.00, suggesting similarities in the structures that were constructed. In sum, although families in the two conditions built similar structures with regard to the number of stories and the number of materials used, those in the Engineering Information condition built sturdier structures than those in the Control condition.

Table 2. Means for Total Pieces, Number of Stories, Number of Decorative Pieces, Number of Functional Pieces and Sturdiness of Final Structures by Experimental Condition

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Engineering Information</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of pieces</td>
<td>18.90 (5.44)</td>
<td>20.40 (6.60)</td>
</tr>
<tr>
<td>Number of stories</td>
<td>1.60 (.68)</td>
<td>1.60 (.75)</td>
</tr>
<tr>
<td>Number of decorative triangles</td>
<td>.15 (.49)</td>
<td>.85 (1.35)</td>
</tr>
<tr>
<td>Number of functional pieces</td>
<td>2.35 (1.95)</td>
<td>1.00 (1.80)</td>
</tr>
<tr>
<td>Ratio of functional-to-total-pieces</td>
<td>.13 (.11)</td>
<td>.05 (.10)</td>
</tr>
</tbody>
</table>

*Note.* Standard deviations in parentheses.

**Conversations in the Exhibit**

**Hypothesis 3: STEM talk.** Providing families with engineering information before the building activity was expected to influence not only their building behaviors, but also their conversations. In other words, mother-child dyads in the Engineering Information condition were also hypothesized to have conversations richer in STEM-related content than those in the Control condition. To test this hypothesis, one-way ANOVAs were conducted, one for each dependent measure (i.e., scientific method, technology, engineering, and mathematics talk), separate for mothers and children. In contrast to the third hypothesis, as shown in Table 3, mothers in the two conditions did
not differ in their scientific method, technology, engineering, or mathematics talk (all $F \leq .20$, $p \geq .65$). Similarly, as shown in Table 4, children in the Engineering Information and Control conditions did not differ in their scientific method, engineering, and mathematics talk ($F$s $\leq .54$, $p \geq .47$). Children in the Control condition ($M = 2.00$, $SD = 1.92$), however, tended to talk more about technology than those in the Engineering Information condition ($M = 1.00$, $SD = 1.45$), $F(1, 38) = 3.46$, $p = .07$.

Another step in the analysis of the mother-child conversations in the exhibit was to investigate whether there were any differences in non-STEM related talk between dyads in the Engineering Information and Control conditions. Specifically, a series of one-way ANOVAs examined whether dyads in the two conditions differed in how directive they were, and the use of evaluations, engagement invitations, talk about time, placeholders, and repetitions. As shown in the bottom portion of Table 3, mothers in the two conditions did not differ significantly in their directing physical action talk, evaluations, engagement invitations, placeholders, or repetitions ($F$s $\leq .62$, $p \geq .44$). Children’s age was significantly related to mothers’ talk about time to complete the building project in the exhibit, $F(1, 27) = 6.10$, $p < .05$, and with this covariate, the main effect of condition was also significant, $F(1, 37) = 5.30$, $p < .05$, such that mothers in the Control condition ($M = 7.90$, $SD = 5.15$) talked significantly more about time than those in the Engineering Information condition ($M = 4.60$, $SD = 3.73$). As shown in the bottom portion of Table 4, children in the Engineering Information and Control conditions did not differ in directing physical action talk, use of evaluations, requests for help, placeholders, talk about time, or repetitions ($F$s $\leq .72$, $p \geq .40$).
<table>
<thead>
<tr>
<th>Dependent Measure</th>
<th>$df$</th>
<th>$F$</th>
<th>$p$-value</th>
<th>Information $M$ ($SD$)</th>
<th>Control $M$ ($SD$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>1, 38</td>
<td>.01</td>
<td>.94</td>
<td>18.45 (8.44)</td>
<td>18.20 (11.37)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 38</td>
<td>.01</td>
<td>.93</td>
<td>6.30 (5.39)</td>
<td>6.15 (5.20)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 38</td>
<td>.08</td>
<td>.78</td>
<td>12.20 (6.73)</td>
<td>12.90 (8.94)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 37</td>
<td>.44</td>
<td>.51</td>
<td>5.50 (3.15)</td>
<td>6.05 (4.44)</td>
</tr>
<tr>
<td>Associations to the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>1, 38</td>
<td>.71</td>
<td>.41</td>
<td>1.30 (1.69)</td>
<td>.90 (1.29)</td>
</tr>
<tr>
<td>Associations to General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1, 37</td>
<td>1.14</td>
<td>.29</td>
<td>.20 (.41)</td>
<td>.60 (1.27)</td>
</tr>
<tr>
<td>Directing Physical Actions</td>
<td>1, 38</td>
<td>.62</td>
<td>.44</td>
<td>18.05 (8.71)</td>
<td>20.50 (10.79)</td>
</tr>
<tr>
<td>Evaluations</td>
<td>1, 37</td>
<td>.44</td>
<td>.51</td>
<td>13.60 (10.50)</td>
<td>15.30 (10.80)</td>
</tr>
<tr>
<td>Engagement</td>
<td>1, 38</td>
<td>.16</td>
<td>.69</td>
<td>5.80 (5.58)</td>
<td>5.15 (4.59)</td>
</tr>
<tr>
<td>Placeholders</td>
<td>1, 38</td>
<td>.00</td>
<td>.96</td>
<td>4.50 (3.13)</td>
<td>4.55 (3.68)</td>
</tr>
<tr>
<td>Time</td>
<td>1, 38</td>
<td>5.38</td>
<td>.03</td>
<td>4.60 (3.73)</td>
<td>7.90 (5.15)</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1, 38</td>
<td>.47</td>
<td>.50</td>
<td>7.05 (5.41)</td>
<td>5.85 (5.62)</td>
</tr>
</tbody>
</table>
Table 4. Summary of the ANOVAs for Children's Talk in the Exhibit

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>df</th>
<th>$F$</th>
<th>$p$-value</th>
<th>Information M (SD)</th>
<th>Control M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific Method</td>
<td>1, 38</td>
<td>.03</td>
<td>.88</td>
<td>4.90 (3.82)</td>
<td>4.70 (4.22)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 38</td>
<td>3.46</td>
<td>.07</td>
<td>1.00 (1.45)</td>
<td>2.00 (1.92)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 38</td>
<td>.54</td>
<td>.47</td>
<td>2.35 (2.37)</td>
<td>2.95 (2.80)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 36</td>
<td>.96</td>
<td>.33</td>
<td>1.74 (1.45)</td>
<td>2.00 (2.36)</td>
</tr>
<tr>
<td>Associations to the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>1, 38</td>
<td>2.13</td>
<td>.15</td>
<td>.30 (.73)</td>
<td>.05 (.22)</td>
</tr>
<tr>
<td>Associations to General</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1, 38</td>
<td>.00</td>
<td>1.00</td>
<td>.20 (.41)</td>
<td>.20 (62)</td>
</tr>
<tr>
<td>Directing Physical Actions</td>
<td>1, 38</td>
<td>.04</td>
<td>.85</td>
<td>8.40 (5.92)</td>
<td>8.10 (3.88)</td>
</tr>
<tr>
<td>Evaluations</td>
<td>1, 38</td>
<td>.72</td>
<td>.40</td>
<td>5.40 (4.21)</td>
<td>6.50 (3.99)</td>
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<tr>
<td>Help</td>
<td>1, 38</td>
<td>.12</td>
<td>.74</td>
<td>1.75 (2.49)</td>
<td>1.50 (2.14)</td>
</tr>
<tr>
<td>Placeholders</td>
<td>1, 38</td>
<td>.01</td>
<td>.93</td>
<td>1.95 (1.47)</td>
<td>1.90 (2.13)</td>
</tr>
<tr>
<td>Time</td>
<td>1, 38</td>
<td>.04</td>
<td>.85</td>
<td>5.20 (4.64)</td>
<td>4.95 (3.73)</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1, 28</td>
<td>.66</td>
<td>.42</td>
<td>1.90 (2.51)</td>
<td>2.55 (2.54)</td>
</tr>
</tbody>
</table>

To summarize, the hypothesis regarding STEM talk was not supported. Mothers in the Engineering Information and Control conditions did not differ in STEM talk. Similarly, children in the two conditions did not differ in their talk about the scientific
method, engineering, or mathematics. However, children in the Control condition tended to talk more about technology than those in the Engineering Information condition.

**Hypothesis 4: Associative talk.** Additional one-way ANOVAs examined whether providing families with engineering information increased their associative talk during the building activity. The analyses focused on mothers’ and children’s use of (a) associations to the pre-exhibit demonstration, and (b) associations to their general knowledge. Means for mothers’ and children’s associative talk are shown in the middle portions of Tables 3 and 4, respectively. As shown, in contrast to the fourth hypothesis, mothers and children in the Engineering Information and Control conditions did not differ in their use of associations while in the exhibit ($p \geq .15$).

**Immediate Assessment of Learning and Transfer**

A measure of immediate learning and transfer involved an assessment of children’s abilities to choose the sturdiest bridge from pairs of photographs, with the correct choice in each pair being a bridge that included triangles, diagonal braces, or cross braces. Overall, the children averaged 1.80 ($SD = 1.11$) out of 3 pairs correct. A one-sample t-test was used to compare the children’s mean score with chance performance of 0.50. This analysis indicated that the children’s selection of the correct items from the pairs was statistically different from chance, $t(39) = 7.38$, $p < .001$. Nevertheless, a one-way ANOVA revealed that children in the Engineering Information ($M = 1.85$, $SD = 1.18$) and Control ($M = 1.75$, $SD = 1.07$) conditions did not differ significantly in their ability to identify strong bridges, $F(1, 38) = .08$, $p = .78$. Therefore, although children performed above chance, there were no significant differences between
those in the Engineering Information and Control conditions with regard to their ability to generalize their knowledge across contexts, tasks, and materials as assessed on the photo task.

Memory Conversations

Recall that mother-child dyads were asked to record memory conversations approximately 1-day and 2-weeks after the museum visit. Of the 26 mother-child dyads who participated in the museum-based portion of this study, 26 (65%) recorded a conversation approximately 1 day after their visit, and 22 (55%) recorded a conversation approximately 2 weeks later; 22 of the families recorded conversations at both intervals. The first memory conversation occurred on average 2.88 days (range 0 – 26 days) after the museum visit; the second conversations occurred on average 20.86 days (range 12 days – 45 days) after the museum visit.

Because of the drop in sample size, it was important to determine if those who participated in the memory portion of this study differed from those who did not participate. As shown in Tables 5 and 6, respectively, families who did and did not participate in the memory portion of the study were not significantly different from one another on any of the demographic measures (ps ≥ .11) or measures of children’s talk in the exhibit (ps ≥ .18). However, mothers who recorded memory conversations (M = 16.85, SD = 7.81) were less directive than those who did not (M = 23.79, SD = 11.61), F(1, 38) = 5.08, p < .05. Furthermore, mothers who recorded conversations (M = 3.62, SD = 2.43) used fewer placeholders in the exhibit than those who did not record conversations (M = 6.21, SD = 4.25), F(1, 38) = 6.11, p < .05. Importantly, as shown in
Table 7, dyads who recorded conversations were not significantly different on any of the other measures of mothers’ talk in the exhibit from those who did not. With regard to the skyscrapers they built in the exhibit, as shown in Table 8, mother-child dyads who participated in the memory portion of the study ($M = .06, SD = .08$) built less sturdier structures than those who did not ($M = .14, SD = .14$), as suggested by their lower ratio of functional-to-total-pieces, $F(1, 38) = 4.56, p < .05$.

Table 5. Families who Recorded a Memory Conversation at the 1-day Delay Compared to Those who did not: Demographics

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Recorded M (SD)</th>
<th>Not Recorded M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mothers' prior engineering knowledge</td>
<td>1, 38</td>
<td>1.02</td>
<td>.32</td>
<td>2.46 (1.45)</td>
<td>2.00 (1.24)</td>
</tr>
<tr>
<td>Mothers' interest in building</td>
<td>1, 38</td>
<td>2.67</td>
<td>.11</td>
<td>2.89 (1.53)</td>
<td>2.07 (1.44)</td>
</tr>
<tr>
<td>Mothers' education</td>
<td>1, 37</td>
<td>.56</td>
<td>.46</td>
<td>16.46 (1.73)</td>
<td>16.00 (2.00)</td>
</tr>
<tr>
<td>Other parent's education</td>
<td>1, 27</td>
<td>1.43</td>
<td>.24</td>
<td>17.36 (2.65)</td>
<td>16.00 (2.58)</td>
</tr>
<tr>
<td>Income</td>
<td>1, 37</td>
<td>1.19</td>
<td>.28</td>
<td>4.42 (1.30)</td>
<td>3.85 (1.99)</td>
</tr>
<tr>
<td>Children's prior engineering knowledge</td>
<td>1, 38</td>
<td>1.40</td>
<td>.24</td>
<td>2.00 (1.06)</td>
<td>1.57 (1.16)</td>
</tr>
<tr>
<td>Children' interest in building</td>
<td>1, 38</td>
<td>2.40</td>
<td>.13</td>
<td>3.96 (1.61)</td>
<td>3.14 (1.56)</td>
</tr>
<tr>
<td>Children's age</td>
<td>1, 38</td>
<td>.53</td>
<td>.47</td>
<td>5.82 (.65)</td>
<td>5.96 (.47)</td>
</tr>
</tbody>
</table>
Table 6. Families who Recorded a Memory Conversation at the 1-day Delay Compared to Those who did not: Children’s Talk in the Exhibit

<table>
<thead>
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<th></th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Recorded M (SD)</th>
<th>Not Recorded M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Method</td>
<td>1, 38</td>
<td>.87</td>
<td>.36</td>
<td>5.23 (4.40)</td>
<td>4.00 (3.01)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 38</td>
<td>1.79</td>
<td>.19</td>
<td>1.23 (1.53)</td>
<td>2.00 (2.08)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 38</td>
<td>1.72</td>
<td>.20</td>
<td>3.04 (2.92)</td>
<td>1.93 (1.64)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 38</td>
<td>1.03</td>
<td>.32</td>
<td>2.08 (1.70)</td>
<td>1.43 (2.31)</td>
</tr>
<tr>
<td>Associations to the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>1, 38</td>
<td>.07</td>
<td>.79</td>
<td>.19 (.63)</td>
<td>.14 (.36)</td>
</tr>
<tr>
<td>Associations to General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1, 38</td>
<td>.26</td>
<td>.61</td>
<td>.23 (.51)</td>
<td>.14 (.53)</td>
</tr>
<tr>
<td>Directing Physical</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actions</td>
<td>1, 38</td>
<td>.82</td>
<td>.37</td>
<td>8.77 (5.16)</td>
<td>7.29 (4.53)</td>
</tr>
<tr>
<td>Evaluations</td>
<td>1, 38</td>
<td>.03</td>
<td>.86</td>
<td>6.04 (4.38)</td>
<td>5.79 (3.64)</td>
</tr>
<tr>
<td>Help/Engagement</td>
<td>1, 38</td>
<td>1.26</td>
<td>.27</td>
<td>1.92 (2.59)</td>
<td>1.07 (1.54)</td>
</tr>
<tr>
<td>Placeholders</td>
<td>1, 38</td>
<td>.31</td>
<td>.58</td>
<td>1.81 (1.60)</td>
<td>2.14 (2.18)</td>
</tr>
<tr>
<td>Time</td>
<td>1, 38</td>
<td>1.89</td>
<td>.18</td>
<td>5.73 (4.39)</td>
<td>3.86 (3.53)</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1, 38</td>
<td>1.16</td>
<td>.29</td>
<td>2.54 (2.76)</td>
<td>1.64 (1.95)</td>
</tr>
<tr>
<td>Total OEQs</td>
<td>1, 38</td>
<td>.39</td>
<td>.54</td>
<td>3.65 (3.51)</td>
<td>3.00 (2.35)</td>
</tr>
<tr>
<td>Total YNQs</td>
<td>1, 38</td>
<td>.15</td>
<td>.71</td>
<td>3.73 (4.50)</td>
<td>3.21 (3.19)</td>
</tr>
<tr>
<td>Total Statements</td>
<td>1, 38</td>
<td>1.55</td>
<td>.22</td>
<td>40.42 (17.58)</td>
<td>33.14 (17.72)</td>
</tr>
</tbody>
</table>
Table 7. Families who Recorded a Memory Conversation at the 1-day Delay Compared to Those who did Not: Mothers’ Talk in the Exhibit

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>F (p-value)</th>
<th>Recorded M (SD)</th>
<th>Not Recorded M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific method</td>
<td>1, 38</td>
<td>2.65 (.11)</td>
<td>20.15 (8.99)</td>
<td>14.93 (10.88)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 38</td>
<td>.88 (.35)</td>
<td>5.65 (5.07)</td>
<td>7.29 (5.54)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 38</td>
<td>1.50 (.23)</td>
<td>13.65 (8.32)</td>
<td>10.50 (6.56)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 38</td>
<td>3.88 (.06)</td>
<td>6.62 (3.73)</td>
<td>4.21 (3.58)</td>
</tr>
<tr>
<td>Associations to the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>1, 38</td>
<td>.02 (.90)</td>
<td>1.08 (1.70)</td>
<td>1.14 (1.10)</td>
</tr>
<tr>
<td>Associations to General</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1, 38</td>
<td>.69 (.41)</td>
<td>.31 (.62)</td>
<td>.57 (1.40)</td>
</tr>
<tr>
<td>Directing Physical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actions</td>
<td>1, 38</td>
<td>5.08 (.03)</td>
<td>16.85 (7.81)</td>
<td>23.79 (11.61)</td>
</tr>
<tr>
<td>Evaluations</td>
<td>1, 38</td>
<td>.50 (.48)</td>
<td>13.58 (11.44)</td>
<td>16.07 (8.84)</td>
</tr>
<tr>
<td>Help/Engagement</td>
<td>1, 38</td>
<td>.00 (.98)</td>
<td>5.46 (5.27)</td>
<td>5.50 (4.82)</td>
</tr>
<tr>
<td>Placeholders</td>
<td>1, 38</td>
<td>6.11 (.02)</td>
<td>3.62 (2.43)</td>
<td>6.21 (4.25)</td>
</tr>
<tr>
<td>Time</td>
<td>1, 38</td>
<td>.76 (.39)</td>
<td>5.77 (4.24)</td>
<td>7.14 (5.63)</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1, 38</td>
<td>1.29 (.26)</td>
<td>5.73 (5.27)</td>
<td>7.79 (5.81)</td>
</tr>
<tr>
<td>Total OEQs</td>
<td>1, 38</td>
<td>2.23 (.14)</td>
<td>12.00 (9.82)</td>
<td>7.43 (7.99)</td>
</tr>
<tr>
<td>Total YNQs</td>
<td>1, 38</td>
<td>.52 (.48)</td>
<td>21.69 (11.98)</td>
<td>18.64 (11.16)</td>
</tr>
<tr>
<td>Total statements</td>
<td>1, 38</td>
<td>1.82 (.19)</td>
<td>75.23 (33.29)</td>
<td>90.36 (34.81)</td>
</tr>
</tbody>
</table>
Table 8. Families who Recorded a Memory Conversation at the 1-Day Delay Compared to Those who did not: Final Structures

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>F</th>
<th>p- value</th>
<th>Recorded</th>
<th>Recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of pieces</td>
<td>1, 38</td>
<td>.19</td>
<td>.67</td>
<td>19.35 (5.00)</td>
<td>20.21 (7.76)</td>
</tr>
<tr>
<td>Number of stories</td>
<td>1, 38</td>
<td>.03</td>
<td>.85</td>
<td>1.62 (.57)</td>
<td>1.57 (.94)</td>
</tr>
<tr>
<td>Number of decorative triangles</td>
<td>1, 38</td>
<td>.10</td>
<td>.76</td>
<td>.46 (.99)</td>
<td>.57 (1.22)</td>
</tr>
<tr>
<td>Number of functional pieces</td>
<td>1, 38</td>
<td>3.31</td>
<td>.08</td>
<td>1.27 (1.56)</td>
<td>2.43 (2.47)</td>
</tr>
<tr>
<td>Ratio of functional-to-total-pieces</td>
<td>1, 38</td>
<td>4.56</td>
<td>.04</td>
<td>.06 (.08)</td>
<td>.14 (.14)</td>
</tr>
</tbody>
</table>

The analyses of the memory conversations were first conducted separately for each delay interval. Then, in order to assess group differences in mother-child talk over the two delay intervals, a series of repeated measures analyses were conducted. There were two main reasons for conducting the analyses separately. First, not all families who recorded the first conversation also recorded the second conversations, and so the repeated measures analyses focus on a reduced sample size. In contrast, the separate analyses focused on all the memory data at each delay interval. Second, in addition to considering the effect of time on dyads’ memory reports, the study also aimed to determine whether the experimental manipulation had an effect on children’s memory reports at each individual time point.
Conversation 1: 1-Day after the museum visit. Each of the analyses reported below was first run with number of days from the museum visit as a covariate. Covariance analyses are reported only when the covariate significantly predicted the dependent measure.

Tables 9 and 10 display the $F$-values, $p$-values, means, and standard deviations for mothers’ and children’s content recall at the 1-day delay, respectively. At the 1-day delay, there was a marginally significant main effect of condition for mothers’ scientific method talk in the memory conversation, $F(1, 24) = 3.74, p = .07$. Mothers in the Control condition ($M = 1.50, SD = 2.11$) tended to talk more about the scientific method than those in the Engineering Information condition ($M = .36, SD = .63$). As shown in Table 9, there were no differences by condition for any of the other memory talk measures ($ps \geq .12$).

There was a significant main effect of condition for children’s talk about technology information in the memory conversations, $F(1, 24) = 10.58, p < .01$. Children in the Control condition ($M = 1.25, SD = 1.22$) included significantly more technology information in their talk during the memory conversation than those in the Engineering Information condition ($M = .14, SD = .36$). As shown in Table 10, no other significant differences in content recall were found between children in the Control and Engineering Information conditions ($ps \geq .10$).
Table 9. Summary of the ANOVAs for Mothers' Recall at the 1-Day Delay

<table>
<thead>
<tr>
<th>Recall Measure</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Information M (SD)</th>
<th>Control M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Method</td>
<td>1, 24</td>
<td>3.74</td>
<td>.07</td>
<td>.36 (.63)</td>
<td>1.50 (2.11)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 24</td>
<td>.01</td>
<td>.93</td>
<td>.71 (1.07)</td>
<td>.75 (.97)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 24</td>
<td>.01</td>
<td>.93</td>
<td>2.00 (2.22)</td>
<td>2.08 (2.54)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 24</td>
<td>.01</td>
<td>.93</td>
<td>1.57 (2.06)</td>
<td>1.50 (1.68)</td>
</tr>
<tr>
<td>Associations to the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>1, 24</td>
<td>1.02</td>
<td>.32</td>
<td>.57 (.94)</td>
<td>.25 (.62)</td>
</tr>
<tr>
<td>Associations to General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1, 24</td>
<td>.11</td>
<td>.74</td>
<td>1.07 (1.64)</td>
<td>1.33 (2.39)</td>
</tr>
<tr>
<td>Demonstration: Triangles</td>
<td>1, 24</td>
<td>2.44</td>
<td>.13</td>
<td>.78 (.80)</td>
<td>.33 (.65)</td>
</tr>
<tr>
<td>Demonstration: General</td>
<td>1, 24</td>
<td>1.75</td>
<td>.20</td>
<td>4.79 (4.06)</td>
<td>3.08 (1.98)</td>
</tr>
<tr>
<td>Building Activity</td>
<td>1, 24</td>
<td>2.64</td>
<td>.12</td>
<td>3.57 (2.41)</td>
<td>2.33 (1.15)</td>
</tr>
<tr>
<td>Affect</td>
<td>1, 24</td>
<td>1.79</td>
<td>.19</td>
<td>1.86 (1.56)</td>
<td>1.00 (1.71)</td>
</tr>
<tr>
<td>Time</td>
<td>1, 24</td>
<td>.89</td>
<td>.36</td>
<td>.50 (.85)</td>
<td>.92 (1.38)</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1, 24</td>
<td>.65</td>
<td>.43</td>
<td>3.93 (2.97)</td>
<td>3.08 (2.23)</td>
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</table>
Table 10. Summary of the ANOVAs for Children's Recall at the 1-Day Delay

<table>
<thead>
<tr>
<th>Recall Measure</th>
<th>$df$</th>
<th>$F$</th>
<th>$p$-value</th>
<th>$M (SD)$</th>
<th>$M (SD)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Method</td>
<td>1, 24</td>
<td>.27</td>
<td>.61</td>
<td>.29 (.61)</td>
<td>.42 (.67)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 24</td>
<td>10.58</td>
<td>.003</td>
<td>.14 (.36)</td>
<td>1.25 (1.22)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 24</td>
<td>1.08</td>
<td>.31</td>
<td>1.43 (1.65)</td>
<td>2.33 (2.74)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 24</td>
<td>.88</td>
<td>.36</td>
<td>1.21 (1.89)</td>
<td>2.00 (2.37)</td>
</tr>
<tr>
<td>Associations to the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>1, 24</td>
<td>.81</td>
<td>.38</td>
<td>.21 (.43)</td>
<td>.08 (.29)</td>
</tr>
<tr>
<td>Associations to General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1, 24</td>
<td>.08</td>
<td>.79</td>
<td>.93 (1.86)</td>
<td>.75 (1.36)</td>
</tr>
<tr>
<td>Demonstration: Triangles</td>
<td>1, 24</td>
<td>3.01</td>
<td>.10</td>
<td>.71 (.83)</td>
<td>.25 (.45)</td>
</tr>
<tr>
<td>Demonstration: General</td>
<td>1, 24</td>
<td>.00</td>
<td>.95</td>
<td>3.00 (4.24)</td>
<td>2.93 (2.11)</td>
</tr>
<tr>
<td>Building Activity</td>
<td>1, 24</td>
<td>.34</td>
<td>.57</td>
<td>2.79 (2.81)</td>
<td>2.25 (1.60)</td>
</tr>
<tr>
<td>Affect</td>
<td>1, 24</td>
<td>2.38</td>
<td>.14</td>
<td>.86 (.86)</td>
<td>.42 (.51)</td>
</tr>
<tr>
<td>Time</td>
<td>1, 24</td>
<td>.88</td>
<td>.36</td>
<td>.29 (.83)</td>
<td>.67 (1.23)</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1, 24</td>
<td>.11</td>
<td>.75</td>
<td>1.86 (1.29)</td>
<td>1.67 (1.67)</td>
</tr>
</tbody>
</table>

**Conversation 2: 2-Weeks after the museum visit.** Again, each of the analyses reported below was first run with number of days from the museum visit that this conversation occurred as a covariate. Table 11 lists the F-values, p-values, means, and
standard deviations for mothers’ recall at the 2-week delay. Results revealed that there was a significant main effect of condition for mothers’ engineering talk, $F(1, 20) = 6.72$, $p < .05$. As shown in the table, mothers in the Engineering Information condition ($M = 2.55, SD = 2.46$) talked more about engineering during the memory conversation than those in the Control condition ($M = .55, SD = .69$). No other differences by condition for mothers’ talk during the memory conversation were found ($p_s \geq .18$).

As illustrated in Table 12, after the 2-week delay, children in the Engineering Information condition ($M = .45, SD = .69$) provided significantly more pieces of information about the scientific method than those in the Control condition ($M = .00, SD = .00$), $F(1, 20) = 4.81$, $p < .05$. Additionally, the main effect of condition for children’s engineering talk during the memory conversation was also significant, $F(1, 20) = 4.41$, $p < .05$. Specifically, children in the Engineering Information condition ($M = 2.45, SD = 2.11$) provided more engineering information than those in the Control condition ($M = 1.00, SD = .89$). Furthermore, there was a marginally significant difference between conditions in children’s talk about the pre-exhibit demonstration, $F(1, 20) = 3.33$, $p = .08$. That is, children in the Engineering Information condition ($M = .73, SD = .90$) tended to talk more about the function of triangles than those in the Control condition ($M = .18, SD = .40$). No other significant differences by condition for children’s talk at this time point were found ($p_s \geq .25$).
Table 11. Summary of the ANOVAs for Mothers’ Recall at the 2-Week Delay

<table>
<thead>
<tr>
<th>Recall Measure</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Information M (SD)</th>
<th>Control M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Method</td>
<td>1</td>
<td>1.91</td>
<td>.18</td>
<td>.45 (.82)</td>
<td>.09 (.30)</td>
</tr>
<tr>
<td>Technology</td>
<td>1</td>
<td>1.82</td>
<td>.19</td>
<td>1.00 (1.26)</td>
<td>.36 (.92)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1</td>
<td>6.72</td>
<td>.02</td>
<td>2.55 (2.46)</td>
<td>.55 (.69)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1</td>
<td>1.10</td>
<td>.31</td>
<td>1.73 (2.41)</td>
<td>.91 (.94)</td>
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<td>Associations to the</td>
<td></td>
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<tr>
<td>Demonstration</td>
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</tr>
<tr>
<td>Associations to General</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>1</td>
<td>.02</td>
<td>.88</td>
<td>.55 (1.21)</td>
<td>.63 (1.50)</td>
</tr>
<tr>
<td>Demonstration: Triangles</td>
<td>1</td>
<td>.45</td>
<td>.51</td>
<td>.45 (1.21)</td>
<td>.18 (.60)</td>
</tr>
<tr>
<td>Demonstration: General</td>
<td>1</td>
<td>1.22</td>
<td>.28</td>
<td>4.73 (4.84)</td>
<td>3.00 (1.90)</td>
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<tr>
<td>Building Activity</td>
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<td>.01</td>
<td>.93</td>
<td>2.91 (1.51)</td>
<td>3.00 (2.76)</td>
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<tr>
<td>Affect</td>
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<td>.03</td>
<td>.87</td>
<td>1.09 (1.04)</td>
<td>1.18 (1.40)</td>
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<tr>
<td>Time</td>
<td>1</td>
<td>.24</td>
<td>.63</td>
<td>.55 (1.04)</td>
<td>.36 (.67)</td>
</tr>
<tr>
<td>Repetitions</td>
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<td>.39</td>
<td>.54</td>
<td>1.45 (1.75)</td>
<td>2.18 (3.46)</td>
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</table>
Table 12. Summary of the ANOVAs for Children's Recall at the 2-Week Delay

<table>
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<tr>
<th>Recall Measure</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Information M (SD)</th>
<th>Control M (SD)</th>
</tr>
</thead>
<tbody>
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<td>Scientific Method</td>
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<td>4.81</td>
<td>.04</td>
<td>.45 (.69)</td>
<td>.00 (.00)</td>
</tr>
<tr>
<td>Technology</td>
<td>1, 20</td>
<td>1.03</td>
<td>.32</td>
<td>.82 (1.33)</td>
<td>.36 (.67)</td>
</tr>
<tr>
<td>Engineering</td>
<td>1, 20</td>
<td>4.41</td>
<td>.049</td>
<td>2.45 (2.11)</td>
<td>1.00 (.89)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1, 20</td>
<td>.40</td>
<td>.54</td>
<td>1.64 (1.63)</td>
<td>1.27 (1.01)</td>
</tr>
</tbody>
</table>

Associations to the

Demonstration  --  --  --  --  --  --

Associations to General

Knowledge       1, 20 | .26  | .62  | .91 (2.02) | .55 (1.21) |
Demonstration: Triangles  1, 20 | 3.33 | .08  | .73 (.90)  | .18 (.40)  |
Demonstration: General    1, 20 | .01  | .94  | 2.91 (3.62) | 2.82 (1.83) |
Building Activity  1, 20 | .20  | .66  | 1.64 (1.43) | 1.36 (1.43) |
Affect            1, 20 | 1.39 | .25  | .73 (1.19)  | .27 (.47)   |
Time              1, 20 | .24  | .63  | .55 (.82)   | .36 (.92)   |
Repetitions       1, 20 | .82  | .38  | 1.82 (1.72) | 1.27 (1.01) |

**Differences in dyads’ memories with time.** Another step in the analysis of the reminiscing conversations was to determine whether there was an effect of delay interval on children’s recall. A series of repeated measures analyses were conducted separately
for mothers and children. Each of these analyses was first run with the number of days from museum visit when the first conversations occurred and then with the number of days from museum visit when the second conversation occurred as covariates. Table 13 summarizes the results of the repeated measures analyses for children’s memory reports. As shown in the top portion of the table, the main effect of delay on children’s talk about the scientific method ($p = .48$), technology ($p = .63$), engineering ($p = 1.00$), and mathematics ($p = .51$) information was not statistically significant. These findings suggest that there were no significant changes in children’s provision of these types of information in the memory conversations over time. Furthermore, the Delay x Condition interactions for children’s scientific method ($p = .17$) and mathematics talk ($p = .27$) were not statistically significant. However, there was a significant Delay x Condition interaction predicting children’s talk about technology, $F(1, 20) = 7.85, p < .05$, indicating that the relation between delay and children’s technology talk depended on experimental condition. Simple effect tests were conducted to determine the nature of the significant Delay x Condition interaction. More specifically, two one-way within subject ANOVAs were conducted comparing the simple main effect of delay on children’s talk about technology information in the Engineering Information and Control conditions. As shown in Figure 3, the first analysis revealed that for children in the Engineering Information condition their 1-day ($M = .18, SD = .40$) and 2-week delay ($M = .82, SD = 1.33$) talk about technology information was not significantly different. However, in the Control condition, children talked significantly less about technology information at the 2-week delay ($M = .36, SD = .67$) compared to the 1-day delay ($M = 1.27, SD = 1.27$). The results of this interaction, thus, indicate that children’s talk about technology stayed
the same if they received Engineering Information and decreased if they did not. There was also a marginally significant Delay x Condition interaction predicting children’s talk about engineering, $F(1, 20) = 3.30, p = .08$. Simple effect tests were conducted comparing the simple main effect of delay on children’s talk about engineering principles and concepts. As shown in Figure 4, the analysis revealed that, for children in the Engineering Information condition, there were no significant differences between their talk about engineering at the 1-day delay ($M = 1.64, SD = 1.80$) and 2-week delay ($M = 2.45, SD = 2.11$), $F(1, 10) = 1.55, p = .24$. Similarly, for children in the Control condition, there were no significant differences between children’s talk about engineering information at the 1-day ($M = 1.82, SD = 2.18$) and 2-week delays ($M = 1.00, SD = .89$), $F(1, 10) = 1.77, p = .21$. These results thus suggested that children’s talk about engineering did not change significantly from 1-day to 2-weeks depending on the condition to which they were assigned.

Figure 3. Children’s technology talk over time. This figure illustrates the main effect of delay on children’s talk about technology
In addition to examining whether there were changes in children’s STEM talk from 1-day to 2-weeks, analyses also focused on children’s associative talk during reminiscing. As can be seen in the middle of Table 13, however, children made associations to the demonstration at the 1-day delay ($M = .18, SD = .39$), but they made no associations to the demonstration at the 2-week delay ($M = .00, SD = 0.00$). Given that the memory reports at the 2-week delay contained no associative comments, it was not appropriate to conduct the repeated measures analysis for associations to the demonstration.

Next, the analyses focused on children’s talk about the pre-exhibit demonstration, building activity, affect, time limitations, and the use of repetitions. As illustrated in Table 13, there were no main effects of delay for children’s talk about the pre-exhibit experience ($ps \geq .58$), children’s reminiscing about affect ($p = .63$), time limitations ($p = .77$), or repetitions ($p = .28$). Moreover, there were no significant Delay x Condition
interactions for children’s talk about the pre-exhibit experience ($p$s $\geq .66$), affect ($p = .87$), time ($p = .38$), or repetitions ($p = .78$). Therefore, the relations between delay interval and children’s talk about these content codes did not depend on whether they were in the Engineering Information or Control conditions. There was a main effect of delay on children’s talk about the building activity, $F(1, 20) = 8.12, p < .05$. Children talked less about the building activity at the 2-week delay ($M = 1.50, SD = 1.41$) than at the 1-day delay ($M = 1.91, SD = 2.31$). The Delay x Condition interaction, however, was not statistically significant, $F(1, 20) = .68, p = .42$, suggesting that the relation between delay interval and children’s talk about the building activity did not depend on experimental condition.

Table 13. Summary of the Repeated Measures ANOVAs for Children’s Recall

<table>
<thead>
<tr>
<th>Recall Measure</th>
<th>df</th>
<th>$F$</th>
<th>$p$</th>
<th>$F$</th>
<th>$p$</th>
<th>$F$</th>
<th>$p$</th>
<th>$F$</th>
<th>$p$</th>
<th>$F$</th>
<th>$p$</th>
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<td>.17</td>
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<td>.67</td>
<td>.27</td>
<td>.47</td>
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<tr>
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<td>.25</td>
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<td>.96</td>
<td>.34</td>
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<tr>
<td>Engineering</td>
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<td>1.01</td>
<td>.33</td>
<td>3.30</td>
<td>.08</td>
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<td>1.82</td>
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<td>1, 20</td>
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<td>.51</td>
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<td>.90</td>
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<tr>
<td>Demonstration: Triangles</td>
<td>1, 20</td>
<td>.00</td>
<td>1.00</td>
<td>3.93</td>
<td>.06</td>
<td>.00</td>
<td>1.00</td>
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<td>.79</td>
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<td>1, 20</td>
<td>8.12</td>
<td>.01</td>
<td>1.11</td>
<td>.31</td>
<td>.68</td>
<td>.42</td>
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<td>Affect</td>
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</table>


Table 14 summarizes the results of the repeated measures analyses that focused on mothers’ talk during the memory conversations. Findings revealed no significant main effects of delay interval for mothers’ talk about the scientific method ($p = .48$), technology ($p = .63$), engineering ($p = 1.00$), or mathematics ($p = .51$) information. Moreover, the Delay x Condition interactions were not statistically significant for mothers’ scientific method ($p = .12$), technology ($p = .47$), or mathematics talk ($p = .66$). However, there was a marginally significant Delay x Condition interaction predicting mothers’ engineering talk, $F(1, 20) = 3.72, p = .07$. Simple effect tests were conducted to determine the nature of the marginally significant interaction. That is, two one-way within subject ANOVAs were conducted comparing the simple main effect of delay interval on mothers’ engineering talk in the Engineering Information and Control conditions. As can be seen in Figure 5, for mothers in the Engineering Information condition, talk about engineering information did not change significantly from 1-day ($M = 2.00, SD = 2.37$) to 2-weeks ($M = 2.55, SD = 2.46$), $F(1, 10) = .45, p = .52$. However, for mothers in the Control condition, talk about engineering information tended to decrease from 1-day ($M = 2.09, SD = 2.66$) to 2-weeks ($M = .55, SD = .69$), $F(1, 10) = .46, p = .06$. 
Table 14. Summary of the Repeated Measures ANOVAs for Mothers’ Recall

<table>
<thead>
<tr>
<th>Recall Measure</th>
<th>Time</th>
<th>Condition</th>
<th>Time x Condition</th>
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<th>2-Day Delay</th>
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<td>df</td>
<td>F</td>
<td>p</td>
<td>F</td>
<td>p</td>
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<td>2.62</td>
<td>.12</td>
<td>.22</td>
<td>.64</td>
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<td>Technology</td>
<td>1, 20</td>
<td>.20</td>
<td>.66</td>
<td>1.37</td>
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<td>Engineering</td>
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<td>.85</td>
<td>.37</td>
<td>1.57</td>
<td>.23</td>
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<td>Mathematics</td>
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<td>.81</td>
<td>.38</td>
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<td>Associations to the Demonstration</td>
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<td>7.66</td>
<td>.01</td>
<td>1.58</td>
<td>.22</td>
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<tr>
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<td>1, 20</td>
<td>3.88</td>
<td>.06</td>
<td>.20</td>
<td>.66</td>
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<tr>
<td>Demonstration: Triangles</td>
<td>1, 20</td>
<td>.79</td>
<td>.38</td>
<td>4.38</td>
<td>.049</td>
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<tr>
<td>Demonstration: General</td>
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<td>.15</td>
<td>.70</td>
<td>1.78</td>
<td>.20</td>
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<td>.00</td>
<td>1.00</td>
<td>.56</td>
<td>.46</td>
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<tr>
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<td>8.88</td>
<td>.007</td>
<td>.02</td>
<td>.89</td>
</tr>
</tbody>
</table>

Figure 5. Mothers’ engineering talk over time. This figure illustrates the main effect of delay on mothers’ talk about engineering.

![Figure 5. Mothers’ engineering talk over time.](image)

There was also a significant main effect of delay on mothers’ use of associations to the demonstration, $F(1, 20) = 7.66, p < .05$. Specifically, although mothers made associations to the demonstration while reminiscing 1-day after the museum experience...
(M = .50, SD = .86), they made no such associations at the 2-week delay interval (M = .00, SD = .00). Given that mothers made no associations to the demonstration at the 2-week delay it was not appropriate to conduct the repeated measures analyses for this type of associations. There was, however, a marginally significant main effect of delay on mothers’ use of associations to general knowledge, $F(1, 20) = 3.88, p = .06$. More specifically, mothers tended to make fewer associations to general knowledge at the 2-week delay (M = .59, SD = 1.33) than at the 1-day delay (M = 1.09, SD = 2.04). The Delay x Condition interaction was not significant, $F(1, 20) = .80, p = .38$, suggesting that the relation between delay interval and mothers’ use of associations to general knowledge did not depend on the condition they were in.

Next, the repeated measures analyses focused on mothers’ talk about the pre-exhibit experience, building activity, affect, time limitations, and repetitions. The results indicated that there were no main effects of delay interval on mothers’ talk about the pre-exhibit experience ($ps \geq .38$), building activity ($p = 1.00$), affect ($p = .48$), or time ($p = .37$). Furthermore, findings indicated that the Delay x Condition interactions were not statistically significant (all $Fs \leq 1.32, ps \geq .32$). In other words, the relation between delay interval and mothers’ talk about the pre-exhibit experience, building activity, time limitations, and affect did not depend on whether they were in the Engineering Information or Control conditions. There was a significant main effect of delay on mothers’ use of repetitions, $F(1, 20) = 8.88, p < .01$. That is, mothers used significantly fewer repetitions at the 2-week delay (M = 1.82, SD = 2.70) than 1-day (M = 3.68, SD =
2.80) after the museum experience. The Delay x Condition interactions, however was not statistically significant, $F(1, 20) = 1.91, p = .18$.

Taken together, the analyses of the memory conversations suggest that the provision of engineering information was linked to dyads’ memory reports at the 2-week delay, but not to dyads’ memory reports at the 1-day delay. In contrast to expectations, mothers in the Control condition tended to talk more about the scientific method at the 1-day delay than those in the Engineering Information condition. Similarly, children in the Control condition talked more about technology at the 1-day delay than those in the Engineering Information condition. At the 2-week delay, however, mothers and children in the Engineering Information condition talked more about engineering principles and concepts than those in the Control condition. Furthermore, children in the Engineering Information condition talked more about the scientific method and tended to talk more about the function of triangles. Importantly, mothers’ talk about engineering stayed the same from 1-day to 2-weeks if they were in the Engineering Information condition, but decreased if they were in the Control condition. Likewise, children’s talk about technology stayed the same over time if they received engineering information and decreased if they did not.

**Associations Between Talk in the Exhibit and Children’s Recall**

**Hypothesis 5: Additive effects.** To test the last hypothesis, predicting that children who would have a better understanding of how to build sturdy skyscrapers and who would have richer conversations in the exhibit would provide more pieces of new information during reminiscing at the two time points, a series of bivariate correlations and regression analyses were run. First, bivariate correlations were conducted to
investigate whether there were any associations between the way in which dyads talked in the exhibit and children’s memories of the museum experiences. Results indicated that mothers’ engineering talk during the building activity was positively related to children’s associative talk at the 1-day delay ($r = .45, p < .05$). Specifically, mothers who talked more about engineering principles and concepts while building in the exhibit had children who made more associations to the pre-exhibit demonstration 1-day later. The next step involved examining whether the experimental condition moderated this relationship. A linear regression analysis was used to test for moderation. The regression analysis revealed that the main effect of condition predicting children’s associations to the demonstration at the 1-day delay interval was not significant, $B = -.18, \beta = -.24, t(22) = -1.38, p = .18$. That is, children in the Engineering Information and Control conditions did not differ in the number of associations to the demonstration they made 1-day after the museum experience. The main effect of mothers’ engineering talk predicting children’s associations to the demonstration was significant, $B = .02, \beta = .52, t(22) = 2.98, p < .01$. This pointed out that mothers who talked more about engineering in the exhibit had children who made more associations to the pre-exhibit demonstration 1-day later. The Condition x Mother Engineering Talk interaction was not significant, $B = .01, \beta = .28, t(22) = 1.59, p = .13$. That is, the relationship between mothers’ engineering talk in the museum and children’s associations to the demonstration 1-day later did not depend on the condition to which the children were assigned.

Additionally, it was found that mothers’ associative talk in the museum was positively associated with children’s talk about the scientific method both at the 1-day
delay ($r = .50, p < .01$) and at the 2-week delay interval ($r = .558, p < .01$), and with
current’s engineering talk at the 2-week delay interval ($r = .562, p < .01$). It was noted
that none of the children in the Control condition talked about the scientific method at the
2-week delay interval, and so the moderation analyses for children’s scientific method
talk were not conducted, as it was not statistically appropriate to do so. Two separate
linear regressions, however, were conducted to investigate whether experimental
condition moderated the other two aforementioned relationships.

First, it was examined whether the link between mothers’ associations to the
demonstration and children’s scientific method talk 1-day later was moderated by
experimental condition. Findings indicated that the main effect of condition predicting
children’s scientific method talk was not significant, $B = .22$, $\beta = .23$, $t(22) = .99$, $p = .33$. In other words, children in the Engineering Information and Control conditions did
not differ in how much they talked about the scientific method 1-day after the museum
visit. The main effect of mothers’ associations to the demonstration predicting children’s
scientific talk was significant, $B = .20$, $\beta = .07$ $t(22) = 2.76$, $p < .05$. That is, mothers
who made more associations to the demonstration while in the exhibit had children who
talked more about the scientific method one day later. However, the Condition x Mother
Associative Talk interaction was not significant, $B = -.02$, $\beta = -.06$ $t(22) = -.29$, $p = .78$. This suggested that the relationship between mothers’ associations to the demonstrations
and children’s scientific method at the 1-day delay did not depend on the experimental
condition.
Second, a linear regression analysis was conducted to determine whether the link between mothers’ associations to the demonstration and children’s engineering talk at the 2-week delay interval was moderated by experimental condition. The regression analysis indicated that the main effect of condition was marginally significant, $B = -1.11$, $\beta = -.33$, $t(18) = -1.98$, $p = .06$. The main effect of mothers’ associations to the demonstration predicting children’s engineering talk was significant, $B = .55$, $\beta = .56$, $t(18) = 3.17$, $p < .01$. That is, mothers who made more associations to the demonstration had children who talked more about engineering 2-weeks later. The Condition x Mothers’ Associative Talk interaction was not significant, $B = .11$, $\beta = .11$, $t(18) = .62$, $p = .54$. This indicates that the relationship between mothers’ associations to the demonstration and children’s engineering talk at the 2-week delay interval does not depend on whether children were in the Engineering Information or Control condition.

Overall, these results indicate that the way in which mothers talked to their children in the exhibit was positively associated with their children’s recall 1-day and 2-weeks later. Mothers who talked more about engineering while building had children who made more associations to the demonstration 1 day later. Moreover, mothers who made more associations to the demonstration had children who talked more about the scientific method at both time points and more about engineering 2 weeks later. Importantly, the relation between mothers’ associations to the demonstration and children’s scientific method talk 2 weeks later depended on the experimental condition. Only those children who received engineering information prior to engaging in the
building activity and whose mothers made more associations to the demonstration included information about the scientific method in their memory reports.
CHAPTER FOUR

DISCUSSION

This study involved an experimental design to examine the impact of direct instruction on mother-child interactions in a science-oriented museum exhibit, as well as on children’s learning, transfer abilities, and remembering. More specifically, one aim of this work was to investigate the impact of instructions about simple engineering principles on parent-child conversations in a building exhibit at Chicago Children’s Museum. Another aim was to determine whether providing mother-child dyads with engineering information facilitated their ability to apply that knowledge in a new situation. Lastly, the influence of instructions on children’s long-term recall was assessed. It was expected that the effects of direct instruction and mothers’ style of talk were additive, such that families who received engineering information and had richer conversations in the exhibit would talk more about STEM-related information one day and two weeks after their museum visit.

In order to examine the effectiveness of the direct instructions in fostering talk about STEM, the mother-child conversations during the building activity were analyzed for differences in content talk. Dyads’ abilities to transfer what they learned during the pre-exhibit demonstration to the building activity were assessed through their associative talk in the exhibit, their ability to build a sturdy skyscraper out of plastic building materials, and their ability to identify strong structures from photographs depicting
structures made out of wood. Furthermore, dyads’ reminiscing talk at two time points, 1-day and 2-weeks later, served as a measure of learning and remembering.

The subsections that follow summarize the main findings and provide interpretations of them. Moreover, it is discussed how these findings relate to and extent past work on children’s learning and remembering. The limitations of this work are also discussed and future directions are provided. The discussion ends with a consideration of the broader impacts of this work for museum research and practice.

**Prior Engineering Knowledge**

The first question of interest concerned children’s prior knowledge about building engineering. It was anticipated that children in the Engineering Information and Control conditions would not differ in their prior engineering knowledge. This hypothesis was based on a small but growing body of work, which documented that young children know very little about engineering and key engineering principles, such as structural integrity and cross bracing (e.g., Cunningham et al., 2005; Davis, Ginns, & McRobbie, 2002; Knight & Cunningham, 2004). Consistent with previous findings, the results of this study indicated that children came with very little engineering knowledge to the museum. They were at chance in terms of their abilities to identify wobbly and sturdy skyscrapers, and they were more likely to provide incorrect explanations for their choice selections and incorrect suggestions for how to fix a wobbly skyscraper. The findings regarding children’s knowledge of how to stabilize structures are similar to those of Davis et al. (2002). In their study, when asked for suggestions on how to make a wood bridge more stable, 6-year-olds suggested hammering the nails of the bridge. In this study, children also provided incorrect suggestions, such as adding more materials.
As expected, random assignment created groups that were generally equal in terms of their prior engineering knowledge. Children in the two groups did not differ in their ability to identify wobbly and sturdy skyscrapers made out of straws, to identify sturdy structures from photographs, or in their ability to explain their wobbly selection. However, those in the Control condition tended to provide more correct explanations for their sturdy selection and more correct suggestions for how to fix a wobbly skyscraper. These trend differences were somewhat unexpected given the results of past work and also the findings from this study showing that mothers did not rate children in the two conditions as having different levels of prior engineering knowledge.

**Building Behaviors**

In addition to assessing children’s prior engineering knowledge, a primary question of interest regarded the effectiveness of the brief pre-exhibit engineering instructions on fostering mother-child dyads’ building behaviors in the museum exhibit. It was expected that dyads that received engineering information would build stronger buildings than those who did not receive such information. In support of the hypothesis, results indicated that mother-child dyads that received engineering information constructed sturdier skyscrapers with more triangular cross braces than those who did not receive engineering information. These findings are in line with those of Benjamin et al. (2010), who also found that providing families with building instructions alone enhanced their building abilities.

Importantly, the current study not only confirmed, but also extended Benjamin et al.’s findings. The researchers reported that simply viewing models of structures with triangular braces throughout did not determine families to incorporate them in their
structures. In the present study dyads participated in a live demonstration that highlighted the important role of triangular braces. Specifically, in this study all families were shown that a skyscraper with braces throughout could withstand a strong wind, as created with a leaf blower, whereas skyscrapers without braces could not. However, seeing this demonstration was also not sufficient to foster dyads’ building abilities. It was only the families who were explicitly told about the function of triangular braces that included them in their structures; the other ones did not. Thus, it appears that families need more guidance in order to learn unfamiliar principles, as they cannot extract the essential information from live demonstrations on their own.

**Parent-Child Conversations in the Exhibit**

The influence of the pre-exhibit demonstration on mother-child conversations was also of major interest in this study. It was thought that providing dyads with information about how to build sturdy buildings would foster not only their building behaviors, but also their talk about the scientific method, technology, engineering and mathematics in the exhibit. Counter to expectations, providing mother-child dyads with engineering information did not boost their talk about STEM in the exhibit. In fact, it was the children in the Control condition who tended to talk more about technology than those in the Engineering Information condition. In retrospect, this particular finding is not very surprising when considering the set-up of the museum exhibit. Specifically, all of the building materials are labeled and so in the absence of other relevant information, it appears that children in the Control condition tended to focus on the only information available to them. The availability of labels might have also invited the talk about the function of the materials. Why there were no group differences in scientific method,
engineering, and mathematics talk in the exhibit is not clear. Perhaps the signage in the exhibit might account for these findings. There are now signs in the exhibit that highlight the role of triangles and that teach children other building techniques. For example, one of the signs features nuts and bolts and includes the caption righty-tighty, lefty-loosey, thus teaching children that to tighten the nut they have to turn it in the right direction.

Similar to the results regarding STEM talk in the exhibit, it was found that having more information about how to construct sturdy structures did not results in more talk about non-STEM related information. Mothers and children did not differ in how directive or repetitive they were, or how many evaluations, requests for help, engagement invitations, or placeholders they used while building in the exhibit. Mothers in the Control condition, however, talked more about time than those in the Engineering Information condition. Given that they did not have information about how to build a strong skyscraper, it makes sense that they were concerned about the time they had left.

Taken together, these findings suggest that families needed more explicit prompting to engage in elaborative conversations. Indeed Benjamin et al. (2010) reported that only families who received both building and conversation instruction talked more about building engineering in the exhibit; those who received building instruction alone only showed a trend. As reviewed in the introduction section, past work on parent-child conversations during events has documented that asking lots of Wh-questions, for example, as an event unfolds can foster children’s understanding of the event (e.g., Boland et al., 2003; Hedrick et al., 2009; McGuigan & Salmon, 2006). By asking such questions mothers not only call their children’s attention to the key aspects of the event, but they can also gauge their children’s prior knowledge and current
understanding (e.g., Haden et al., 2001). Mothers in this study were not encouraged to employ elaborative conversational techniques while building in the exhibit. If mothers would have received such information and would have been informed about the potential of such strategies to enhance understanding and learning, they might have used them. Past work has noted that parents can be trained to use such conversational techniques (e.g., Boland et al., 2003; Jant et al., 2013). Future work could assess whether providing families with both engineering information and explicit instructions about elaborative conversational techniques would result in conversations richer in STEM-related content. Benjamin et al. focused on engineering talk, but it would be interesting to examine whether coupling building and conversational instructions could also boost talk about the scientific method, technology, and mathematics. After all it is essential that we identify ways to facilitate children’s problem solving skills, not only their learning of a specific set of instructions.

**Knowledge Transfer**

Another important aim of this study was to investigate whether providing families with engineering information would foster children’s transfer abilities. It was hypothesized that children in the Engineering Information condition would be more likely to generalize their knowledge to new situations than those in the Control condition. The proposed hypothesis was partially supported. As anticipated, dyads in the Engineering Information condition were able to use the knowledge they gained during the pre-exhibit demonstration about triangular bracing to the building activity, as illustrated by the sturdy skyscrapers they constructed. That is, dyads in the Engineering Information condition were able to transfer across contexts (pre-exhibit demonstration room to
building space in the Skyline exhibit) and across building materials (straws to plastic building materials).

However, the children in the two conditions did not differ in their ability to identify the stronger structure from pairs of photographs. In thinking about these unexpected results, it is important to consider that the pictures depicted bridges made out of wood sticks. Thus, this task required children to transfer across structures (skyscraper to bridge), materials (straws to wood), and time (approximately 30 minutes later).

Moreover, in comparison to the building activity, children did not benefit from the help of their parents when working on the paired-comparison task. Previous work focusing on children’s transfer abilities has revealed that transferring across contexts and materials is quite difficult for young children in the absence of extensive training (Blote, Resing, Mazer, & Van Noort, 1999; Spencer & Weisberg, 1986). Past studies have also noted that what children learn in one context often stays “fixed” in that context and that children have a difficult time applying that knowledge to new situations (Brown, Bransford, Ferrara, & Campione, 1983; Tulving & Thomson, 1973). The fact that the building materials were colorful and interesting might have also interfered with children’s abilities to generalize their knowledge across contexts. McNeil and colleagues (2009), for instance, reported that children made more mathematical errors when asked to solve problems with real money than with blank bills.

The expectation that children would be able to transfer their engineering knowledge to new problems was contingent on mothers’ style of talk. Essentially, it was hypothesized that mothers who would make the most associations to prior knowledge would have children with higher transfer skills. Previous studies have highlighted that
associative talk, which involves linking the event under discussion to prior knowledge, can enhance children’s learning and transfer skills (Tessler & Nelson, 1994; Jant et al., 2013). However, in this study, the mothers in the two conditions did not differ in their making of associations to children’s general knowledge or to the pre-exhibit demonstration. Perhaps if the mothers would have connected the building activity in the exhibit to the pre-exhibit demonstration they might have helped their children make such connections on their own. By pointing out that the same engineering principle – cross bracing – worked not only when building with straws but also with plastic building materials, the mothers could have better prepared their children to apply that knowledge when asked to identify the stronger bridges made out of wood. In future work it will be interesting to investigate whether associative talk during initial encoding could facilitate children’s transfer abilities.

**Memory Conversations**

In a further attempt to determine the influence of direct instruction on children’s learning, mother-child dyads were invited to record memory conversations 1-day after the museum visit and 2-weeks later.

**One-day Delay**

Results revealed no differences in terms of mothers’ talk about engineering, technology, or mathematics 1 day after the museum visit. For reasons that are not clear, however, findings revealed that at the 1-day delay mothers who did not receive engineering information tended to talk more about the scientific method than those who did receive such information. One can speculate that this result may be driven by mothers focusing on what went wrong and what they could have done better with their
children, which is captured in the scientific method talk. Because the Control group was building wobblier buildings, their discussions might have included more of this problem solving and hypothesis testing type talk.

Also counter to expectations, children who did not receive engineering information, talked the most about technology in their memory reports. As mentioned previously, when considering the set-up of the exhibit this finding may make more sense. The museum has attached labels next to each of the building materials and thus all families were exposed to them. It appears that children who did not receive engineering information were focused more on labeling and describing materials one day later. It should be noted that, at this time point, no other group differences in STEM-related or non-STEM related memory talk were found for mothers or children.

**Two-week Delay**

In contrast to the inconsistent findings found at the 1-day delay, at the 2-week delay the results were more consistent with expectations. Specifically, mothers who received engineering information talked more about engineering at the 2-week delay. Moreover, the memory reports of children who received engineering information included more engineering and scientific method pieces of information than those of children who did not receive engineering information. Children who received engineering information also tended to talk more about the role of triangles at the 2-week delay. No other group differences were found at the 2-week delay. Overall, providing families with brief engineering information helped mothers and children encode the engineering information in such a way that it became accessible weeks later and in a different context. This conclusion, however, should be considered with caution as only a
portion of the participating dyads completed the memory conversations. Nevertheless, it points to the possibility that providing families with simple engineering information can foster children’s long-term remembering of STEM information.

**Memory Reporting Over Time**

Considering the memory reports over time, mothers in the Engineering Information condition maintained their level of talk about engineering over time, whereas those in the Control condition did not. No other changes in mothers’ talk over time were observed.

Although children in the Engineering Information group provided more pieces of engineering and scientific method information than those in the Control group at the 2-week delay, there were no changes from 1-day to 2-weeks based on group membership in talk about engineering and scientific method. Importantly, children in the Control group started off higher in talk about technology than children in the Engineering Information group, but they showed a drop in technology talk over time whereas those in the Engineering Information group did not. It seems likely that in the absence of a richer understanding of the museum experience, it was difficult for children to retain the labels of the building materials and/or their function.

**Associations Between Talk in the Exhibit and Children’s Memory Reports**

Lastly, it was predicted that the effects of engineering instruction and elaborative conversations on children’s memories are additive. In other words, it was thought that children who would receive engineering information and would have richer conversations in the exhibit would recall more at the two time points – 1 day and 2 weeks after the museum visit. The hypothesis was only partially supported. Essentially, it was found
that, irrespective of experimental condition, mothers who talked in more elaborative ways while building in the exhibit had children who talked more about the scientific method and engineering at the 2-week delay. That is, regardless of whether they received engineering information or not, children whose mothers made more associations to the pre-exhibit demonstration while building had children who talked more about scientific method at the two time points and more about engineering at the 2-week time point. These findings support previous work demonstrating the importance of associative talk for children’s learning and remembering (Crowley & Jacobs, 2002; McGuigan & Salmon, 2006; Tessler & Nelson, 1994). Crowley and Jacobs (2002), for example, found that children whose parents explained fossils by associating them to previous experiences recalled more names of the fossils than children whose parents did not make such associations. These results extend previous work by showing that associative comments can also boost children STEM learning and recall.

Additionally, the findings indicated that talk richer in engineering content could also foster children’s learning and subsequent recall of the museum experience. That is, children whose mothers talked more about engineering in the exhibit made more associations to the pre-exhibit demonstration 1-day later. It seems that by talking about engineering principles and concepts mothers helped children make better sense of their experiences. The demonstration was inherently about engineering, and so it might have been easier for children to recall it. This result is particularly exciting given past findings that associative talk can boost children’s memories.
Limitations

The present study provided important information regarding ways to facilitate parent-child building behaviors and children’s learning and remembering. However, the work is not without limitations.

First, the majority of the sample was comprised of Caucasian, highly educated, middle-class families. Therefore, it is hard to know whether the current findings generalize to more diverse families. It could be that the families who agreed to participate in this study are qualitatively different from the general population. Although data collection also took place on days that offered free museum admission, it is possible that the families who were willing to take 30 minutes of their time to participate in this project were different from the ones who declined to participate. For example, these parents might have valued research more. Future studies should aim to recruit larger and more diverse samples.

Moreover, because of the small and pretty homogenous sample, it was not possible to investigate whether cultural differences played a role in children’s learning and remembering. Previous studies have noted that parents from different cultural groups come to the museum with ideas about the museum and about their role in their children’s learning process (Feinberg & Leinhard, 2002; Gaskins, 2008). Gaskins (2008), for instance, found that European-American, African-American, and Hispanic-American parents come to the museum with different expectations about participation in museum activities. Whereas European-American families expect that they will join in their children’s playful activities, African American families expect that their children will explore the museum on their own. Hispanic American families, on the other hand, think
of the museum visit as a social and fun activity in which all family members should partake. In this study mothers were instructed to help their children with the building activity, but this might not have matched African Americans and Hispanic families’ expectations of what should happen at the museum and they might have underperformed. Indeed Haden et al. (2013) found that African American families asked fewer open-ended questions and talked less about STEM while engaging in a building activity at the museum compared to European American families. It would be beneficial if future work will investigate whether the expectations parents bring with them to the museum influence parent-child conversations in the exhibit and children’s subsequent recall of the museum visit.

Lastly, this study is limited in the sense that it only focused on reminiscing conversations at two time points, and thus it does not speak to the types of activities families might have engaged in the days and weeks following the museum visit. Even though collecting the memory data proved to be pretty challenging, the findings suggest that future work focusing on reminiscing conversations in the weeks and perhaps months after a museum visit might help us better understand the impact of brief and simple instructions on children’s long-term learning and remembering. It could well be that museum visits spark interest in a topic and might thus determine children to seek further knowledge about the topic. In turn, engaging in similar activities, such as reading a book on the topic or engaging in a similar building activity, could consolidate children’s initial memories of the visit and further build upon that knowledge (Bauer, 2012). These ideas clearly warrant further consideration as they could provide valuable information to parents and educators interested in fostering STEM learning.
Conclusions and Implications for Museum Practice

Taken together, the results of this study provide important information regarding ways to boost children’s STEM learning and remembering in informal settings. First, they suggest that short and simple instructions can foster children’s building activities and their long-term recall of a museum visit. Second, the findings indicate that mothers can and do support their children’s STEM learning in informal contexts, such as museums. In some cases, parents lack the necessary knowledge – in this case of key STEM concepts and principles – and so they cannot support their children’s learning. In other cases, parents tend to think that children’s learning about science, technology, engineering, and mathematics takes place primarily in school and do not really realize that they can too play an important role in the learning process (NRC, 2009). The results of this study point out that museums can encourage and assist parents in their efforts to facilitate children’s STEM learning. Specifically, the results suggest that adopting empirically based programs such as the one used in this study could help families benefit more from their museum experiences. By providing families with simple exhibit-related information, museum educators could help parents make the most out of their time in the museum. Furthermore, such programs could spark children’s interest in the topic – in this case engineering – and thus help children on a path to science learning and discovery.

It is important to acknowledge, however, that the pre-exhibit demonstration used in this study did not boost children’s talk about STEM in the building exhibit. Future work should aim to identify what types of pre-exhibit experiences would be better at fostering STEM talk. As suggested above, it is plausible that encouraging families to employ elaborative conversational techniques, such as open-ended questions and
associations, could be sufficient. Moreover, it would be important to determine whether such conversation instructions could also enhance children’s transfer skills. In this study, the engineering information did not facilitate children’s abilities to generalize their knowledge to a “farther transfer” task that involved applying their knowledge across contexts, materials, and time (Khlar & Chen, 2011). Children in the Engineering Information group only transferred their knowledge to the building activity, but it is important to keep in mind that children built the skyscrapers with their mothers and, according to Khlar and Chen (2011), the task would be considered a near transfer task as only the materials and physical context were different. Perhaps the use of associative comments would foster children’s “far transfer” skills.

Lastly, this work provided important information regarding the effects of the brief pre-exhibit demonstration and elaborative conversations on mother-child dyads’ long-term recall. Families who were provided with information about key engineering principles talked more about engineering and the scientific method 2 weeks later. Thus, the modest demonstration was capable of producing long-term benefits for families. Furthermore, associative talk was also associated with children’s talk about engineering and the scientific method at the 2-week delay. These results thus suggest that museums might consider developing ways to boost families making of associations while in the museum, as such comments could foster children’s memories of the museum experience. Discovering ways to make the pre-exhibit demonstration sustainable for the museum experience might also be beneficial as it could facilitate families’ nonverbal behaviors in the exhibit. Most importantly, this work highlights that the modest pre-exhibit
demonstration has the potential to boost children’s STEM learning and their long-term memories of informal experiences.
APPENDIX A

INSTRUCTIONS FOR THE REMINISCING CONVERSATIONS
MEMORY CONVERSATION WORKSHEET:

Memory Conversation #1 – Within about 24 hours of the museum visit

Recorder directions
- You will use this recorder to make these recordings. It is really easy to use. To turn it on, just slide the HOLD ● POWER ON/OFF switch downward in the direction of “POWER ON/OFF” for more than 2 seconds. “Accessing…” animation will display.
- When you are ready to start recording, press the ● REC/PAUSE.
- Place the recorder on a table or the floor with the microphone pointed in the direction of your child.
- When you are done recording, just hit the white square button □ (stop). If you accidently hit the red button, that’s okay, just go ahead and hit the white square button.
- To turn the recorder off, slide the HOLD ● POWER ON/OFF switch downward in the direction of “POWER ON/OFF” for more than 2 seconds. “Power off” will display.

Memory Conversation Instructions
- Pick a time that is good for you and your child, and find a quite spot to talk together.
- Turn the voice recorder on to record your conversation with your child.
- **We are interested in what young children remember. We want you to talk with your child about your museum visit. We especially want you to help your child to remember your experiences building in the Skyline exhibit. We are interested in all that your child can remember about the exhibit experience. You should talk as long as you like. You and your child are welcome to talk about other parts of your museum visit, too. Help your child to remember all about what you saw and did.**
- When you have finished the conversation, below, please record the date and approximate time that you made this first recording. Feel free to write down any comments you think would be helpful to us about the recording.

**Memory Conversation #1**

**DATE:** ___________________________ **TIME:** ________________

**COMMENTS:** ____________________________________________
____________________________________________________________________
____________________________________________________________________

Please mail this Memory Conversation Worksheet back to us in the box provided.
MEMORY CONVERSATION WORKSHEET:

Memory Conversation #2: About 2 weeks after Museum Visit

Recorder directions
- You will use this recorder to make these recordings. It is really easy to use. To turn it on, just Slide the HOLD•POWER ON/OFF switch downward in the direction of “POWER ON/OFF” for more than 2 seconds. “Accessing…” animation will display.
- When you are ready to start recording, press the REC/PAUSE.
- Place the recorder on a table or the floor with the microphone pointed in the direction of your child.
- When you are done recording, just hit the white square button (stop). If you accidently hit the red button, that’s okay, just go ahead and hit the white square button.
- To turn the recorder off, Slide the HOLD•POWER ON/OFF switch downward in the direction of “POWER ON/OFF” for more than 2 seconds. “Power off” will display.

Memory Conversation Instructions
- Pick a time that is good for you and your child, and find a quiet spot to talk together.
- Turn the voice recorder on to record your conversation with your child.
- We are interested in what young children remember. We want you to talk with your child about your museum visit. We especially want you to help your child to remember your experiences building in the Skyline exhibit. We are interested in all that your child can remember about the exhibit experience. You should talk as long as you like. You and your child are welcome to talk about other parts of your museum visit, too. Help your child to remember all about what you saw and did.

- When you have finished the conversation, below, please record the date and approximate time that you made this first recording. Feel free to write down any comments you think would be helpful to us about the recording.

Memory Conversation #2

DATE: ____________________________ TIME: ____________________________

COMMENTS: ____________________________

________________________________________

________________________________________

Please mail this Memory Conversation Worksheet back to us in the box provided.
APPENDIX B

DYADS’ ELABORATIVE TALK IN THE BUILDING EXHIBIT
Table 1B. Summary of the ANOVAs for Mothers' Total Open-Ended Questions, Yes/No Questions, Statements, and Total Talk in the Exhibit

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Engineering M (SD)</th>
<th>Information M (SD)</th>
<th>Control M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total open-ended questions</td>
<td>1, 36</td>
<td>.46</td>
<td>.50</td>
<td>12.32 (11.40)</td>
<td>8.70 (7.09)</td>
<td></td>
</tr>
<tr>
<td>Total yes-no questions</td>
<td>1, 36</td>
<td>.01</td>
<td>.94</td>
<td>21.79 (12.88)</td>
<td>19.35 (13.02)</td>
<td></td>
</tr>
<tr>
<td>Total statements</td>
<td>1, 36</td>
<td>2.59</td>
<td>.12</td>
<td>73.20 (28.02)</td>
<td>86.32 (39.15)</td>
<td></td>
</tr>
<tr>
<td>Total talk</td>
<td>1, 36</td>
<td>.97</td>
<td>.33</td>
<td>(38.92)</td>
<td>(48.02)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2B. Summary of the ANOVAs for Children's Total Open-Ended Questions, Yes/No Questions, Statements, and Total Talk in the Exhibit

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
<th>Engineering M (SD)</th>
<th>Information M (SD)</th>
<th>Control M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total open-ended questions</td>
<td>1, 38</td>
<td>.20</td>
<td>.66</td>
<td>3.20 (3.61)</td>
<td>3.65 (2.66)</td>
<td></td>
</tr>
<tr>
<td>Total yes-no questions</td>
<td>1, 36</td>
<td>.06</td>
<td>.81</td>
<td>3.40 (4.27)</td>
<td>3.42 (3.82)</td>
<td></td>
</tr>
<tr>
<td>Total statements</td>
<td>1, 36</td>
<td>1.59</td>
<td>.22</td>
<td>36.21 (16.71)</td>
<td>38.55 (19.01)</td>
<td></td>
</tr>
<tr>
<td>Total talk</td>
<td>1, 36</td>
<td>1.67</td>
<td>.21</td>
<td>42.26 (21.49)</td>
<td>45.90 (21.34)</td>
<td></td>
</tr>
</tbody>
</table>
REFERENCE LIST


VITA

Maria Marcus graduated *Summa Cum Laude* and Honors in Psychology from Loyola University Chicago in May 2010. During her undergraduate years she worked as a research assistant to Dr. Christine Li-Grining and as a teaching assistant to Ms. Deanne Chung, Former Academic Coordinator of the Learning Enrichment for Academic Progress (LEAP) program at Loyola. Her honors thesis, titled “Developing a Comprehensive Maternal Report Aggregate of Children’s Self-Regulation Using the NICHD Study of Early Child Care and Youth Development”, focused on ethnic minority children’s self-regulation.

Following completion of her B.S. degree, Marcus entered the Developmental Psychology Ph.D. program at Loyola University Chicago. She has served as a graduate research assistant to Dr. Catherine A. Haden. After receiving her doctorate degree she will pursue a post-doctoral position that will allow her to apply her research knowledge and skills.
THESIS APPROVAL SHEET

The thesis submitted by Maria Marcus has been read and approved by the following committee:

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The final copies have been examined by the director of the thesis and the signature that appears below verifies the fact that any necessary changes have been incorporated and that the thesis is not given final approval by the committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

___________________                                 _________________________
Date                                  Director’s Signature