An Experimental Investigation of Contrasting
Instructional Conditions on Children's Developing Memory Skills

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ABSTRACT

JENNIE K. GRAMMER: An Experimental Investigation of Contrasting Instructional Conditions on Children's Developing Memory Skills
(Under the direction of Peter A. Ornstein, Ph.D.)

Results from observational work conducted in elementary school classrooms have indicated that teachers do not explicitly teach skills for remembering, but it is also apparent that specific aspects of instruction are important for children's mnemonic development. A rich literature has characterized the development of children's mnemonic strategies and highlighted the importance of social contexts, such as the elementary school classroom, for the emergence of these skills. Although linkages between aspects of teachers' language in the classroom and children's memory performance have been documented, these investigations have largely been correlational in nature. Thus, it is not possible to make causal statements about the impact of classroom instruction on children's mnemonic abilities. Given these limitations, this project was designed to increase understanding of the impact of classroom instruction on memory development through the use of an experimental manipulation of the way in which new information was taught to children.

Teachers were trained to lead an instructional unit in memory-rich and low-memory modes of instruction. First- and second-grade children participated in 10 days of lessons on a unit entitled "Things that Move" that varied in terms of the teachers' use of memory-relevant language. In addition, the children were given pretest, posttest, and 1-month follow-up assessments of memory strategy use and content knowledge. The goals of the project included (1) training instructors in the use of contrasting levels of memory-relevant language, (2) exploring

relations among measures of children's mnemonic skill and content knowledge, and (3) examining children's performance on these measures as a function of assignment to the memory-rich or low-memory condition.

The data from this project suggest that it is possible to train teachers in the use of memory-relevant instructional techniques. In addition, linkages between children's memory strategy use and recall for familiar and content specific items were identified. Although memory-rich instruction was not found to be related to children's performance on memory strategy tasks involving familiar items, children who participated in the memory-rich instructional unit exhibited more sophisticated strategy use in a content-specific memory task and demonstrated higher levels of content-related strategy knowledge than did their peers exposed to low-memory instruction.

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I. Introduction

Age-related changes in children's use of strategies for remembering information, such as rehearsal and organization, have been widely documented across the elementary school years (Schneider & Pressley, 1997). In addition to developmental changes in children's mnemonic techniques, researchers have also described simultaneous growth in their use of strategies in the classroom setting in content domains such as reading and mathematics (e.g., Pressley & Hilden, 2006). Given that these skills emerge in conjunction with children's exposure to formal instruction in elementary school, and that their use can have direct implications for achievement in school, it follows that there is something about the classroom setting that is impacting growth in these cognitive processes. Moreover, although children may come to make use of mnemonic techniques on their own, a growing body of evidence has highlighted the important role that the social context – and more specifically interactions with peers and adults – plays in the emergence of these skills.

A number of factors point to the importance of formal schooling – and interactions with teachers – for the development of these techniques. Specifically, research conducted cross culturally (Rogoff, 1981) and with the school-cutoff method (Morrison, Smith, Dow-Ehrensberger, 1995) has highlighted the unique role that the school context plays in children's mnemonic development. Further, cross-national studies (e.g., Kurtz, Schneider, Carr, Borkowski, & Rellinger 1990) have provided initial insight into what specific aspects of the classroom context, including a teacher's provision of strategy relevant information in school lessons, may impact this development most. Despite this wealth of evidence pointing to the importance of the classroom setting for children's cognitive growth, just how these basic memory skills are transmitted from the teacher to student is not entirely clear. More specifically, the question remains: What instructional techniques facilitate children's independent skills for learning and remembering?

Observational studies of classroom instruction (Moely et al., 1992; Coffman, Ornstein, McCall, & Curran, 2008) and mother-child interactions during discussions of previously-experienced events (Reese, Haden, & Fivush, 1993) have provided important information regarding what aspects of the interactions with teachers and parents are linked to children's remembering. Specifically, both of these lines of research have demonstrated that particular types of conversational exchanges, such as a mother's use of an elaborative conversational style including Wh- questions (Ornstein, Haden, & Hedrick, 2004), or a teacher's provision of metacognitive and strategy-relevant talk in the context of instruction (Coffman et al., 2008), are linked to children's independent abilities to recall information and make use of mnemonic strategies. In addition to the important insights provided from these observational paradigms, evidence from a number of laboratory and school-based experiments suggests that subtle task differences, including questions and direct strategy training, can elicit strategic behaviors from children.

Importantly, although linkages between children's memory performance and conversation with adults have been documented across a number of studies, the majority of these investigations have been correlational in nature and have focused on interaction between mothers and children. As a result, it is not possible to make causal statements about the impact of classroom instruction on children's mnemonic abilities. Given these limitations of previous work, the project outlined here was designed to increase understanding of the impact of classroom instruction on memory development through the use of an experimental manipulation of the way in which new information is taught to children.

1.1 Evidence for the Importance of Schooling

Initial evidence for the link between formal schooling and the use of strategies was seen in a number of cross-cultural investigations conducted in regions of the world where at the time formal Western-style schooling was not experienced by all children (Rogoff, 1981; Wagner, 1974; Sharp, Cole, & Lave, 1979). For example, a series of cross-cultural investigations conducted in both Liberia (e.g. Scribner & Cole, 1978) and Morocco (e.g., Wagner, 1978) contrasting the performance of children matched in chronological age but who differed in terms of whether they had or had not participated in Western-style schooling revealed that children who attended school were more skilled in specific types of deliberate memory skills, as evidenced by their sorting patterns (Sharp et al., 1979), and their primacy recall, which is considered to be an indicator children's use of an active rehearsal strategy (Wagner, 1978), than those children who had not experienced formal schooling.

Overall, evidence from these cross-cultural comparisons led Rogoff (1981) to conclude that experience in the classroom setting seemed necessary for the development of specific types of mnemonic techniques such as the use of organizational strategies for remembering. Although this line of research pointed to school as an important context for children's use of memory strategies, the schooled and unschooled groups did not differ in cognitive skills, such as rule learning or logical thought (Rogoff, 1981). Moreover, although cross-cultural investigations indicated that children in Western-style schooling were better able to make use of specific strategies for remembering new information, it is important to note that similar differences in performance were not seen in memory tasks that were embedded in culturally-relevant, everyday activities. Rogoff (1981; see also Cole, 2006) noted that the majority of tasks used to assess mnemonic skills in cross-cultural investigations were similar to those that children encounter everyday in the school setting. Despite the frequency of routine memorization activities in the classroom (e.g. learning spelling lists or the names of presidents), less emphasis is often placed on these skills outside of the school context (Cole, 1992).

Extending on this cross-cultural work, evidence for the impact of schooling on memory performance is also found in cross- national studies, in which children with similar amounts of exposure to schooling in different context are compared. Based on findings that that German students evidenced higher levels of categorical sorting during study and clustering in recall and greater metacognitive understanding than did their same-aged peers in American schools (Carr, Kurtz, Schneider, Turner, & Borkowski, 1989), Kurtz and colleagues (e.g., Kurtz et al., 1990) investigated teacher differences that may be linked to these skills as well. More specifically, the researchers asked teachers from Germany and the United States about the ways in which they instructed strategy use in their classroom. Interestingly, differences across the teachers' self-reported behaviors in the classroom mirrored the skills of children from the two countries. German teachers reported that they instructed strategies more frequently than teachers from the United States. Interestingly, however, overall both sets of teachers reported very little metacognitive and strategy-rich instruction.

1.2 Aspects of Context that Shape Children's Independent Skills

1.2.1 The Importance of Conversational Interaction

Despite the linkages identified in cross-cultural and cross-national investigations, these studies allowed for little more than speculation about why the school context appeared to be so important for the development of skilled remembering. One hint as to the specific aspects of the classroom setting that may matter most for this development comes from a range of cross-sectional and longitudinal investigations that suggests that mother-child conversations are likely to have an important impact on preschoolers' memory. Indeed, Fivush and her colleagues (e.g., Fivush & Fromhoff, 1988; Reese et al., 1993) have shown that remembering of past events is greatly aided by mothers' provision of detailed information about events and by increased opportunities for children to report their experiences. Moreover, extending findings that conversations about the past may serve to mediate the development of children's independent memory skills, Haden and her colleagues (Haden, Ornstein, Eckerman, & Didow, 2001) have shown that adult-child discussions about novel events while they are being experienced together can also affect children's recall. In a range of cross-sectional and longitudinal investigations, researchers have demonstrated that talk during events, including asking Wh-questions, making associations, following in on the child's lead, and positive evaluations of what children are saying during an event, also have been identified as important aspects of this exchange for children's later memory for events (Ornstein et al., 2004).

Although the evidence from cross-cultural and cross-national studies highlights the importance of formal schooling for children's developing mnemonic skills and research involving conversational exchanges between mothers and children suggests that social interactions in particular may facilitate changes in children's ability to recall personally experienced events, less is understood about the mechanisms by which this development is occurring. Specifically, how do children gain metacognitive and strategic abilities that they make use of independently? In their discussion of the importance of the social environment for children's cognitive growth, Brown and Reeve (1987) drew on the work of Vygotsky and suggested that individual thought processes are created through social interactions. Thus, just as metacognitive information provided directly to children in the context of training studies impacts children's mnemonic performance, Brown and Reeve proposed that the very social exchanges in which children engage daily with peers and adults may lead to the internalization of metacognitive information, which may facilitate children's independent efforts at remembering.

Importantly, Brown and Reeve (1987) also noted that social interactions do not always lead to the acquisition of independent skills for learning and remembering. For example, as has been documented in the research on mother-child interactions, there is a great deal of variability in the ways in which mothers talk with their children about previously experienced and ongoing events. It follows that social exchanges that children have with their parents and teachers provide more or less opportunity for these independent cognitive skills to develop. Even two decades after Brown and Reeve's insight, many questions still remain about how to best characterize and understand the specific aspects of adult-child interactions that may be most effective in inducing cognitive growth. Furthermore, the extent to which these exchanges can be manipulated to benefit children's mnemonic skills is not fully articulated. Although work in these areas is currently being conducted to explore the impact of social interactions on the cognitive development of children, more research must be carried out to understand ultimately the extent to which social collaborations are related to children's independent skills, and more importantly, to attempt to explicate the process underlying the acquisition of strategies for learning and remembering.

1.2.2 The Role of Metacognitively-Rich Instruction: Evidence from Training Studies

Given that preschoolers' abilities to discuss and remember previously experienced events have been widely documented, and the importance of social interactions for young children's autobiographical remembering has been documented repeatedly (e.g., Ornstein et al., 2004; Fivush, Haden, & Reese, 2006), it follows that the same type of exchanges may be influencing children's strategic memory skills as well. Indeed, around the same time that children begin to show extensive memory for events, they are also exhibiting the first signs of strategic behavior to aid in remembering (Brown, Bransford, Ferrera, & Campione, 1983; Pressley & Hilden, 2006). For example, when given a group of objects, even 4-year-old children, when asked to work to remember them, appear to be more deliberate in their approach, and play less with the items than when they are told to play with them (Baker-Ward, Ornstein, & Holden, 1984). Also, even very young children will use simple strategies when asked to remember the location of objects (DeLoache, Cassidy, & Brown, 1985).

Although strategic skills can be documented early on in development, it is important to note that they tend to be limited to contexts that are familiar to the child, and are most easily seen when the demands of the task are minimal (Brown & DeLoache, 1978, Brown et al., 1983). Once children enter elementary school, however, their ability to be deliberately strategic improves markedly (Schneider & Pressley, 1997). Indeed, even though they enter kindergarten and first grade with a limited set of strategies that they may be able to employ more or less consistently or efficiently, by the end of the fifth grade, most children have a whole host of strategies from which to choose when approaching the task of remembering. Moreover, data from a series of cross-sectional studies of children's use of strategies – including rehearsal (e.g., Ornstein & Naus, 1978), organization (e.g., Lange, 1978), and elaboration (e.g., Pressley, 1982) - indicate that children's use of these strategies increases across the elementary school years, and that the use of memory strategies is linked causally to recall performance across the years.

Despite the timing of the emergence of these skills, it is not entirely clear that the same aspects of mother-child interactions – such as asking Wh-questions – that influence autobiographical remembering also facilitate children's strategic memory performance. To date, little evidence exists for a link between young children's deliberate strategy use and mother-child interactions while talking with their children about the past. An exception to this is the linkage between children's deliberate efforts to remember in the Object Memory task, in which children are asked to remember a set of everyday objects, with their mother's elaborative style during a reminiscing task that has been reported by Rudek and Haden (2005).

In addition to evidence of the importance of metacognitive and strategic instruction reported by teachers (Kurtz et al., 1990), and hints from the mother-child literature, many illustrations of what aspects of instruction are important for children's use of strategies can be seen in experimental training studies of strategy use. Although the use of more sophisticated mnemonic techniques improves with age, it is also clear that subtle task differences and direct training in strategy use can elicit strategic behaviors from children before they begin to use them spontaneously (Ornstein, Baker-Ward, & Naus, 1988). Results from experimental manipulations of aspects of the memory tasks that may scaffold performance, including instructions, materials, and modes of presentation, indicate that these types of subtle differences can affect strategic behavior in children. Moreover, in a variety of investigations that were designed to examine the impact of different types of adult-led training, researchers have repeatedly demonstrated that children can be successfully trained to make use of rehearsal, organizational, and elaborative strategies, and that they subsequently benefit from their use.

Despite clear evidence that children can be trained to make use of these mnemonic techniques in advance of developing them, it is often the case that they do not successfully transfer these newly learned skills when told to remember in different contexts. In their review of experimental manipulations of training on children's transfer of memory strategies, Cox, Ornstein, and Valsiner (1991) drew on the work of Brown and colleagues, and described these investigations as falling into four categories that varied in the amount of aid provided to participating children. Specifically, Cox et al. grouped studies as a function of the extent to which training provided children with information that allowed them to evaluate their own performance as well as the amount of training that promoted the internalization of the strategy.

Of the training studies they reviewed, those that they identified as least likely to promote transfer of the trained strategy were ones in which children were instructed in a strategy, but were given very little additional information. In examples of this type of "blind" training, participating children were given instructions on how to make use of an individual strategy, but were given no feedback regarding their performance, choice in the use of the specific strategy trained, or rationale for why the trained technique would be useful in another context or even when experiencing the same task with different items at a later time. Cox et al. concluded that although these blind training methods were often able to promote short-term benefits for children's strategic behaviors, they were particularly poor at encouraging transfer, because the participants were not provided with adequate metacognitive information about the utility and effectiveness of employing the strategy.

Similar to blind training, experimental conditions labeled by Cox and colleagues as "laissez-faire" were those in which children were encouraged to make use of both an efficient and an inefficient strategy during a training session, and then subsequently allowed to decide the strategy they preferred to use in later trials. By offering participants two contrasting strategies to choose from, the goal was to allow them to deduce on their own which strategy would be most efficient. Importantly, however, children were not provided with feedback regarding their performance using either of the strategies targeted in training (e.g., Pressley, Levin, & Ghatala, 1984). As with blind training conditions, Cox et al. suggested that the success of these types of training methods was limited because, although experimenters provided children with the opportunity to choose the strategy used during the task, they were not given the chance to learn important information regarding the effectiveness of the techniques available.

Although blind and laissez-faire training were not often seen to result in lasting transfer of mnemonic techniques, Cox and colleagues identified additional types of training studies that did frequently benefit children's memory and strategy use. Fundamentally, the most effective training protocols were those in which children were given metacognitively relevant information about the value and effectiveness of strategic behavior. The provision of metacognitive information was effective before, during, and after training, in the form of both instructions and in feedback specific to children's performance. Indeed, results from a number of investigations point to the importance of the inclusion of metacognitive information for successful acquisition and transfer of a range of strategies for remembering (e.g., Paris, Newman, & McVey, 1982; Pressley, Ross, Levin, & Ghatala, 1984; Ringel & Springer, 1980).

One illustration of the impact of this technique can be seen in evidence from a microgenetic study of strategy acquisition conducted by Paris et al. (1982). In this investigation, participants in two contrasting groups (control and experimental conditions) were trained over the course of a week in a range of techniques to aid in remembering (i.e., sorting, labeling, cumulative rehearsal, self-testing, and clustering). Importantly, children in the experimental condition were provided with an elaborated demonstration of these strategies that included explanations of why each would be helpful. In addition to this direct instruction, the children in the experimental training condition were given metacognitive feedback in the form of elaborated praise regarding their performance on subsequent trials of the memory tasks. Thus, children in the control condition were trained in the same strategies, but were not provided with any metacognitive information either about the strategies or about their performance. Importantly, although both groups of children showed improved recall and strategy use on the day that they were trained, only children in the experimental condition who experienced the elaborated training and feedback continued to make use of the strategies they had learned after a two-day delay.

In general, the most successful training studies reviewed included some elements of metacognitive information and feedback. Not only do these training methods highlight helpful information for children about the importance of strategy choice, but they also allow for the provision of useful feedback that children can use to make informed decisions about strategy use in the future. The success of training manipulations, such as that of Paris and colleagues, encouraged researchers to think about how similar aspects of instruction in experimental and classroom settings could improve children's use of academically-relevant strategies, as well.

Whereas laboratory-based experiments of memory strategy use have clearly demonstrated the importance of the provision of metacognitive information from the experimenter, similar benefits for children's use and knowledge of strategies have been identified when the same information is elicited through individual reflection. In general, self-explanation is accepted as an instructional tool that is thought to be an important means of promoting learning across domains that can facilitate the creation of new problem-solving techniques (Siegler, 2002) and increases in conceptual knowledge (Chi, Bassock, Lewis, Reimann, & Glaser, 1989). In addition, requests for children to explain problem solving techniques to themselves have also been shown to increase both the learning of information (Woloshyn, Pressley, & Schneider, 1992) and strategy transfer in academic domains (Chi et al., 1989). Clear examples of this can be seen in investigations of the acquisition of mathematics strategies that reveal that prompts to self-explain improve procedural learning and transfer, regardless of whether or not children are instructed directly to make use of specific problem solving strategies (e.g., Rittle-Johnson, 2006).

Although the techniques children use to remember information and solve problems in an applied educational setting are different in many ways, the mnemonic skills they employ in laboratory-based tasks are variations of the types of skills that children use every day when they encounter a goal for learning. In each case, children must make decisions about the most efficient way to solve a problem, implement a technique, and in turn they gain feedback regarding their performance, which could inform their use of a strategy on a similar problem in the future. In addition, although the impact of training on children's independent use of strategies for remembering or learning new information may be due to a number of child-level and task-specific factors, including attentional capacity, effort requirements, and information processing supports, the social interactions children have around the metacognitive information matter. Moreover, for memory and classroom-based strategy use, it appears that, as Brown and Reeve suggested (1989), sharing internal thought processes with children, either by providing them with metacognitive information or eliciting it from them, leads to the internalization of skills. Overall, the range of available evidence from training studies indicates clearly that the provision of metacognitive information is important for successfully training children not only to make use of – but also continue to use – strategies for remembering.

1.3 Research in the Classroom Setting

Just as training conditions that encourage metacognitive understanding have been shown to result in optimal maintenance and transfer of strategies, metacognitively-rich language has been identified as critical to the development of independent strategy use across multiple instructional domains, and demonstrations of the ways in which such instruction could be implemented in the classroom to create "skilled thinkers" in reading, writing, and problem solving can be seen in classroom-based research (Pressley & Hilden, 2006, Pressley & Harris, 2006). Moreover, Pressley and his colleagues emphasized the importance of the implementation of techniques such as direct explanation, modeling, and teacher-monitored practice of comprehension strategies in classroom instruction (e.g., Block & Pressley, 2002).

Examples of the importance of this type of strategy instruction for children's independent skills are clearly demonstrated in a range of experimental investigations embedded in learning contexts. Consider, for example, extensive research conducted that focuses on children's acquisition of reading strategies. Drawing on the existing literature on effective reading comprehension strategies, Palinscar and Brown's (1984) model of reciprocal teaching involved many of the elements of effective training methods developed in the laboratories of psychologists interested in more basic cognitive skills. Specifically, to optimize the maintenance and generalization of trained reading strategies, Palinscar and Brown's reciprocal teaching technique included elements designed to facilitate children's learning of the desired comprehension strategies. Thus, although the strategy training was embedded in literacy instruction with participating middle-school students, it included active student participation, feedback on the utility of strategic behavior, and instruction on when and where a specific strategy may be applied.

Palinscar and Brown characterized reciprocal teaching as involving lessons that began with discussions of previously learned information, with the goal of activating the prior knowledge of the students. When engaging with the reading materials, the adult instructor modeled the desired comprehension strategies (including questioning, summarization, prediction, and seeking clarification) and guided the students to employ these strategies themselves through the use of prompting, instruction, and modification. Throughout these lessons, the children were told explicitly that the activities that they were engaging in were strategic and were meant to help them better understand what they read. In addition to information regarding the utility of the strategies, the students were also told that the techniques would also be effective when they read independently.

Results from this applied example of strategy-rich instruction involving both experimenter- and teacher-led training demonstrate the power of these techniques when applied to the instruction of reading strategies. Following participation in the transactional strategies approach administered by teachers in Brown et al.'s investigation, children had enhanced memories of texts and also were better able to interpret what they had read in their reading groups relative to their peers experiencing regular literacy instruction. Brown and her colleagues concluded that these differences indicated that the transactional strategies approach led children to learn more from their reading group lessons than other students. Importantly, these students also experienced long-term benefits, including greater awareness of reading comprehension strategies by the end of the academic year.

Research conducted by Duffy and his colleagues (1987) further illustrated the importance of strategic instruction for the development of reading comprehension strategies. Focusing on the potential benefit of the direct explanation of strategies during reading instruction, Duffy et al. taught a group of randomly selected third-grade teachers to place emphasis on directly explaining and modeling strategies used by skilled readers. Teachers participating in this experimental training were also instructed to encourage their students to use these skills and strategies flexibly by describing other instances in which the strategies might be useful. These instructional efforts, combined with extensive guided practice - including consistent reinforcement of the importance of strategic behavior throughout the school day when children encountered new tasks - were implemented by the teachers and were modified to suit the developing skills of the child across the school year. After experiencing this type of direct explanation strategy instruction, when compared to students taught by teachers who were not trained in these strategically rich methods, children performed better on standardized measures of reading performance.

In their broad overview of the development of both memory and applied learning strategies, Pressley and Hilden (2006) noted that the benefits of strategy-rich instruction had been shared in a number of ways with classroom educators. Indeed, many of the techniques identified through careful experimentation of instruction in literacy lessons, including direct explanation, modeling and teacher monitored practice of comprehension strategies, are outlined in professional texts for teachers and are practiced in elementary schools across the country (Block & Pressley, 2002; Harvey & Goudvis, 2000). Despite the emphasis placed on strategy-rich instruction in a number of applied interventions in the classroom setting and instructional materials for teachers, however, little observational evidence has been collected to determine the extent to which teachers make use of these techniques while teaching.

1.4 Cross-Sectional Observations of the Elementary School Classroom

Given the documented importance of the provision of strategic and metacognitive information for children's performance both on basic memory tasks and on more applied activities such as reading comprehension, as well as the range of evidence highlighting the elementary school context as being an important environment for the development of mnemonic skills, it is evident that the classroom instruction plays a large role in shaping children's cognitive abilities. Despite this, to date only two observations studies of the classroom setting have been conducted to investigate the extent to which teachers make use of these types of techniques during regular instruction. In the first of these investigations, seeing the connection between the elementary school classroom and children's developing mnemonic skills, Moely et al. (1992) conducted a systematic series of studies designed to (a) describe teachers' instruction of cognitive processing techniques, especially the nature of their suggestions for children's use of memory strategies, and (b) observe ways in which teachers might promote strategy use and maintenance.

The observational instrument used by Moely et al. (1992) was a coding scheme that was composed of 23 distinct categories that described various aspects of the teaching process. Using this coding system, Moely and her colleagues made observations in 30-second intervals in classrooms in which they worked. Given the evidence for the importance of strategy instruction demonstrated in experimental studies, Moely and colleagues focused largely on instances in which the teacher was observed describing or suggesting a cognitive process, suggesting a strategy, or giving rationales or feedback for strategy use. In addition, while observing classroom instruction, Moely and her colleagues, also noted specific examples of strategy suggestions and suppressions. For example, teachers were observed suggesting that students check their work for errors, use specific aids when working to solve a problem (e.g. counting blocks to represent addition and subtraction problems), and to use general knowledge to deduce a correct answer (e.g. looking for root words).

Observation in 69 teachers' classrooms, from kindergarten through grade 6, revealed relatively infrequent teaching of cognitive processing activities – accounting for only 9.5% of intervals observed – that varied by grade (occurring more often in grades 2 and 3 than in higher or lower grades) and by the content of instruction (more in mathematics than in language arts). In addition, strategy suggestions were found in only 2.28% of the intervals, with 10% of the 69 teachers offering no strategy suggestions during the observations. The occurrence of strategy suggestions also varied across grade level, and the types of strategies suggested varied by subject matter.

After providing a general description of the classroom, Moely and her colleagues identified teachers of classrooms that were essentially equal in other instructional behaviors, such as the provision of content information and positive feedback to the children, but differed in the amount of instruction they provided about strategies. They selected two groups of instructors who fell into one of two categories, one style that included some instructions for strategy use and a second that involved almost no such instruction. A sample of participating first-, second, and third-grade children with high, moderate, and low levels of achievement from each of these two groups of classrooms was then administered a sort-recall task across baseline, training, and generalization trials in order to compare the performance of students from the different styles of classrooms on their use of an organizational strategy and recall.

It was revealed that children from classrooms led by teachers who gave strategy instructions ("high strategy teachers") were more likely to spontaneously generate strategies to use when approaching the recall tasks. Differences were also shown in the recall performance of children from the high versus low strategy classrooms, but only for children who were average or low achievers. That is, average and low achievers whose teachers were high in strategy suggestions were more likely to benefit from the strategy instruction, to use organization during recall, to recall more items, and to organize items during study (the last was especially obvious in first grade). Moreover, in an effort to better understand their metacognitive knowledge of sorting and clustering strategies, the children were also questioned about strategic behavior in the sort-recall task. As might be expected, following training, the children's awareness of the importance of categorization increased, and those from the high strategy classrooms were better able to explain the organizational strategy they were taught than were those from low strategy classrooms. In addition, high and moderate achieving children were more likely to mention the importance of categorization when compared to low achieving students.

Interestingly, an interaction of grade by teacher indicated that only in first grade did children whose teachers more often made strategy suggestions use the target strategy of category clustering more. In addition, these first graders in "high strategy classrooms" better maintained the use of the strategies on a third generalization trial than those whose teachers were low in strategy suggestion. This finding implies that first graders, with limited metacognitive and self-regulatory skills, may be dependent upon their teachers for guidance about how to process information for later retrieval.

Despite the results from Moely et al.'s (1992) work, it must be noted that very few strategy suggestions took place in any of the elementary school classrooms that were observed. In fact, general information about cognitive processes was noted in, on average, 9.5% of the intervals in which observations were made; moreover, fewer than 3% of the observation intervals were shown to contain strategy suggestions. In looking at these results, it becomes apparent that teachers are not directly instructing the children in how to use strategies. These results confirm the need for additional examination of potential sources of the facilitation of memory strategy development that is occurring in early elementary school. Even though there is little in the way of strategy instruction in the classroom, perhaps something about the nature of teacher-student interactions may enable children to discover strategies that are effective for remembering.

1.5 Longitudinal Exploration of the Impact of the Elementary School Classroom

In an effort to extend Moely's findings as well as to examine the linkages between the classroom context and children's developing memory skills over time, Ornstein and colleagues carried out a longitudinal investigation in first-, second-, fourth-, and fifth-grade classrooms. This five-year longitudinal study included both teacher observations and memory assessments with students embedded in these classrooms as they moved through elementary school. When combined, the data from this project allow not only for tracking individual children's developing strategic abilities, but also for the characterization of the aspects of the classroom that may be contributing to this growth. Although observations have revealed that teachers do not explicitly teach children skills to aid in remembering, it is clear that they are creating an important context in which these abilities are developing (Coffman et al., 2008).

In each year of this longitudinal investigation Ornstein and colleagues conducted a series of observations focused on teachers' memory-relevant language during language arts and mathematics lesson using the *Taxonomy of Teacher Behaviors* (Coffman et al., 2008). Using the measure, based in part on the work of Moely and colleagues (1992) and following procedures recommended by Cairns, Santoyo, Ferguson, and Cairns (1991), two trained research assistants observed in each classroom, alternating between (1) using the *Taxonomy* to make decisions every 30 seconds about the nature of a teacher's instructionally-relevant conversation, and (2) writing a detailed contextual narrative of the lesson as it unfolds, including descriptions of the content, the dominant teacher and child activities, and the children's verbal responses. To characterize the nature of instruction in each classroom, the assistants observed 60 minutes of language arts and mathematics instruction, for a total of 120 minutes, (240 30-second intervals) per teacher each year.

Using the *Taxonomy*, Ornstein and colleagues classified instruction in the classrooms into four categories: instructional activities, cognitive structuring activities, memory requests, and metacognitive information. The average percent occurrence of each of the instructional codes in grades 1, 2, 4, and 5 can be seen in Table 1. In addition, the full coding scheme can be found in Appendix A.

Instructional codes were used when a teacher provided *specific task information* (e.g., how to form the letter W), *general information* (e.g., in describing a frog's habitat), a *prospective summary* about an upcoming activity (e.g., alerting the class to a field trip next week), or if she engaged in *book reading* to the class. Although children's attention and comprehension are necessary for successful teaching, these codes were used when information was presented without requiring specific actions by the students.

Cognitive Structuring Activity codes captured teacher talk that encouraged children to engage materials in ways that have been found in laboratory studies to prompt deep levels of processing and to affect the encoding and retrieval of information (Craik & Lockhart, 1972; Hyde & Jenkins, 1969). Examples of Cognitive Structuring Activities included *attention regulation* (e.g., regulating behavior or focusing attention), *massed repetition* (e.g., performing an action in unison), *identifying features* (e.g., circling the "it" family words), *categorization* (e.g., sorting by shape or color), *identifying relationships* (e.g., comparing and contrasting water and ice), *making connections with personal experiences* (e.g., relating a current activity to a child's previous experience), *drawing inferences* (e.g., asking what might happen next in a story), and *visual imagery* (as in imagining oneself as an animal).

Memory Request codes were employed when a teacher asked students to retrieve information or to prepare for future activities. Such requests could be *episodic* (e.g., retrieval of an event: "What did you do at your birthday party?"), *semantic* (e.g., report of a learned fact: "What comes after 10?"), *procedural* (e.g., recalling how to perform an action: "How do we set up the tape recorder?"). Memory demands that were future-oriented were labeled as either *prospective* (e.g., a behavioral goal: "Bring your lunch money tomorrow!"), or an *anticipated request* (e.g., a learning goal: "Remember this set of numbers.").

Metacognitive Information codes were used when teachers provided or solicited metacognitive information with the goal of facilitating children's performance. Teachers may offer a *metacognitive rationale* (e.g., "Reading the word problem twice is helpful because as you get older the problems will get more complicated"), use *metacognitive questioning* (e.g., "How did you study those words?"), or make a *suggestion* (e.g., "If you make a picture in your mind, it will help you to remember."). In contrast, instances in which a teacher might use *suppression* of a strategy ("Don't count on your fingers."), and may suggest a *replacement* (e.g., "Don't erase your mistakes. Just cross them out.") were also captured.

To supplement the coding of teacher behavior, research assistants also captured rich contextual information in the form of a narrative. From these descriptions of the ongoing instruction, inferences about the *Nature of the Memory Demand* were made, and teachers' memory requests were subsequently classified as reflecting *expressed*, *implied deliberate,* or *incidental* memory demands. In addition *non-memory-relevant activities, including* all instructional time that did not contain memory-relevant prompts, were also captured.

1.5.1 Linking the Classroom Context and Children's Mnemonic Skills

Based on findings previously reported that indicate the importance of the first-grade classroom for children's memory skills (Morrison et al., 1995), Ornstein and colleagues first sought to link aspects of the first-grade classroom with children's use of memory strategies in the same year (Coffman et al., 2008). The mean percent occurrence of each of the individual codes captured using the Taxonomy across all teachers observed in grade one can be seen in the first column of Table 1. Importantly, across the 14 first-grade classrooms in which they observed, teachers were rarely observed informing students that remembering was an expressed goal, however the teachers made frequent indirect memory requests (see Table 1). Indeed, expressed deliberate memory demands were observed in only 5.4% of the intervals (range across classrooms = 2.1 – 10.4%), whereas implied deliberate memory demands were seen in 47.2% of the intervals (range = 36.7 – 62.5%). This variability in memory demands was paralleled by comparable variability in other components of memory-related language, as, for example, in the provision of metacognitive information (range = 2.5 – 19.2%) and the use of cognitive structuring activities that encourage in-depth processing (range = 25.4 – 62.5%).

Table 1
Mean Percent Occurrences of Teacher Behaviors in Grade 1

	Overall	High Mnemonic	Low Mnemonic
Implied Deliberate Memory Demands	47.2%	57.6%	47.7%
Expressed Memory Demands	5.4%	6.6%	4.2%
Instructional Activities – Category Total	78.2%	78.2%	78.2%
Book Reading	11.7%	10.2%	13.2%
General Information Giving	41.8%	45.7%	37.9%
Prospective Summary	7.0%	6.6%	7.4%
Specific Task Information	40.1%	39.1%	41.0%
Cognitive Structuring – Category Total	42.6%	45.1%	40.1%
Attention Regulation- Behavioral Goal	18.6%	13.4%	23.8%
Attention Regulation- Instructional Goal	14.1%	13.7%	14.5%
Massed Repetition	9.3%	11.4%	7.2%
Identifying Features	4.5%	5.1%	4.0%
Categorization	2.2%	2.9%	1.5%
Identifying Relationships	6.3%	6.0%	6.1%
Connections- Personal Experiences at Home	2.0%	1.6%	2.4%
Connections- Personal Experiences at School	8.1%	9.6%	6.6%
Drawing Inferences	3.9%	3.5%	4.4%
Visual Imagery	0.3%	0.5%	0.1%
Memory Requests – Category Total	52.6%	57.6%	47.7%
Episodic	4.0%	3.5%	4.5%
Semantic	47.0%	52.9%	41.2%
Procedural	1.3%	1.4%	1.1%
Prospective	0.8%	0.8%	0.8%
Anticipated	2.3%	2.4%	2.2%
Metacognitive Instruction – Category Total	9.5%	13.5%	5.5%
Metacognitive Rationale	1.2%	1.9%	0.5%
Metacognitive Questioning	4.9%	6.9%	2.9%
Suggestion	4.9%	7.3%	2.5%
Suppression	0.1%	0.2%	0.1%
Replacement	0.1%	0.1%	0.1%
Co-occurrence of Deliberate Demand with:			
Instructional Activities	37.6%	42.1%	33.2%
Cognitive Structuring	23.5%	25.4%	21.5%
Metacognitive Information	5.9%	8.9%	2.8%

On the basis of these classroom differences, Ornstein and colleagues created a composite measure to characterize the mnemonic orientation that is reflected in the classrooms. Included in this measure were the teachers' use of individual codes including *strategy suggestions* and *metacognitive questions* as well as combination codes that included both *deliberate memory demands* and either *instructional activities*, *cognitive structuring activities,* or *metacognitive information*. Making use of the variability across classrooms and using a median split, each teacher's mnemonic style was characterized as being either "high mnemonic" or "low mnemonic," based on the extent to which the teachers made use of memory-relevant language in instruction. The mean percent occurrence of individual codes for "high mnemonic" and "low mnemonic" instruction can be seen in the last two columns in Table 1.

To illustrate the differences observed by Ornstein and colleagues (Ornstein, Coffman, & Grammer, 2009) in first-grade instruction, as can be seen in Appendices B and C, "high mnemonic" in contrast to "low mnemonic" instruction in language arts and mathematics is characterized by more instances of the memory-relevant language described above, such as asking the children if a word selection makes sense or eliciting a specific strategy for answering a mathematics problem. Alternatively, as can be seen in the next two lesson excerpts in Appendix C, the "low mnemonic" instruction is characterized by fewer instances of the memory-relevant language described above. Although the teachers in each of the examples provided engage the students in the topics being discussed, in contrast to the high mnemonic teachers illustrated above, excerpts from the low-mnemonic lessons are characterized by more basic questions, decreased focus on strategy use, and a lack of emphasis on understanding *why* a specific answer may be correct.

Using a multitask battery, including a variety of measures of mnemonic performance and achievement, Ornstein and colleagues assessed 107 children at multiple times across the first-grade year. Three of these assessments conducted in the fall, winter, and spring included both the

Object Memory task (Baker-Ward et al., 1984) and Free Recall with Training task (Moely et al., 1992). Both the Object Memory and Free Recall tasks were used to measure children's deliberate memory, with Object Memory capturing children's spontaneous use of simple strategies for remembering and Free Recall tapping into children's ability to make use of a more complex strategy on which they were trained. Importantly, although the children did not vary in their strategic behavior on either task at the beginning of the school year, by the spring of grade 1, children who were taught by high mnemonic teachers exhibited more sophisticated strategy use on both tasks (Coffman et al. 2008). Interestingly, the same pattern of differences were seen in children's use of the trained sorting strategy in the Free Recall task throughout the second grade, even when these children were taught by different teachers (Ornstein, Coffman, & Grammer, 2007).

In addition to the linkages that Ornstein and colleagues identified between teacher mnemonic orientation and children's strategic abilities in the first and second grades, they have also found evidence for preliminary long-term implications of the first-grade classroom on children's strategic performance in later elementary school. When the children entered the fourth grade, they were administered a Sort-Recall task (Bjorklund, Ornstein, & Haig, 1977). In contrast to the Free Recall task that was used in grades 1 and 2 – with strongly-associated taxonomic materials – the new Sort Recall task was administered with low-associated items. By changing to materials that did not have salient interitem connections, it was possible to explore the extent to which the children sought out and imposed their own organization on the items when given instructions to remember. When focusing only on the 58 participating children who continued in the investigation from the first through the fourth grade and examining the differences in their sorting performance on the Sort-Recall task across grade 4, differences as a function of the first-grade classroom were identified (Grammer, Ornstein, & Coffman, 2008). Specifically, children who had a high mnemonic teacher in grade 1 made greater use of meaning-based sorting in the fall and the winter of the fourth grade year.

Similar long-term linkages were also found in children's performance on the Study Skills task (Brown & Smiley, 1977; 1978) used in the fourth and fifth grades (Grammer, Guthrie, Coffman, & Ornstein, 2008). This task, in which children were asked to "work to remember" a short passage derived from grade-appropriate science and social studies texts, was included to assess the development of academically-based study skills. Similar differences as a function of the first-grade classroom context were also observed among the continuing fourth graders in terms of their strategic behavior on the Study Skills task. Although these differences were not statistically significant in the fall at the first presentation of the task, in the winter and spring children in high mnemonic classrooms significantly outperformed their peers who had a low mnemonic first-grade teacher.

1.5.2 Linking the Classroom Context and Children's Mathematical Achievement

In addition to investigating the linkages between teachers' mnemonic orientation and children's strategies for remembering, Ornstein and colleagues have also explored the impact of instructional style on student achievement. Interestingly, inspection of the classroom observational data revealed that mathematics lessons were, on average, more mnemonically rich than language arts, in grades 1 through 5. Given these differences across subject matter in the same classrooms, Ornstein and colleagues examined the extent to which the teachers' mnemonic style in mathematics instruction might be linked to academic achievement in this subject area.

Analyses of the second grade data suggested that the teachers' mnemonic orientation when teaching mathematics (but not language arts) was related to growth across grade 2 in mathematics achievement, as assessed on the Woodcock-Johnson Tests of Academic Achievement (WJ-III). Indeed, although on average all children made gains in mathematics achievement across the second grade, the magnitude of the growth varied as a function of their teachers' mnemonic style in mathematics instruction On both the calculation and math fluency subscales, children who had second grade teachers who were classified as high mnemonic in mathematics showed significantly more improvement than children whose teachers were classified as low mnemonic in math.

1. 6 Experimental Studies of Context

The convergence of findings from observational studies conducted by Moely and Ornstein, indicate that instruction rich in metacognitive and memory-relevant language is important for children's mnemonic development. Importantly, the impact of this type of instruction does not seem to be limited to children's use of strategies within the first-grade alone. Their longitudinal findings suggest instead that the impact of the instructional environment in the first-grade classroom may have a long-lasting impact on children's skills for remembering. In addition, preliminary evidence of the importance of mnemonically rich instruction for children's achievement growth in mathematics – a strategy-rich content domain – provides further evidence for the potential importance of this type of instruction. Although linkages between children's memory performance and conversation with adults have been documented across these and other studies, the majority of these investigations have been correlational in nature. As a result, it is impossible to make causal statements about the impact of classroom instruction or maternal conversational style on children's mnemonic abilities.

To date, a few experimental manipulations of conversational style involving both mothers and trained experimenters have been conducted to further investigate the nature of the relations between context and preschooler's developing memory skills. For example, based on observations of mothers from longitudinal work demonstrating importance of enriched mother-child conversational interactions as events are jointly experienced for children's subsequent remembering (Haden et al., 2001; Hedrick, San Souci, Haden, & Ornstein, 2009), Boland, Haden, & Ornstein (2003) trained a group of mothers in the use of specific conversational techniques that were designed to enhance their children's remembering. Importantly, Boland and colleagues demonstrated that mothers could be trained to make use of elaborative conversational techniques while interacting in a novel event with their children and that the children of the trained mothers exhibited higher recall of the event the two experienced together than did the children of mothers who did not receive the training.

1.7 The Current Investigation

Just as Boland et al. (2003) capitalized on the findings of longitudinal observations of naturally occurring differences in maternal conversational style to experimentally test theories regarding the socialization of remembering in young children, the goal of this investigation is to extend the longitudinal work linking the classroom context to children's developing memory strategies. Up to this point, there have been no experimental manipulations of teacher mnemonic instructional style. Thus, the goal of experiment presented here is to provide a greater understanding of how teacher instructional style influences children's strategic memory skills. Ultimately, with converging evidence from longitudinal and experimental investigations, the objective is to be able to create future experimental manipulations of teacher style that will lead to instructional interventions with teachers in elementary school classrooms.

Specifically, in this experiment, children experienced an instructional unit of novel physics content involving Legos in one of two contrasting styles of instruction. These instructional activities were designed to supplement the children's experience in the camp or after-school program. Although all activities and material covered throughout the experiment were the same, differences in the presentation of the information across the instructional unit were modeled after naturally occurring variability observed in lessons in first-grade elementary school classrooms (e.g. Coffman et al., 2008). Thus, half of the children participating in the experiment experienced instruction that is rich in memory-relevant and metacognitive language similar to that observed by Ornstein and colleagues (2009) in high mnemonic classrooms through lessons designed to be high in the provision of *strategy suggestions* and *metacognitive questions,* as well as instances in which both *deliberate memory demands* and either *instructional activities*, *cognitive structuring activities,* or *metacognitive information* were present. Alternatively, the other half experienced the same instructional unit with significantly less of this type of instructional language.

In addition to this instructional manipulation, at both the beginning and the end of the instructional unit, the children participated in assessments of their strategic memory skills, memory capacity, and knowledge of the content presented. Along with more frequently used measures of memory strategy use, including the Object Memory task (Baker-Ward et al., 1984) and the Free Recall with Organizational Training task (Moely et al., 1992), children's strategic behavior when asked to remember content specific items was measured with a newly created Content Specific Sort-Recall Task. Children's understanding of Lego building strategies and knowledge of the content presented were also assessed. Relations among performance on these child-level tasks were explored, and the impact of memory-rich and low-memory instruction on these skills was examined.

Paralleling the results of training conducted by Boland and colleagues, preliminary pilot testing of the instructional unit utilized in this investigation was conducted. Importantly, results from this initial work – including one week of memory-rich instruction and one week of lessons characterized by the provision of less memory-relevant information – indicated that it is possible to successfully train teachers to make use of memory-rich instruction. Moreover, data collected through observations of instruction and child-level tasks have provided helpful information that informed both the goals and hypotheses of the project, as well as revisions in the design of the experiment.

1.8 Goals and Hypotheses

Goal 1: To successfully train an instructor in the use of memory-rich and low-memory modes of instruction.

Question and Hypotheses:

1A. Can an instructor be trained to vary the presentation of the instructional unit as a function of memory- and metacognitively-rich language?

i. After a series of initial training sessions, instructors will be able to successfully implement memory- and metacognitively-rich language in the context of the lessons provided.

ii. Coding of videotaped instruction will reveal that the percent occurrence of individual instructional codes in the lessons, including *strategy suggestions* and *metacognitive questions* as well as combination codes such as *deliberate memory demands* and either *instructional activities*, *cognitive structuring activities,* or *metacognitive information,* in the memory-rich and low-memory conditions that are similar to those observed in high and low mnemonic classrooms reported by Coffman et al. (2008).

Goal 2: To examine relations among measures of children's performance on assessments of mnemonic skill and content knowledge.

Question and Hypotheses:

2A. What are the relations among measures of memory strategy use and recall?

i. Moderate correlations among measures of recall on all three memory tasks (Object Memory, Free Recall with Organizational Training, and Content Specific Sort Recall) will be found at the pretest, posttest, and 1-month follow up assessments.

ii. Linkages between children's use of strategic sorting on the Free Recall and Content Specific Sort Recall tasks will be found after children gain knowledge about the content based on experiences during the instructional unit.

2B. What linkages will exist between children's content and strategic understanding and Lego building skills?

i. In advance of the instructional unit at the pretest assessment, children's content knowledge and building performance not be highly related to one another.

ii. Linkages between these skills will be higher at the posttest and 1-month assessments.

2C. Will children's performance on the Content Specific Sort-Recall task be related to their content knowledge?

i. Prior to instruction, low correlations will be seen between performance on the Content Specific Sort-Recall task and content knowledge.

ii. After experiencing instruction, across both conditions, higher correlations will be seen among children's strategy use, recall and content knowledge.

Goal 3: To examine children's performance in measures of memory strategy use, knowledge of the instructional content, the sophistication of building strategies as a function of assignment to memory-rich or low-memory condition.

Question and Hypothesis:

3A. Do children across both instructional conditions perform similarly on baseline measures of memory capacity and strategy use?

i. Children assigned to both conditions will exhibit similar levels of working and short-term memory and there will be no differences at the baseline measure in terms of children's strategy use and recall.

3B. After experiencing different forms of instruction, do children in the memory-rich instructional condition outperform their peers in the low-memory condition on memory strategy measures?

i. Strategy use and recall from the Free Recall with Training task and recall in the Object Memory task will be shown to be higher at the posttest and 1-month assessments for children in the memory-rich condition .

ii. In addition to superior strategy use initially on the Free Recall task, at the posttest and 1-month assessments, children in the memory-rich instructional condition will be shown to have benefited more from the training they receive in the Free Recall task. These gains will be seen in their strategic sorting and clustering as well as recall.

iii. Children in the memory-rich condition will use more sophisticated methods of sorting the content related materials than children in the low-memory condition.

3D. After experiencing different forms of instruction, do children in the memory-rich instruction condition outperform their peers in the low-memory condition in measures of content knowledge and building strategies?

i. Children in both groups will have relatively low amounts of knowledge about the content covered during the experiment at the baseline assessment.

ii. After experiencing instruction, all children will have increased knowledge of the material presented, as evidenced by higher scores on the knowledge assessment.

iii. Coding of the verbal reports of the children during the talk-aloud Lego Building task will reveal that children who experience memory-rich instruction will make use of more sophisticated building strategies when compared to students in the low-memory condition.

iv. At the posttest and 1-month assessments, children who experience memory-rich instruction will have greater increases in scores on the knowledge assessment relative to students in the low-memory condition.

II. Method

2.1 Participants

The participants included 54 children, 25 boys and 29 girls, recruited from local after-school programs in the Chapel Hill-Carrboro City Schools in three elementary schools. All of the participating children were drawn from after-school programs in which they had been previously enrolled by their parents. At the beginning of the experiment, the children were 7 years and 2 months of age, on average, and included an even number of first and second grade students. The diversity of the sample reflected the southern suburban area from which the participants were drawn, with 57% of the families describing their ethnicity as Caucasian, 15% as African American, 11% as Latino, 11% as Asian, and 6% as being mixed ethnicity.

2.2 Design and Procedure

2.2.1 The Instructional Experience

Each child participated in an instructional unit themed around "Things that Move." These units consisted of 10 hour-long lessons that were held across 10 consecutive weekday afternoons during the after-school program. In total, six separate instructional units, each including 7 – 10 children, were led by instructors and assistants.

Each of the 1-hour lessons was organized around basic physics concepts, with specific emphasis placed on the utility of simple machines, the wheel and axle, and gears. The lesson content was chosen after a review of the North Carolina Standard Course of Study for science education revealed that these concepts are not taught in public elementary schools in kindergarten, first, or second grade, ensuring that the content covered would be novel for most if not all of the participating children. All of the activities and lessons were developed with the assistance of elementary school teachers to be grade appropriate. A range of activities, including mini-reading and mathematics activities, were also included to engage the children with the new concepts presented.

Complementing these lessons, Lego Simple Machine sets were also used to facilitate children's exploration of these concepts by allowing the children to build machines with wheels and axles on their own. During each day of instruction, new content information about topics such as simple machines, Lego terminology and building techniques, gears, or gear ratios, was presented. Broadly, children participated in activities that include researching and learning about specific simple machine terminology, planning out machines to build, examining gear ratios, and building machines involving wheels, axles, and gears to test out the concepts learned. An outline of the lessons and activities for each day can be seen on the following page in Table 2.

Table 2 - *Lesson Activity Outline*

Week 1

Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Simple Machines **Content:** • Engineering • Simple machines • Introduction to things that move • Initial Lego build	***Wheels & Axles*** **Content:** • Introduction of wheels and axles • Introduction to Lego sets • Building wheel and axle combinations with Legos	***Sturdy Cars*** **Content:** • Discussion of sturdy structures • Building walls to pass the flick test • Practicing other ways to connect Legos	***Drop Test*** **Content:** • Engineer plans • Building cars with wheels and axles • Drop tests	***Force & Distance*** **Content:** • Introduction of force and distance • Measuring force relative to wheels size
Activities: • Discussion of simple and compound machines • Brainstorming different types of things that move • Using Lego sets to identify types of Legos build tallest and flattest structures	**Activities:** • Discuss background information about wheels and axles • Book: "Wheels, Axles, Spokes, and Sprockets" • Brainstorm types of wheels and axles, differentiate between two forms • Introduce new Lego sets • Sliding vs. Rolling Activity with Legos	**Activities:** • Three Little Pigs • Introduce sturdy structures with house and other structural examples • Building walls and testing with the "flick test" • Strongest shape activity to demonstrate use of other Legos (e.g., connector pegs, bushings)	**Activities:** • Planning and drawing plans for car building • Building cars in pairs • "Drop test" • Group discussion about car building and "drop test" results	**Activities:** • Toy truck activity – measuring force relative to wheel size • Group hypothesis generation about speed of cars built previously • Testing force relative to wheels size with Lego cars on ramp and other surfaces

Week 2

Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
Gear Introduction **Content:** • Introduction of Gears • Initial discussion of gear trains and gear ratios	***Gear Trains*** **Content:** • Building gear trains with all of the gear types • Counting gear ratios	***Cars with Gears*** **Content:** • Building Lego cars with gears	***Final Build*** **Content:** • Planning and starting final builds	***Wrap Up*** **Content:** • Finalize car building • Testing cars for speed and friction • Letter writing
Activities: • Introduction to gears and new terms related to them • Brainstorm examples of gears, examine examples like egg beater • Bike activity – counting gears and describing their importance to aiding in work	**Activities:** • Introduce remaining gear types • Discuss different jobs of different types of gears • Building gear trains with Lego pieces • Introduce building goal for next day – car with gears • Plan for car building with gears for the next day	**Activities:** • Revisit planning before building with the Legos • Build Lego cars with gears in pairs • Share cars with group • Complete engineer logs for car and gear building	**Activities:** • Brainstorm building vehicles • Begin planning for final build with engineer notebook and planning activities • Begin building final vehicles	**Activities:** • Finish building final vehicles • Test vehicles on different surfaces and different ramp sizes • Complete final engineer logs • Letter writing

2.2.2 Teacher Instruction

Each 10-day instructional unit was led by a certified elementary school teacher who was also a trained member of the research team. A total of three teachers participated in extensive training on the lesson content and Lego building techniques. Each of these teachers received the same background information on the Legos and physics concepts to review to supplement their training, and was also trained to instruct the lessons in both memory-rich and low-memory styles of instruction.

Following this initial introduction to the lesson materials, teachers were randomly selected to first teach the unit using either high levels of memory-relevant language or low levels of memory-relevant language. Thus, during the course of the experiment, each of these three teachers taught two separate groups of children. Each condition was labeled by color (either Green or Blue), and the teachers were not provided with specific information about the basis for the manipulation. The teachers were instead told that each unit was developed to focus differentially on two different ways in which information could be presented to students. The teachers were then instructed in the specific elements that were to be focused on in advance of each instructional unit and provided with scripted lessons to study in advance of teaching each unit.

Experimental Manipulation. Participating children were assigned to either a memory-rich or low-memory instructional unit. The children were randomly assigned to each condition, with special consideration given to (a) family schedules and (b) balancing the grade levels of participants across conditions. Both sets of children across the two conditions took part in the same activities and were presented identical information during the course of the experiment. To achieve differences in instructional styles, however, lessons were written to vary as a function of subtle linguistic differences identified in the longitudinal investigation of Ornstein and his colleagues as being potentially important for the emergence of children's strategy use. For sample memory-rich and low-memory lessons, see Appendices F and H, respectively.

More specifically, during the memory-rich lessons, the instructor made more frequent use of *strategy suggestions* and posed greater numbers of *metacognitive questions* of the children. In addition, in the memory-rich condition, the instructor more regularly requested that the children remember information such as facts, events, or procedures, in conjunction with other routine instructional activities thought to support children's remembering. These included *instructional activities* (e.g. book reading and providing general information), *cognitive structuring activities* (e.g., identifying features and categorizing information) or the provision or solicitation of *metacognitive information*. Examples and definitions of each of the instructional elements that were used more frequently in the memory-rich instructional condition can be seen in Table 3.

Table 3

Memory-Relevant Instructional Techniques

Instructional Techniques	**Definitions**	**Example**
Strategy Suggestions	Recommending that a child adopt a method or procedure for remembering or processing information	"If you are having trouble thinking of ways to connect the wheel and axle, you can look at the diagram to help you."
Metacognitive Questions	Requesting that a child provide a potential strategy, a utilized strategy, or a rationale for a strategy they have indicated using	"How did you figure out which pieces you would need to build a sturdy structure? How did you know that would work?"
Instructional Techniques Co-Occurring with Deliberate Memory Demands		
Instructional Activities	Requests for information from memory **and** the presentation of instructional information by the teacher	"Today we will be building our own cars. Who knows the first step we take when building a new structure?"
Cognitive Structuring Activities	Requests for information from memory **and** teacher instruction that could impact the encoding and retrieval of information, such as focusing attention or organizing material	"All of these modes of transportation have wheels. What is another vehicle that you have seen around town that also has wheels?
Metacognitive Information	Requests for information from memory **and** the provision or solicitation of metacognitive information	"What kind of gear is this? What clue did you use to help you figure that out?"

The goals for the extent to which instruction varied along the targeted instructional elements – or more specifically, in the percent of instructional intervals the instructor engaged in the techniques seen in table below – were based on the naturally-occurring variability in the lessons observed by Coffman et al. (2008) in contrasting groups of high- and low-mnemonic teachers (for additional information see Table 1 above). In addition to the scripted whole group mini lessons for each of the 10 lessons, the instructors and research assistants who aided with the lessons were all trained in the use of memory-rich and low-memory language to use in their one-on-one interactions with the children. For an overview of memory-rich (blue) and low-memory (green) instructional goals provided to each teacher, see Appendices D and E. Target percentages for the scripted lessons, based on those observed in high and low mnemonic first-grade classrooms observed by Coffman and colleagues, can be seen in Table 4. To help ensure instructor fidelity to the content and instructional style, an experimenter was present during each of the lessons to observe the presentation. Based on these observations, the instructors were also provided with daily feedback during and after each lesson regarding both the content covered and, when necessary, the use of memory-relevant language. In addition, all instructional activities, including whole-group lessons and one-on-one interactions with the children were filmed for subsequent coding and analyses.

2.2.3 Child-level Assessments

During the project, the children participated in pretests and posttests of their memory strategy use and their knowledge of the concepts covered during the instructional experience, as well as an assessment of their long-term retention of the lessons covered and strategic skills. The first assessment took take place in advance of the instructional unit, serving as a baseline measure of the children's performance on the memory tasks and their understanding of the instructional content prior to the start of instruction. The posttest assessments took place within 1 to 3 days after the completion of the instructional unit. The final assessment was conducted 1 month after the posttest assessment. Each of these assessments was conducted one-on-one with individual children by a trained experimenter and lasted around 40 to 45 minutes. The assessment battery included measures of deliberate strategy use, memory capacity measures, and assessments of children's content specific knowledge and strategy use. In addition, to measure children's receptive language, the Peabody Picture Vocabulary Test-Revised (PPVT-IV) (Dunn & Dunn, 2007) was administered at the final assessment. An outline of the assessment plan and the task order at the pretest, posttest, and 1-month follow up assessments can be seen below in Table 4.

At the pretest, posttest, and 1-month assessments, all children were seen. Equipment failure and children's non-compliance led to the loss of only a few measures (range = 0 – 2) per assessment point.

Table 4

Child Assessment Battery

Pretest	**Posttest**	**1 Month Follow up**
Object Memory	Object Memory	Object Memory
Free Recall	Free Recall Generalization	Free Recall Generalization
Free Recall with Training		
Knowledge Assessment	Knowledge Assessment	Knowledge Assessment
Lego Building Task	Lego Building Task	Lego Building Task
Content Specific Sort Recall	Content Specific Sort Recall	Content Specific Sort Recall
Free Recall Generalization	Digit Span	PPVT

2.3 Measures

2.3.1 Assessments of Instructional Fidelity

Instructional Style.

Rationale: Throughout the experiment, instruction was videotaped for later coding in the laboratory. In addition to the scripted lessons, one-on-one interactions between the instructor and individual students were also documented. Informal observations were conducted during each of the lessons to provide feedback to the instructor and ensure instructional fidelity.

Coding and Measures: Instructional style during whole-group interactions between the instructor and children were assessed using the *Taxonomy of Teacher Behaviors* (see Appendix A; Coffman et al., 2008). Specifically, 1-hour lessons from the 2nd, 3rd, 7th, and 10th day of each instructional unit were selected for coding using the Taxonomy. Videos of instruction were coded using Noldus Observer 9 with decisions made for each 30-second interval of instruction. The percentage of intervals that contained the individual codes as outlined in the Taxonomy was observed for each individual was assessed and examined for whole-group and one-on-one interactions separately.

Reliability: Prior to coding on this project, all coders reached initial reliability with a master coder by coding a set of 8 lessons that totaled 1 hour of instruction and reflected kindergarten, first and second grade lessons across several content areas. All coders reached at least 80% agreement on each of the master files.

2.3.2 Child-Level Assessments – Memory Measures

Object Memory Task (Baker-Ward et al., 1984).

Rationale. This task was developed to assess the types of behavioral and linguistic strategies children display while attempting to remember a set of stimulus objects. It was included as a part of the battery so as to document the use of relatively simple techniques for deliberate remembering.

Method. Following procedures used by Baker-Ward et al. (1984), the children were asked to remember sets of 15 familiar and colorful objects. At each of the three assessments, the children were given a 2-minute study period and told that it was important to "work to remember these things." At the conclusion of the study period, the examiner hid the objects and asked the child for recall. Three different object sets were counterbalanced across participants and assessment points.

Coding and Measures: Recall measures were obtained by the experimenter and were later checked by reviewing the video-taped session.

The Free-Recall with Organizational Training Task (Moely et al., 1992).

Rationale: Some young children are able to evidence relatively sophisticated deliberate memory skills, such as those involved in organizing a set of to-be-remembered materials. This task, adapted from Moely and colleagues (1992), was included to measure the use of organizational strategies for sorting and clustering.

Method: At the pretest assessment, each child was presented with three individual trials of the Free-Recall task, including baseline, training, and generalization assessments. At the posttest and 1-month follow up, children were presented with a single non-instructed generalization trial.

At the baseline trial at the pretest, the picture cards were presented in a quasi-random order such that categorically-related items were not displayed alongside each other, and the children were told to do whatever they could to remember the pictures. On the subsequent training trial, the children were instructed in the use of categorization during study (sorting) and recall (clustering) as aids for remembering. To assess children's ability to make use of sorting and clustering strategies in the absence of specific instructions to do so, a generalization trial was administered 15 minutes later with a new set of cards. Four card sets with different groups of pictures were counterbalanced across participants and assessment points. Subsequent assessments of generalization of the trained sorting strategy were obtained at the posttest and 1-month follow-up.

Coding and Measures: Throughout the administration of the task, the experimenter recorded the children's sorting patterns, the number of items recalled, and the order in which the items were recalled. With this information, a standard index of categorical grouping, the Adjusted Ratio of Clustering (ARC) Score (Roenker, Thompson, & Brown, 1971), was calculated to characterize the children's sorting during the study period. The ARC scores could range from -1 (below chance organization), to 0 (chance), to 1 (complete categorization).

Reliability: Two coders independently scored all records, with any discrepancies being resolved through examination of the original videotapes.

Content Specific Sort-Recall Task (Bjorklund et al., 1977).

Rationale: The purpose of this task was to assess children's use of spontaneous semantic organization when presented with items that were related to the content learned during the instructional unit, but that might not have clear salient connections between them before exposure to the information presented during the experiment. By using materials drawn from the content that was unfamiliar at the initial assessment point that children would not view as having salient inter-item connections, it was possible to explore the extent to which the children imposed their own organization on the items. At the subsequent assessments, children's sorting patterns could be examined in relation to their newly acquired knowledge of the content. In addition to measures of children's semantic organization, the number of correctly identified Legos upon initial presentation, and recall data were also gathered with this task.

Method: At each assessment point, children were presented with one of two counterbalanced sets of 15 pictures of Lego pieces including, plates, beams, gears, wheels, axles, and bushings. At the beginning of the task, children were asked to label each picture. If they could not identify an image, the experimenter provided the correct name for each item. The experimenter then asked each child to form groups with the cards on a sorting board that will help him or her to remember. The children were further instructed that they could make as few as two or as many as five groups with the cards. Each child was given three minutes following presentation of the cards to sort the cards into groups and "work to remember." During the study period, the experimenter made notes that captured the sorting patterns of the children. Recall for the items was assessed immediately following the study period. In addition, following the trial, the experimenter asked the child to explain the groups and to nominate anything that he or she did to help remember.

Coding and Measures: Review of the video-taped assessments was conducted to first assess the number of correctly identified Lego pieces. Next, children's use of an organization sorting strategy was scored by two independent raters. Each sorted group was initially scored to reflected the extent to which the cards were sorted randomly or based on visual aspects of the Lego pieces (i.e., color or shape), functional relationships among the pieces, or semantic associations among the items (for additional information, see Appendix J). Ratings for the overall sorting patterns of each child were then made based on the records of the sorted groups and the children's self-reported rationales. Scores ranged from 0 (sorting was done at random), to 2 (at least one of the groups were sorted on the basis of semantic or functional linkages), to 4 (the majority of the groups were organized by strong semantic of functional associations).

Reliability: All files were scored independently by two coders for comparison. Discrepancies were later resolved through discussion, and a third coder scored each file to reach agreement, when necessary.

2.3.3 Child-Level Assessments – Content Specific Tasks

Lego Building Task.

Rationale: The Lego Building task was designed for this experiment in order to measure the children's understanding of Lego building strategies and their Lego building skill. In this task, the children were asked to work at building a small vehicle using an instruction manual and Lego building blocks.

Method: At the beginning of this task, children were presented with one of three counterbalanced sets of Legos. Each of the three Lego sets contained 18 Lego pieces needed to build the structure, 10 lure Lego pieces, and 6 cards with pictures of each of the six building steps. All building steps were balanced for the number of pieces added with the presentation of each picture, and each set was pretested for difficulty in advance of the investigation. In addition, the lure Lego pieces were specifically chosen to be similar to the ones needed to complete the "build," varying on dimensions such as size and color.

At the beginning of the task, the children were told that the experimenter was trying to make an instructional video to share with other children to show them how to build with Legos. In an effort to elicit their strategic knowledge about Lego building, the children were also asked to talk out loud while building and were told that the experimenter may ask questions about what each individual is doing while he or she is building. The experimenter then showed each child the six cards with pictures that provided building instructions. These were presented one-by-one to the child as he or she completed each building step. At the presentation of each card, the experimenter asked a series of standardized prompts such as, "Tell me about what you are doing next." and "Explain to me which pieces you would need" while presenting the building instructions to elicit children's strategic and procedural knowledge about Lego building. If the child completed a step incorrectly, the experimenter would the child if he or she needed assistance. If the child agreed, the experimenter would fix the step without providing any additional feedback and allow the child to continue building. At the completion of the build, the children were asked to share any tips or strategies that they might tell their friends if they were going to build a similar Lego structure. This task was conducted at the pretest, posttest, and 1-month follow up. The entire task was videotaped, and extensive experimenter notes were made to capture the accuracy of children's building and verbalizations during the task.

<u>Coding and Measures:</u> Accuracy in building was documented by the experimenter while working with each child. Subsequent video transcription was conducted to capture the language used by the children during the task. Each of these transcriptions was then coded by two independent raters who first coded the utterances made by the children during each of the building steps. Each utterance was coded for the extent to which it referred to strategy use, building procedures, and comments relevant to the task (for additional details, see Appendix K).

Based on these codes, the raters then classified children's language for each building step as being either procedural (e.g., direct reference to the procedure of building, "I am putting this piece here and next I put this piece there.") or strategic (e.g., "I counted the dots on the Legos in the picture so I know that this one is the right piece."). Thus, for each step during which the child described his or her building, a code was given to capture the strategy relevant talk. The same coding system was used to rate children's recommendations to their peers about what they should do if they were to build the same structure, allowing for the classification of strategic verses procedural recommendations.

Reliability: All files were scored independently by two coders for comparison. Discrepancies were later resolved through discussion, and a third coder scored each file to reach agreement when necessary.

Knowledge Assessment.

Rationale: An assessment of content knowledge was developed to measure children's knowledge of the Legos and concepts introduced as well as Lego building strategies that were provided throughout the instructional unit.

Method: The children were read a series of questions designed to tap into content covered during the instructional unit. Multiple choice and fill in the blank questions were used to assess children's factual knowledge of the content presented. A total of 26 points could be earned for answering each of the questions correctly.

In addition to these items, to tap into the children's strategic knowledge, eight free answer questions were posed, including ones in which the children were asked to describe their approaches to solving a Lego building challenge or to outline their strategies for Lego building. The children completed the same knowledge assessment at the pretest, posttest, and 1-month assessment.

Scoring and Measures: The children's responses to multiple choice and fill in the blank questions were scored as being correct or incorrect, and the number correctly answered out of 26 was determined. Responses to open ended questions were transcribed, and scored for the number of correct, unique responses.

2.3.4 Child-level Assessments – Memory Capacity and Language

Digit Span.

Rationale: The Digit Span task (McCarthy, 1972) was included to provide a measure of children's short term (forward span) and working memory (backward span).

Method: Following standardized assessment procedures, during the posttest assessment, two forward and backward span trials were administered. On each forward span trial, strings of numbers of increasing length were presented, with the child's task being that of repeating the numbers in sequence. On each backward span trial, strings of numbers were presented, and the children were asked to repeat the numbers in the opposite order from which they were read.

Scoring and Measures: The child's forward and backward span was measured as the length of the longest string of digits (out of the two administered trials) that could be produced without error. Two coders independently scored all records, with any discrepancies being resolved through examination of the original coding sheet.

PPVT.

The Peabody Picture Vocabulary Test-Revised (PPVT-IV) (Dunn & Dunn, 2007) was conducted at the final 1-month assessment to measure receptive language. Using standardized assessment procedures, in this task the children were shown four pictures and asked which one best describes a given word, and their standardized scores were calculated.

2.3.5 Parent Questionnaire

Parents of each of the participating children were asked to fill out a brief questionnaire (Appendix L). The questionnaire was designed to provide information about the home environment that may be relevant to children's memory development. Included in this questionnaire is the Home Literacy Environment Index (Griffin & Morrison, 1997) that provides a measure of the home literacy environment, as well as a home numeracy scale (LeFevre et al., 2009), and two subscales from the short form of the Children's Behavior Questionnaire (Putnam & Rothbart 2006).

III. Results

The results presented below are organized to reflect the three main project goals that include: (1) to train instructors in the use of contrasting levels of memory-relevant language during instruction, (2) to explore relations among measures of the children's performance on assessments of mnemonic skill and content knowledge, and (3) to examine the children's performance on measures of memory strategy use, knowledge of the instructional content, and sophistication of building strategies, as a function of assignment to memory-rich or low-memory condition.

First, results from coded lessons are presented to describe the instructional manipulation in detail. In addition to providing information overall about observed instructional activities, the use of instructional techniques across each instructional condition is also examined. Next, children's performance on memory strategy measures is presented, followed by descriptions of outcomes related to content covered in the instructional unit. In addition to describing the mean performance of children on each of these tasks, differences as a function of grade and gender are also explored. After outlining outcomes for each of these individual tasks, linkages between these outcomes and children's receptive language, working memory, and short-term memory are described. Following this, associations across each of these tasks are explored.

Finally, differences in children's performance on posttest and 1-month follow up assessments on measures of memory strategy use and skills related to the instructional unit are presented. In addition, significant differences in children's use of sorting strategies on the Content Specific Sort-Recall task as well as strategy knowledge as a function of instructional condition are explored and described in greater detail.

3.1 The Instructional Manipulation

Coding was carried out for the subsample of the videotaped lessons using Noldus Observer 9. For each lesson, coding decisions were made for each 30-second interval of whole group instruction. Across the four lessons selected, a total of 1,058 minutes of data were coded for each instructional unit using this method, resulting in 2,117 coded intervals of instruction.

For each of the sessions taught, four lessons including the same content were coded. Specifically, for three separate sets of memory-rich lessons and three sets of low-memory lessons, whole group activities during days 2, 3, 7, and 10 were coded (lesson outlines for each day can be found in Appendices F, G, H, and I). The mean percent of intervals containing each code can be seen below, averaged across the lessons from each of the two conditions. In total, 1,141 memory-rich and 976 low-memory intervals are reflected below (see Table 5).

Table 5.

Mean Percent Occurrences of Teacher Behaviors in Memory-Rich and Low-Memory Lessons

	Overall	Memory Rich	Low Memory
Implied Deliberate Memory Demands	33.6%	35.3%	32.0%
Expressed Memory Demands	9.6%	11.0%	8.1%
Instructional Activities – Category Total	85.1%	81.7%	88.5%
Book Reading	9.3%	8.7%	9.8%
General Information Giving	61.6%	58.5%	64.7%
Prospective Summary	9.1%	8.3%	9.8%
Specific Task Information	41.3%	37.7%	44.9%
Cognitive Structuring – Category Total	37.4%	40.9%	33.9%
Attention Regulation- Behavioral Goal	11.0%	10.4%	11.6%
Attention Regulation- Instructional Goal	17.0%	18.2%	15.8%
Massed Repetition	0.2%	0.4%	0.1%
Identifying Features	6.6%	6.1%	7.1%
Categorization	3.3%	3.9%	2.7%
Identifying Relationships	6.6%	6.1%	7.1%
Connections- Personal Experiences at Home	1.4%	1.4%	1.4%
Connections- Personal Experiences at School	10.4%	12.3%	8.5%
Drawing Inferences	1.7%	0.9%	2.6%
Visual Imagery	0.1%	0.3%	0.0%
Memory Requests – Category Total	43.2%	46.3%	40.1%
Episodic	7.0%	6.3%	7.7%
Semantic	33.9%	37.3%	30.4%
Procedural	0.8%	1.3%	0.3%
Prospective	0.8%	1.0%	0.7%
Anticipated	3.7%	4.3%	3.2%
Metacognitive Instruction – Category Total	14.8%	25.4%	4.1%
Metacognitive Rationale	0.9%	1.8%	0.1%
Metacognitive Questioning	9.5%	16.8%	2.3%
Suggestion	6.0%	10.4%	1.6%
Suppression	0.2%	0.3%	0.1%
Replacement	0.1%	0.1%	0.1%
Co-occurrence of Deliberate Demand with:			
Instructional Activities	36.7%	37.7%	35.7%
Cognitive Structuring	21.5%	25.5%	17.5%
Metacognitive Information	7.3%	12.6%	2.0%

Inspection of Table 5 reveals that, in general, in both instructional units the teachers spent the majority of observed intervals engaged in *instructional activities*. The percent occurrence of individual instructional activity codes can be seen directly below the overall amount of instructional activities. It should be noted that the overall percent of observed intervals for a subset of codes is not equal to a sum of each of the individual codes within a specific area. Instead, it was possible for 2 or more instructional activities to have been observed in a single interval. In general, even though these activities were seen across both memory-rich and low-memory lessons, low-memory instruction involved greater amounts of *instructional activities* ($_{\text{Memory Rich}}$=81.7% and $M_{\text{Low Memory}}$=88.5%). Indeed, even though activities such as book reading, occurred equally as frequently across both sets of lessons, low-memory lessons included more intervals than high memory units that involved specific task instructions ($M_{\text{Memory Rich}}$=37.7% vs. $M_{\text{Low Memory}}$=44.9%) and general information giving ($M_{\text{Memory Rich}}$=58.5% and $M_{\text{Low Memory}}$=64.7%).

Cognitive structuring activities were also commonly observed during the scripted whole-group lessons (M=37.4%). In this case, these instructional techniques were observed more regularly during memory-rich (M=40.9%) as opposed to low-memory (M=33.9%) lessons. Inspection of the percent occurrence of individual codes reveals, for example, that memory-rich lessons included more instances in which teachers made explicit reference to categorizing information than did low-memory lessons. Comparable differences were also observed in the teachers' efforts to direct the children's attention toward an instructional goal and to reference experiences that the children previously had at school.

Overall, a considerable number of intervals of instruction included some form of deliberate memory demand (M=43.2%), but these types of demands were made with greater frequently in memory-rich (M=46.3%) as opposed to low-memory (M=40.1%) lessons. The majority of these requests were made for semantic information ($M_{\text{Memory Rich}}$=37.3% and $M_{\text{Low Memory}}$=30.4%). Moreover, of these deliberate memory requests, on average, 9.6% involved an explicit reference to remembering.

The greatest differences in instruction across the two conditions was found in the percentage of intervals during which teachers provided or requested *metacognitive information* of the children ($M_{\text{Memory Rich}}$=25.4% and $M_{\text{Low Memory}}$=4.1%). As can be seen below, on average, instruction in the memory-rich lessons included higher frequencies of *strategy suggestions* ($M_{\text{Memory Rich}}$=10.4% vs. $M_{\text{Low Memory}}$=1.6%) and *metacognitive questions* ($M_{\text{Memory Rich}}$=16.8% and $M_{\text{Low Memory}}$=2.3%).

Importantly, inspection of Table 6 also reveals that the percentage of intervals containing the subset of codes targeted in the memory-rich condition (*strategy suggestions, metacognitive questions, and the co-occurrence of deliberate and instructional activities*, *cognitive structuring activities* and *metacognitive information)* differed substantially across the two instructional conditions. Moreover, when comparing these results to those naturally observed in grade 1 classrooms on which the manipulation was based (in the last two columns on the right side of the table), it appears that training was clearly successful in that it resulted in the instructors' use of differing levels of strategy suggestions and metacognitive questions. Indeed, the percent occurrences of each of these codes was greater for the memory-rich instructional condition than was observed in grade 1 high mnemonic classrooms studied by Coffman et al. (2008).

Table 6

Mean Percent Occurrences of Memory-Relevant Instructional Techniques in the Experimental Investigation and Grade 1 (Grade 1 values drawn from Coffman et al., 2008)

	Experimental Instruction			Grade 1	
	Overall	Memory Rich	Low Memory	High Mnemonic	Low Mnemonic
Instructional Techniques					
Strategy Suggestions	6.0%	10.4%	1.6%	7.3%	2.5%
Metacognitive Questions	9.5%	16.8%	2.3%	6.9%	2.9%
The Co-Occurrence of Deliberate Memory Demands and:					
Instructional Activities	36.7%	37.7%	35.7%	42.1%	33.2%
Cognitive Structuring Activities	21.5%	25.5%	17.5%	25.4%	21.5%
Metacognitive Information	7.3%	12.6%	2.1%	8.9%	2.8%

In addition to differences observed in the provision of specific metacognitive techniques, differences in the combined occurrence of deliberate memory demands and instructional activities, cognitive structuring activities, and metacognitive information in the scripted lessons were also found to be similar to those naturally occurring in the first grade classroom. Indeed, as can be seen in the bottom half of Table 6, as was the case in the lessons of the first grade teachers observed by Coffman et al. (2008), memory-rich (*M*=37.7%%) and low-memory (*M*=35.7%%) lessons were observed to be relatively comparable in the percentage of intervals in which instructional activities and deliberate memory demands were made. In contrast, memory-rich lessons were found to contain a greater percentage of intervals involving both cognitive structuring activities and deliberate memory demands than low-memory lessons.

3.1.1 Effectiveness of the Instructional Manipulation

As mentioned above, each instructor taught two 2-week sessions, one in each of the contrasting instructional styles. To determine the extent to which individual teachers were able to make use of the memory-rich and low-memory instructional techniques, the percent occurrence for each lesson type was compared. These values, presented in Table 7, indicate that although there was variability in the use of individual codes during lessons taught by the teachers, each individual teacher was able to implement the two types of lessons with contrasting amounts of memory-relevant language. For example, when considering each individual teacher's provision of metacognitive information across the two instructional unit each taught, it is apparent that they were able to use this type of language during instruction in the memory-rich lessons and suppress it in the low-memory lessons.

Table 7 – *Mean Percent Occurrences of Teacher Behaviors in Memory-Rich and Low-Memory Lessons for Individual Teachers*

	Teacher 1		Teacher 2		Teacher 3	
	Memory Rich	Low Memory	Memory Rich	Low Memory	Memory Rich	Low Memory
Instructional Activities – Category Total	83.2%	81.0%	80.0%	91.5%	82.1%	91.9%
Book Reading	8.8%	12.4%	9.4%	10.2%	7.8%	7.6%
General Information Giving	54.4%	53.8%	57.9%	69.8%	62.6%	68.8%
Prospective Summary	8.5%	13.8%	7.2%	5.2%	9.4%	10.5%
Specific Task Information	40.0%	41.0%	36.5%	40.0%	36.9%	51.7%
Cognitive Structuring – Category Total	40.6%	22.8%	37.7%	40.7%	44.7%	37.0%
Attention Regulation- Behavioral Goal	5.6%	10.0%	11.3%	13.4%	13.8%	11.3%
Attention Regulation- Instructional Goal	24.1%	13.1%	13.9%	15.7%	17.7%	17.8%
Massed Repetition	0.9%	0.0%	0.0%	0.3%	0.3%	0.0%
Identifying Features	4.1%	1.4%	5.5%	13.8%	8.6%	6.0%
Categorization	3.8%	0.7%	2.2%	6.2%	5.7%	1.3%
Identifying Relationships	6.2%	1.4%	6.3%	3.9%	8.3%	4.2%
Connections- Personal Experiences at Home	2.1%	2.8%	1.4%	1.0%	0.8%	0.8%
Connections- Personal Experiences at School	8.2%	4.8%	14.7%	9.2%	13.2%	10.8%
Drawing Inferences	1.2%	3.1%	0.7%	1.6%	0.8%	2.9%
Visual Imagery	0.0%	0.0%	0.2%	0.0%	0.5%	0.0%
Memory Requests – Category Total	47.4%	33.1%	44.0%	44.3%	47.8%	42.0%
Episodic	7.1%	8.3%	6.0%	5.9%	6.0%	8.7%
Semantic	39.1%	22.8%	36.3%	37.0%	36.9%	31.0%
Procedural	0.9%	0.7%	0.5%	0.0%	2.6%	0.3%
Prospective	0.3%	0.7%	0.7%	1.3%	1.8%	0.3%
Anticipated	4.7%	2.1%	3.4%	2.3%	4.9%	4.7%
Metacognitive Instruction – Category Total	19.7%	2.4%	23.8%	2.6%	32.2%	6.6%
Metacognitive Rationale	0.6%	0.0%	1.0%	0.0%	3.6%	0.3%
Metacognitive Questioning	12.6%	2.4%	17.3%	1.6%	20.0%	2.6%
Suggestion	6.8%	0.0%	8.4%	0.7%	15.8%	3.7%
Suppression	0.0%	0.0%	0.2%	0.3%	0.5%	0.0%
Replacement	0.3%	0.0%	0.0%	0.3%	0.0%	0.0%
Co-occurrence of Deliberate Demand with:						
Instructional Activities	37.6%	27.2%	35.3%	42.3%	40.3%	36.7%
Cognitive Structuring	25.3%	11.4%	21.4%	22.0%	30.1%	18.6%
Metacognitive Information	12.1%	1.7%	11.3%	1.6%	14.5%	2.6%

3.2 Child-level Performance on Measures of Mnemonic Skills and Content Knowledge

Before examining the impact of instructional style on children's mnemonic skills, preliminary analyses were conducted to determine the children's mean performance on each task, the within-task correlations across the three assessment points, and differences in performance as a function of gender and grade. Next, associations among memory capacity, verbal ability and measures of memory performance and content related tasks were examined. Finally, across-task linkages between performance on measures of memory performance and content specific tasks were explored. Before running these analyses, the data were checked for outliers, and none were found.

3.2.1 Overall Performance on Memory Tasks

Object Memory Task.

Recall Performance: In the Object Memory task, the children's recall out of 15 possible items was tallied after a 2-minute study period. As can be seen in Table 8, across the three assessment points recall was relatively stable (at approximately 9 items). Recall performance between the pretest and posttest was moderately correlated ($r = .31$, $p < .05$), and linkages were also identified between the first two assessments and the 1-month follow up (pretest: $r = .46$, $p < .01$; posttest: $r = .50$, $p < .01$).

Demographic Differences: At both the pretest assessment and the 1-month follow up, differences in recall performance were found as a function of gender, with girls outperforming boys in the number of items recalled, $F\ (1,51) = 6.67$, $p < .01$, and $F\ (1,52) = 4.46$, $p < .05$, respectively (see Table 8 for mean recall as a function of gender). In addition, at the initial assessment, second graders outperformed their peers in first grade, $F\ (1,52) = 6.94$, $p < .05$; $M_{Grade\ 2}$=9.85 and $M_{Grade\ 1}$=8.50. Similar differences as a function of grade were identified at the 1-month follow up assessment $F\ (1,52) = 3.87$, $p < .05$; $M_{Grade\ 2}$=9.07 and $M_{Grade\ 1}$=7.89.

Table 8

Object Memory Recall Performance Overall and as a Function of Gender

Object Memory Recall	Pretest			Posttest			1-Month		
	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Overall	9.19	(1.97)	5 – 13	8.78	(2.29)	3 - 14	8.48	(2.27)	3 - 14
Girls	9.79	(1.66)	7 – 13	9.28	(1.95)	5 -12	9.07	(2.12)	5 – 14
Boys	8.46	(2.11)	3 – 14	8.20	(2.57)	3 - 14	7.80	(2.12)	3 – 10

The Free-Recall with Organizational Training Task.

Sorting ARC Scores: As can be seen in Table 9, prior to training in organizational sorting, the children's average baseline sorting ARC scores were essentially at chance levels, reflecting an absence of semantic-based grouping (M = -.09) before the experiment began. On the training trial, all children sorted were guided in sorting all of the cards. In general, children's performance improved substantially after training, as is indicated by the increased ARC scores on the generalization trial at the pretest (M = .53; t(54)=.27, p =.05). At the subsequent generalization trials at the posttest and 1-month follow-up assessments, ARC scores increased considerably, with means of .72 and .69, indicating that the children sorted over 12 of the 16 cards according to their taxonomic groups.

Although, in general, the children's organized sorting increased with training, as can be seen in the top section of Table 9, the girls in the sample exhibited greater amounts of strategic sorting prior to training at the baseline trial than did the boys, F (1,52) = 4.19, $p < .05$, and they did so, as well on the immediate generalization trial, F (1,52) = 8.66, $p < .01$. Indeed, although the majority of the children (N=46) in the sample did not sort the cards at all on the baseline trial, of the 8 children who made use of the strategy at the beginning of the investigation, 5 were girls who sorted all 16 of the cards into semantic groups without being trained to do so. In addition to differences across gender, second grade children (M = .02) also demonstrated significantly greater sorting than did first graders (M = -.23) at the baseline trial, F (1, 52) = 8.66, $p < .01$.

Table 9

Free Recall Performance: Sorting ARC Scores

	Pretest			Posttest			1-Month		
Sorting Arc Scores	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Baseline									
Overall	-0.09	(0.37)	-0.23 - 1						
Girls	.00	(.47)	-0.23 - 1						
Boys	-.20	(.11)	-0.23-.27						
Generalization									
Overall	0.53	(0.60)	-0.23 - 1	0.72	(0.51)	-0.23 – 1	0.69	(0.51)	-0.23 - 1
Girls	0.74	(0.51)	-0.23 - 1	0.83	(0.43)	-0.23 – 1	0.81	(0.43)	-0.23 - 1
Boys	0.29	(0.61)	-0.23 - 1	0.59	(0.58)	-0.23 – 1	0.55	(0.58)	-0.23 - 1

Clustering ARC Scores: As can be seen in Table 10, the children's categorical clustering at recall also greatly improved after being trained at the initial assessment, with performance increasing from the baseline ($M = .42$) assessment to the training trial, during which the children clustered most of the items that they recalled on average ($M = .91$, see Table 10). At the initial generalization and subsequent trials that were conducted two and six weeks later, children's clustering scores remained high. As was the case with strategic sorting, girls also demonstrated higher levels of clustering at many of the measurement points than boys, with significant differences found on the initial generalization trial at the pretest, $F(1,52) = 5.38$, $p < .05$.

Table 10

Free Recall Performance: Clustering ARC Scores

	Pretest			Posttest			1-Month		
Clustering Arc Scores	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Baseline									
Overall	.42	(.47)	-1 – 1						
Girls	.48	(.44)	-.50 – 1						
Boys	.34	(.49)	-1 - 1						

Training Trial									
Overall	0.91	(0.14)	.42 – 1						
Girls	0.94	(0.13)	.54 – 1						
Boys	0.87	(0.16)	.42 - 1						
Generalization									
Overall	0.80	(0.30)	0 – 1	0.81	(0.26)	-.16 – 1	0.81	(0.26)	-.25 - 1
Girls	0.88	(0.25)	.07 – 1	0.86	(0.18)	.33 – 1	0.84	(0.20)	.38 – 1
Boys	0.70	(0.33)	0 - 1	0.75	(0.33)	-.16 -1	0.77	(0.31)	-.25 – 1

Recall Performance: Commensurate with changes in children's use of sorting and clustering, as indicated in Table 11, the number of items children recalled also increased overall after the baseline trial. The greatest amount of recall, 14 of the 16 items on average, was seen during the training trial. Although inspection of the means revealed that recall decreased at the subsequent generalization trials, it still higher than at baseline.

Consistent with their sorting and clustering performance, inspection of Table 11 indicates that girls in the sample also recalled more items than boys on the baseline ($F\ (1,51) = 11.82, p < .01$) and training trials ($F\ (1,52) = 10.34, p < .01$) at the pretest, as well as on the posttest trial ($F\ (1,51) = 9.38, p < .01$) and 1-month follow up ($F\ (1,51) = 5.38, p < .05$). No differences in performance as a function of grade were identified.

Table 11

Free Recall Performance: Recall Performance

		Pretest			Posttest			1-Month	
Free Recall	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Baseline									
Overall	9.45	(2.81)	4 – 16						
Girls	10.55	(2.65)	4 – 16						
Boys	8.13	(2.44)	4 - 13						
Training Trial									
Overall	14.24	(1.57)	10 – 16						
Girls	14.83	(1.20)	11 – 16						
Boys	13.56	(1.69)	10 - 16						
Generalization									
Overall	10.93	(3.34)	3 - 16	12.45	(2.90)	6 – 16	11.60	(3.03)	4 - 16
Girls	11.59	(3.24)	6 – 16	13.48	(2.31)	8 – 16	12.45	(3.24)	4 – 16
Boys	10.16	(3.35)	3 - 16	11.21	(3.09)	6 – 16	10.58	(2.47)	5 – 16

Within Task Correlations: At each administration of the Free Recall Task with Training Task, significant correlations were found between children's strategy use and recall. Inspection of the top left panel of Table 12 indicates that recall, strategic sorting, and clustering are correlated. At the baseline trial, children's strategy use and recall were significantly correlated. In addition, the use of strategic sorting was related to the use of clustering ($r = .43$, $p <.01$). After training, at the generalization trial, as portrayed in the bottom right panel of the table, even higher linkages among the three measures can be seen (*r*s = .53 - .64). Children's sorting ARC scores and recall at baseline were also positively correlated with their performance on these same outcomes on the initial generalization trial. In addition, recall scores on each trial of the task were correlated with each other at the pretest assessment.

Table 12

Free Recall Performance: Correlations among Sorting, Clustering, and Recall at Pretest

	Baseline			Training		Generalization	
	Sorting	Recall	Clustering	Recall	Clustering	Sorting	Recall
Baseline							
Recall	0.44**						
Clustering	0.43**	.40**					
Training Trial							
Recall	.19	.63**	.24				
Clustering	-.04	.17	.15	.36**			
Generalization							
Sorting	.27*	.32*	.22	.31*	.20		
Recall	.19	.45**	.30*	.51**	.34**	.64**	
Clustering	.22	.29*	.22	.32*	.35**	. 64**	.53**

Note. *p<.05, **p<.01

When considering children's performance after the initial training they experienced at the pretest assessment, linkages were also found among measures of children's strategic sorting, clustering, and recall at the generalization trials at the pretest, posttest, and 1-month assessments (see Table 13). Importantly, as is shown in the first three columns of Table 13, after the initial training in strategic sorting, children's scores appear to have continued to be relatively stable across the subsequent assessment points. In addition, significant associations between the children's recall at each assessment were also observed. The patterns for clustering across the generalization trials were different than those observed with sorting and recall, as can be seen by the non-significant intratask correlations below.

Table 13

Free Recall Performance: Intratask Correlations across Pretest, Posttest, and 1-Month Generalization Trials

	Pretest			Posttest			1-Month	
	Sorting	Recall	Clustering	Sorting	Recall	Clustering	Sorting	Recall
Posttest								
Sorting	.44**	.38**	.48**					
Recall	.30*	.50**	.35**	.59**				
Clustering	.08	.26	.25	.68**	.63**			
1-Month								
Sorting	.56**	.45**	.37**	.80**	.45**	.39*		
Recall	.61**	.64**	.46**	.35*	.43**	.17	.48**	
Clustering	.34*	.17	.21	.28**	.26	.16	.45**	0.10

Note. **p*<.05, ***p*<.01

Content Specific Sort-Recall Task.

Identification of Lego Items: At each assessment point, before the Content Specific Sort-Recall task was administered, the children were asked to label each of the Lego items, with the correct labels being provided for any pieces that could not be identified. The identification of the items was taken to be a measure of how accurately the children could label the pieces that they were being asked to sort. As can be seen in the top row of Table 14, consistent with expectations, the children were able to identify an average of less than one item. However, by the end of the instructional unit, the children could correctly identify almost half of the items at the subsequent assessment points ($M_{posttest}$ = 6.30; $M_{1\text{-month}}$ = 7.15).

Sorting: The sorting records were coded independently to classify the level of semantic organization imposed on the materials by each participant. The scores ranged between 0 and 4, reflecting a continuum from random sorting to that based on clear semantic associations. The children's mean sorting scores and recall performance at each assessment are displayed on the second and third rows, respectively of Table 14. At the baseline trial, before the children were familiar with the Lego pieces, they received an average sort score of 1.24, suggesting that, on average, they made use of visual cues to sort the items. As can be seen, the children's sorting improved at the posttest (*M*=1.83) and at the 1-month follow up (M=2.04), indicating that many of them established at least one group based on semantic or functional associations among the items.

Recall: At the baseline assessment, children recalled an average of 2.30 of the Lego pieces. Mean recall increased dramatically at both the posttest (*M* = 8.00) and the 1-month assessment (*M* = 8.26; $t(53)=16.49$, $p <.01$). Interestingly, the children's average recall on each trial was higher than the mean number of items that they identified at the corresponding measurement points.

Table 14

Content Specific Sort Recall Performance

	Pretest			Posttest			1-Month		
	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Total Number Identified	.76	(.78)	0 – 3	6.30	(3.80)	0 - 14	7.15	(3.36)	0 - 14
Sorting Scores	1.24	(.75)	0 - 3	1.83	(1.19)	0 - 4	1.85	(1.27)	0 – 4
Recall	2.30	(1.72)	0 – 6	8.00	(3.56)	0 - 15	8.26	(3.68)	0 - 15

Demographic Differences: It should be noted that at the posttest, the participants who were in the second grade recalled substantially more Lego pieces ($M = 9.37$) than did those in the first grade ($M = 6.58$), $F(1, 51) = 9.47$, $p < .01$. The same trend was also seen for children's recall at the 1-month follow up ($M_{Grade1}=7.26$, $M_{Grade2}=9.26$; $F(1, 52) = 4.23$, $p < .05$). No differences in the number of Lego items correctly identified, items recall, or sorting on the Content Specific Sort-Recall task as a function of gender were found at any of the assessment points.

Inter- and Intratask Correlations: Linkages among the number of Lego pieces identified, sorting scores, and recall can be seen below in Table 15. At the baseline trial, a significant association between sorting scores and recall was identified ($r = .49$, $p < .01$). The correlation between these measures decreases at the posttest ($r = .26$, $p =.06$), but is again significant at the 1-month follow up ($r = .49$, $p < .01$). The children's recall performance across the three assessment points was also correlated significantly, and at each assessment point recall and the number of Legos identified was also linked.

In addition to linkages among measures of recall across the assessments, children's sorting scores at the pretest were related significantly to their sorting scores at the posttest ($r = .36$, $p < .01$) and 1-month assessment ($r = .54$, $p < .01$). In addition, correlations between scores on the posttest and the final assessment 1 month later were also significant ($r = .61$, $p < .01$).

Table 15

Content Specific Sort-Recall Task: Intratask Correlations across Pretest, Posttest, and 1-Month Assessments

	Pretest			Posttest			1-Month	
	Identified	Sorting	Recall	Identified	Sorting	Recall	Identified	Sorting
Posttest								
Sorting	.07							
Recall	.26	.49**						
Posttest								
Identified	.40**	.25	.27					
Sorting	-.17	.36**	.04	.02				
Recall	.34*	.19	.41**	.61**	.26			
1-Month								
Identified	.28	.16	.38**	.67**	.16	.69**		
Sorting	-.17	.54**	.31*	.12	.61**	.33*	.19	
Recall	.23	.35**	.38**	.64**	.26	.79**	.54**	.49**

Note. *p<.05, **p<.01

3.2.2 Overall Performance on Content-Specific Tasks

Lego Building Task.

Lego Building Steps: The children's accuracy in completing a 6 step Lego building activity, in which they were given a series of 6 pictures depicting building steps and a novel set of Legos, was assessed by tallying the number of correct steps completed by the child. At the pretest assessment, the participants completed were successful at the task, on average, completed 4.22 of the 6 steps correctly. Building accuracy increased slightly by the posttest assessment (*M* = 4.78) and the 1-month follow up (*M*=5.04) (see the top row of Table 16 for the mean number of successfully completed building steps). The successful completion of building steps was correlated across measurement points (*r*s = .28 - .51). No differences as a function of gender or grade were seen on building performance.

Strategic Talk about Building: The language used by the children to describe their building techniques was also coded to capture how many of the 6 total steps were characterized by descriptions of strategy use. As can be seen in the bottom row of Table 16, the number of steps characterized by strategic talk (eg., counting, matching size and/or shape to determine the correct pieces, guessing and checking, and planning out what steps to do next) remained low and relatively stable across each assessment (*r*s= .33 - .37). Although some children engaged in this type of description of their building process, on average children made use of this type of talk during approximately 2 of the 6 intervals. As was the case with children's building performance, the number of intervals in which strategy occurred was not related to their gender or grade.

Relations Between Strategic Language and Building Skill: The number of building steps during which children referenced strategy use in their descriptions of how they were building was not correlated with their building success at the pretest, but was found to be significantly related at the posttest assessment ($r = .31, p < .05$). This association was also not seen between the number of building steps correctly completed and language describing building at the 1-month assessment. Moreover, associations across time between these measures were identified.

Table 16

Lego Building Task Performance

	Pretest			Posttest			1-Month		
	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Accurately Completed Building Steps	4.22	(1.79)	0 – 6	4.78	(1.31)	0 – 6	5.04	(1.13)	2 – 6
Steps Characterized by Strategic Talk	1.87	(1.23)	0 – 6	2.00	(1.28)	0 – 6	1.85	(1.41)	0 – 6

Knowledge Assessment.

Children's knowledge of the content presented during the instructional unit was assessed with a series of questions. These questions reflected two aspects of the content shared with the children throughout the lessons and included both factual information (e.g., names of the parts of a gear train and information related to simple machines) as well as knowledge of building and problem solving strategies related to Lego activities.

Factual Knowledge: As anticipated, on the pretest assessment of content knowledge, the children provided very few correct responses (*M* = 1.83). Performance on this measure increased considerably by the posttest (*M* = 11.42) and the 1-month follow up (*M* = 10.07). Although a great deal of variability was seen in performance on this measure, no differences were found in the percent of correctly answered questions based on gender or grade. Additional descriptive results can be found in the top line of Table 19 below.

Table 19

Knowledge Assessment Scores

	Pretest			Posttest			1-Month		
	Mean	*(SD)*	Range	Mean	*(SD)*	Range	Mean	*(SD)*	Range
Factual Knowledge	1.83	(1.83)	0 - 5	11.42	(5.58)	3 - 24	10.07	(4.82)	3 - 23
Strategy Knowledge	1.64	(1.53)	0 - 5	7.78	(3.38)	1 – 15	6.91	(2.74)	0 - 12

In addition, as can be seen below in the top left corner of Table 20 below, significant correlations were identified across all three assessments of factual knowledge. Although strong linkages were seen between children's performance on the pretest and posttest ($r = .44$, $p < .01$), the strongest relations were identified between children's posttest scores and those they received one month later ($r = .88$, $p < .01$), suggesting that there was consistency in the amount that children remembered across time.

Strategy Knowledge: The children's strategic understanding, as assessed on the basis of their open-ended responses to a series of building scenarios, was also limited at the initial assessment. As can be seen in bottom half of Table 19 above, children reported 1.64 strategies about building techniques and ways to solve Lego building challenges before participating in the experiment. This result indicates that, on average, the children had a general understanding of at least one or two Lego-related building techniques in advance of the instructional unit. By the posttest, children were nominating 7.78 unique strategies on average, and continued to offer similar amounts of information on average one month later ($M = 6.91$).

On this measure (see the bottom right corner of Table 20), the children's responses in advance of the experiment were not significantly correlated with those given at the posttest ($r = .24$, $p = .09$). A linkage between children's strategic knowledge at the posttest and 1-month assessments, however, was identified ($r = .64$, $p < .01$).

Relations between Factual and Strategic Knowledge: Concurrent linkages between factual and strategic knowledge were observed at the pretest ($r = .59$, $p < .01$), posttest ($r = .47$, $p < .01$), and 1-month assessments ($r = .45$, $p < .01$). As can be seen in the bottom left corner of Table 20, time-lagged correlations were also observed across the three assessment points.

Table 20

Linkages between Knowledge Measures across Pretest, Posttest, and 1-Month

	Facts			Strategies	
	Pretest	Posttest	1-Month	Pretest	Posttest
Facts					
Posttest	.44**				
1-Month	.48**	.88**			
Strategies					
Pretest	.59**	.39**	.42**		
Posttest	.29*	.47**	.52**	.24	
1-Month	.09	.46**	.45**	.37**	.64**

Note. *$p<.05$, **$p<.01$

3.2.3 Measures of Memory Capacity and Receptive Vocabulary

Digit Span.

The children's performance on measures of Digit Span forward span (short-term memory) and backward span (working memory) was assessed at the posttest. Overall, the children's longest forward span was an average of 5.24 (*SD* = .87), and their mean backward span was 3.48 (*SD* = .82). As was anticipated, these two measures were well correlated with each other ($r = .55$, $p < .01$).

<u>Short-Term Memory:</u> Short-term memory scores, as measured by the longest span of numbers that children could correctly recall in order, were moderately correlated with measures of recall and clustering on the Free Recall task at the baseline assessment ($r = .33$, $p < .05$ and $r = .31$, $p < .05$, respectively). Children's recall on the Free Recall task at the 1-month follow up was also significantly correlated with short-term memory ($r = .29$, $p < .05$). Additional linkages were found between short-term memory and the number of Lego items that the children identified correctly ($r = .29$, $p < .05$) and recalled ($r = .37$, $p < .01$) on the posttest assessment of the Content Specific Sort Recall task. Moreover, linkages were also identified between children's PPVT standard scores and short-term memory ($r = .30$, $p < .05$). No further associations between aspects of children's performance and short-term memory were found.

<u>Working Memory:</u> As can be seen in the first three columns of Table 21, children's working memory scores, as measured by the backward digit span, were more highly related to a number of memory strategy and recall measures than was their short-term memory. In addition to relations with recall on the Object Memory task at the posttest ($r = .30$, $p < .05$) and 1-month follow-up ($r = .34$, $p < .05$), associations were also identified between working memory and strategic sorting, recall, and clustering scores on various assessments of the Free Recall task. Although linkages (presented midway down on the left side of Table 21) were strongest between working memory and strategic performance at the pretest (*r*s ranging from .24 to .54) before all children were taught to use sorting and clustering strategies on the task, associations were also found between working memory and recall on the task at the posttest ($r = .35$, $p < .01$) and 1-month assessment ($r = .36$, $p < .01$).

Perhaps more surprising were linkages identified between the number of Lego steps children correctly completed on the Lego Build task and working memory scores at the pretest (*r*

= .33, $p < .05$) and posttest ($r = .35$, $p < .01$). Although these correlations are not large, it was not expected that children's building ability would be directly related to working memory scores at multiple time points. No associations between working memory and the knowledge assessments or PPVT were found.

Table 21

Relations between Working Memory and PPVT and measures of Children's Strategy Use and Lego Building across Pretest, Posttest, and 1-Month

	Working Memory			PPVT		
	Pretest	Posttest	1-Month	Pretest	Posttest	1-Month
Object Memory Recall	.30*	.30*	.34*	.22	.21	.09
Free Recall						
Baseline						
Sorting	.24			.18		
Recall	.54**			-.06		
Clustering	.37**			.14		
Training Trial						
Recall	.32*			.10		
Clustering	.04			.35*		
Generalization						
Sorting	.33*	.11	.22	.41**	.32*	.28*
Recall	.47**	.35**	.36**	.22	.26	.17
Clustering	.14	.22	.06	.28	-.10	.28*
Content Specific Sort-Recall						
Lego Identification	.01	.28*	.14	.31*	.38**	.52**
Sorting Scores	.36**	-.03	.38**	.34*	.09	.33*
Recall	.44**	.38**	.36**	.32*	.33*	.25
Lego Building Task						
Building Steps	.33*	.35**	.25	-.17	-.06	.25
Strategy Talk	.22	.08	.05	-.07	.01	.05

Note. *$p<.05$, **$p<.01$

PPVT.

On average, children received a standard score of 112.94 on the PPVT. This measure of receptive vocabulary was correlated with a measures of children's use of sorting and clustering strategies on the Free Recall task at each assessment (*r*s = .32 - .41, *p*s < .05; see the right three columns of Table 21). Even though relations were identified between children's strategy use and language scores, comparable correlations between PPVT scores and recall in the task were not found.

As was the case with relations between working memory and performance on the Content Specific Sort-Recall task, as can is portrayed in the bottom right side of Table 21, linkages were also identified between children's PPVT scores and measures of Lego item identification, sorting, and recall on the Content Specific Sort Recall task at the pretest, posttest, and 1-month time points. There were no linkages between performance on the Lego Building task and PPVT scores.

In addition to associations between PPVT and strategic performance, relatively strong and consistent correlations were found between children's PPVT performance and their knowledge of factual information at the pretest ($r = .50$, $p < .01$), posttest ($r = .38$, $p < .01$), and 1-month follow up ($r = .43$, $p < .01$). In contrast, linkages between children's PPVT scores and strategy knowledge were only found at the initial assessment ($r = .42$, $p < .01$).

3.2.4 Linkages Among Memory Measures

Object Memory and the Free Recall Task.

Based on previous research, it was expected that there would be correlations between children's recall on the Object Memory task and measures of strategy and recall on the Free Recall task. As can be seen in Table 22, consistent linkages both within (*rs* = .42 - .47) and across assessment point (*rs* = .29 - .58) were found between measures of recall on both tasks. Fewer associations were identified between children's use of strategies on the Free Recall task and recall in Object Memory. Only clustering scores on the training trial of the Free Recall task, and children's initial generalization of the sorting strategy at the pretest were concurrently correlated with children's Object Memory recall ($r = .35$, $p < .01$, and $r = .34$, $p < .01$, respectively).

Table 22

Relations between Recall on the Object Memory Task and the Free Recall Task

	Object Memory		
Free Recall	Pretest	Posttest	1-Month
Pretest			
Baseline	.47**	.37**	.37**
Training	.50**	.30*	.41**
Generalization	.48**	.39**	.58**
Posttest	.57**	.44**	.44**
1-Month	.29*	.38**	.42**

Note. $*p<.05$, $**p<.01$

Associations among Measures of Recall and Strategy Use on the Content Specific Sort Recall Task, Object Memory, and the Free Recall Task.

Of particular interest in this investigation was the relation between children's memory strategy use and their recall on the Object Memory and Free Recall tasks, as well as their performance on a content based assessment of children's strategy use as assessed on the Content Specific Sort Recall task. First, relations between children's recall on the Content Specific Sort Recall, Object Memory, and Free Recall tasks were explored. Next, linkages between strategic sorting on both the Content Specific Sort Recall task and the Free Recall task were investigated.

Recall: As can be seen in the top half of Table 23, concurrent and time-lagged associations between children's recall performance on the Object Memory task (rs = .19 - .43) and Free Recall task (rs = .17 - .50) were found with recall performance on the individual pretest, posttest, and 1-month assessments of the Content Specific Sort Recall task. These linkages, as indicated in the bottom half of Table 23, became more consistent across recall measures on the

Free Recall and Content Specific Sort Recall task after the children had been trained to use organized sorting in the Free Recall task at the pretest assessment.

Table 23

Relations between Recall on the Object Memory Task, Free Recall Task, and Content Specific Sort Recall

	Content Specific Sort Recall		
	Pretest	Posttest	1-Month
Object Memory			
Pretest	.19	.29*	.19
Posttest	.36**	.36**	.32*
1-Month	.43**	.33*	.33*
Free Recall			
Pretest			
Baseline	.24	.28*	.32*
Training	.17	.34**	.25
Generalization	.50**	.38**	.39**
Posttest	.25	.36**	.30*
1-Month	30*	.47**	.44**

Note. *p<.05, **p<.01

Strategic Sorting: After documenting relations between children's recall of general and content specific items, children's use of strategic sorting on these contrasting sets of materials was explored. Interestingly, children's use of sorting strategies, as assessed by ARC scores on the Free Recall task (ranging from -1 to 1) and performance on the Content Specific Recall task were related at both the pretest assessment (r = .47, p < .01) and posttest (r = .29, p < .05). When considered concurrently, the linkage between the two measures of strategy use was also significant at the 1-month follow up (r = .29, p < .05). It was also the case that children's sorting ARC scores on the Free Recall task at the posttest were significantly related to their sorting scores on the Content Specific Sort Recall task a month later at the 1-month follow up (r = .34, p < .01).

3.2.5 Relating Content Specific Measures

Relations between the children's content specific knowledge of facts and strategies and their performance on the Lego Building task were explored both concurrently and across the three assessment points. As can be seen in Table 24, correlations were infrequently observed between children's knowledge and performance on the Lego Building task. Of note, however, were the linkages indentified between children's strategy knowledge and strategy related talk on the Lego Building task, both concurrently and at the posttest assessment ($r = .34, p < .01$) and at the 1-month follow up ($r = .32, p < .05$).

Table 24

Relations between Children's Performance on Measures of Knowledge and Lego Building

	Lego Building Steps			Lego Strategy Talk		
	Pretest	Posttest	1-Month	Pretest	Posttest	1-Month
Factual Knowledge						
Pretest	.13	.14	.18	.09	-.06	-.18
Posttest	.25	.21	.24	.09	.19	.23
1-Month	.25	.19	.22	-.16	.25	.25
Strategy Knowledge						
Pretest	.15	.12	.24	-.12	.04	-.06
Posttest	.19	.10	.19	.26	.34**	.26
1-Month	.37**	.35**	.25	-.07	.32*	.17

Note. *p<.05, **p<.01

3.2.6 Linking Memory and Content Specific Performance

After exploring relations among the memory and content specific tasks separately, additional analyses were run to identify linkages between memory strategy use and content-related performance. Of greatest interest were relations between the children's strategy use and recall on the Content Specific Sorting task and performance on the Lego Building and Knowledge assessments.

Content Specific Sorting and Lego Building.

The numbers of successfully completed building steps at each time point were ere correlated with children's content specific sort recall at the 1-month follow-up (*r*s .34 - .45; see the top left corner of Table 25). Additional linkages were found between the children's initial content specific sort recall sorting scores at the pretest and the building steps completed at the posttest and 1-month assessments ($r = .36$, $p < .01$, and $r = .27$, $p < .05$, respectively). Aside from these associations that were identified after the children had gained significant amounts of experience with the Lego-related content during the instructional unit, no linkages between their strategy talk while Lego building and Content Specific recall or sorting were observed.

Table 25

Relations between Content Specific Sorting and Lego Building

	Content Specific Recall			Content Specific Sort Score		
	Pretest	Posttest	1-Month	Pretest	Posttest	1-Month
Lego Building Steps						
Pretest	.11	.23	.34*	.20	.15	.27*
Posttest	.26	.20	.43**	.36**	.02	.15
1-Month	.19	.35*	.45**	.27*	.05	.35**
Lego Strategy Talk						
Pretest	.01	.21	.11	.05	-.12	-.08
Posttest	-.01	.30	.22	.05	-.02	-.07
1-Month	.06	.25	.04	-.09	-.11	-.26

Note. *p<.05, **p<.01

Content Specific Sorting and Knowledge.

As can be seen below in Table 26, concurrent and time-agged linkages between children's strategy use and recall on the Content Specific Sort Recall task and measures of content knowledge were observed. Interestingly, the children's knowledge of facts was related to their recall and strategy use on the sorting task, concurrently at each assessment (*r*s .29 - .65). In addition, strategy use in the sorting task was significantly related the children's strategy knowledge concurrently at the pretest ($r = .53$, $p < .01$), posttest ($r = .27$, $p < .05$), and 1-month follow up ($r = .27$, $p < .05$).

Table 26

Relations between Content Specific Sorting and Knowledge

	Content Specific Recall			Content Specific Sort Score		
	Pretest	Posttest	1-Month	Pretest	Posttest	1-Month
Factual Knowledge						
Pretest	.35**	.38**	.31*	.53**	.26	.39**
Posttest	.40**	.65**	.56**	.43**	.29*	.40*
1-Month	.43**	.61**	.63**	.46**	.24	.36**
Strategy Knowledge						
Pretest	.36**	.29**	.29*	.41**	.16	.37**
Posttest	.29*	.40**	.28*	.36**	.27*	.20
1-Month	.36**	.30*	.37**	.27*	.23	.27*

Note. *p<.05, **p<.01

3.3 Child-level Performance as a Function of Instructional Style

After exploring the children's memory performance and content related skills, a series of analyses were conducted to examine the impact of instructional style on their performance after experiencing the 10-day instructional unit. Before testing the impact of instruction, potential differences in age, memory capacity, and receptive language skills were examined across children who were randomly assigned to the memory-rich and low-memory instructional conditions. In addition, the impact of instructional style on these outcomes at the posttest and 1-month follow up was explored using repeated-measures ANOVAs.

3.3.1 Child-Level Characteristics as a Function of Group Assignment

A total of 54 children participated in the investigation, with 28 assigned to the memory-rich instructional and 26 to the low-memory conditions. Overall, the sample included greater numbers of girls than boys, and the number assigned to each condition reflected the composition of the sample (see Table 27 below). Although equal numbers of first and second graders took part in the study, more first-grade children participated in the memory-rich condition. However, a one-way ANOVA revealed that the groups did not differ significantly in age at the beginning of the investigation ($M_{\text{Memory Rich}}$ =85.9 months and $M_{\text{Low Memory}}$=88.0 months).

Table 27

Gender and Grade of Participants

	Number of Participants	
	Memory Rich	Low Memory
Girls	15	14
Boys	13	12
Grade 1	15	12
Grade 2	13	14

Memory Capacity and Language.

In addition to considering the balance of age and gender across groups, differences between children's performance on short-term and working-memory as well as receptive vocabulary were also explored. On average, children in the memory-rich condition were found to have significantly lower short-term memory scores (M=4.96) than their peers in the low-memory group (M=5.54) at the pretest, F (1, 52) = 6.52, $p < .01$. Significant differences were also seen between the groups in terms of working-memory, with the participants in the low-memory (M=3.77) outperforming those in the memory-rich condition (M=3.21), F(1, 52) = 6.89, $p < .01$. Comparison of PPVT scores, in contrast, did not reveal differences between the two groups ($M_{\text{Memory Rich}}$ = 111.85; $M_{\text{Low Memory}}$ = 114.12).

Initial Performance on Memory and Content Specific Measures at Pretest.

Exploration of both memory strategy task measures at the initial assessment – i.e., prior to the start of instruction – revealed only one difference in the performance of memory-rich versus low-memory condition participants. As can be seen in Table 29, on average, children assigned to the low-memory condition had greater sorting ARC scores at the baseline trial in the

Free Recall with Training task (*M* = .02) than did children in the memory-rich condition (*M* = -.20), $F(1, 52) = 5.70$, $p < .05$. Indeed, although only two children assigned to the memory-rich condition engaged in limited sorting at the initial assessment, five of those in the low-memory group sorted all of the cards at the baseline trial before being trained to do so. No other differences on outcomes on the memory strategy of content specific tasks were seen between the groups at the initial assessment.

3.3.2 Posttest and 1-Month Memory Performance as a Function of Instructional Condition

After examining group differences in advance of the instructional unit, posttest and 1-month outcomes on the memory strategy measures were assessed to determine the extent to which they varied based on the experimental condition to which the children were assigned.

Object Memory.

Mean pretest, posttest and 1-month recall can be seen for each group in Table 28. Inspection of the means suggested that the two groups varied in the number of items recalled at the end of the instructional unit but not at the 1-month follow up. An ANOVA, with instructional conditions as between-subjects factors and assessment point as a within subjects factor, confirmed visual inspection of the table. Specially, although the main effect of instruction was not significant, $F\ (1, 51) = 2.09$, $p = .13$, there was a significant interaction effect between time and condition, $F\ (2, 51) = 5.61$, $p < .05$. Additional analyses showed that group differences were not seen in advance of the instructional unit, but that, contrary to original hypotheses, after experiencing instruction the children in the low-memory condition significantly outperformed their peers in the high mnemonic condition by the posttest, $F(1,52) = 5.42$ $p <.05$. These differences as a function of instructional condition were not identified at the 1-month follow up assessment.

Table 28

Recall in the Object Memory Task as a Function of Instructional Style

	Memory Rich		Low Memory	
	M	*(SD)*	M	*(SD)*
Object Memory Recall				
Pretest	9.14	(2.03)	9.24	(1.94)
Posttest	8.11	(2.18)	9.64	(1.89)
1-Month	8.79	(2.13)	8.36	(2.16)

Free Recall with Organizational Training.

As described above, at the baseline assessment children in the low-memory condition had greater sorting ARC scores on average than children in the memory-rich condition. Although not significant, similar trends in can also be seen when comparing clustering and recall measures on the same trial of the task. After training, as can be seen in the middle rows of Table 29, group differences are not observed, i.e., on the generalization trials within the pretest assessment, the posttest, or the 1-month follow up.

Table 29

Strategy Use and Recall in the Free Recall Task as a Function of Instructional Style

	Memory Rich		Low Memory	
	M	*(SD)*	M	*(SD)*
Pretest				
Baseline				
Sorting	-.21	(.10)	.02	(.49)
Recall	8.82	(2.53)	10.16	(3.00)
Clustering	0.32	(0.47)	0.53	(0.44)
Training				
Recall	14.18	(1.39)	14.31	(1.76)
Clustering	0.91	(0.13)	0.90	(0.16)
Generalization				
Sorting	0.47	(0.62)	0.61	(0.57)
Recall	10.61	(3.31)	11.27	(3.39)
Clustering	.77	(.32)	.83	(.28)

Posttest				
Sorting	.65	(.55)	.79	(.65)
Recall	12.00	(2.83)	12.96	(2.95)
Clustering	.80	(.28)	.81	(.25)
1-Month				
Sorting	.58	(.58)	.80	(.42)
Recall	11.04	(3.11)	12.24	(2.88)
Clustering	.81	(.22)	.81	(.30)

Content Specific Sort Recall Task.

When considering children's strategic memory performance in response to instructions to "work to remember" items drawn from the content presented across the instructional unit, recall on the Content Specific Sort Recall task did not differ between groups at the pretest, posttest, or 1-month assessments. As can be seen in Table 30, inspection of children's mean strategic sorting scores, also revealed no significant differences as a function of instructional group at the pretest assessments. By the posttest measure, however, it appeared that there were differences in strategic sorting on the Content Specific Sort Recall task after experiencing the instructional unit.

Analyses revealed that although there was not a main effect of condition on children's strategic sorting, $F(1, 51) = 2.38$, $p < .13$, there was a significant interaction between instructional condition and time, $F(2, 51) = 3.53$, $p < .05$. Further analyses indicated that there were significant differences as a function of instructional condition at the posttest assessment in the sophistication of children's sorting, $F(1, 51) = 5.56$, $p < .05$. Indeed, by the posttest, those who participated in the memory-rich instructional unit engaged in more semantically related sorting, making on average at least one semantic or functionally related group with the content-specific stimuli after participating in the experiment. Similar differences were not identified at the 1-month follow up.

Table 30

Strategy Use and Recall in the Content Specific Sorting Task as a Function of Instructional Style

	Memory Rich		Low Memory	
	M	*(SD)*	M	*(SD)*
Recall				
Pretest	2.21	(1.64)	2.40	(1.83)
Posttest	7.86	(3.19)	8.16	(4.00)
1-Month	8.39	(3.17)	8.12	(4.23)
Sorting Scores				
Pretest	1.25	(0.8)	1.23	(0.71)
Posttest	2.18	(1.31)	1.44	(0.92)
1-Month	2.07	(1.33)	1.67	(1.62)

3.3.3 Posttest and 1-Month Content Specific Performance as a Function of Instructional Condition

Lego Building Task.

As can be seen by visual inspection of the means presented in Table 31, children in both instructional conditions performed equally across all assessments of the Lego Building task. These results suggest that, in general, across each of the assessments children's Lego building skills as evaluated by the number of correctly completed Lego building steps, was comparable across the groups. In addition, the children who experienced different forms of instruction did not engage in differing levels of strategy-related talk while building.

Table 31

Lego Building Performance as a Function of Instructional Style

	Memory Rich		Low Memory	
	M	*(SD)*	M	*(SD)*
Building Steps				
Pretest	4.61	(1.47)	3.81	(2.02)
Posttest	4.89	(1.17)	4.65	(1.47)
1-Month	5.19	(1.00)	4.88	(1.24)

Strategy Talk				
Pretest	1.79	(1.29)	1.96	(1.31)
Posttest	2.19	(1.21)	1.81	(1.02)
1-Month	1.85	(1.41)	1.84	(1.43)

Knowledge Assessment.

The children's performance on measures of factual and strategic knowledge can be found below in Table 31. Inspection of the means revealed that at the pretest assessment, the children's knowledge of facts and strategies was relatively comparable across groups, with children in the low-memory condition demonstrating knowledge of slightly more information than their peers in the memory-rich condition ($M_{\text{Memory Rich}} = 1.63$ vs. $M_{\text{Low Memory}} = 2.06$). By the end of the instructional unit, when assessed at the posttest, the children's knowledge of information presented in the lessons was nearly the same ($M_{\text{Memory Rich}} = 11.61$ vs. $M_{\text{Low Memory}} = 11.21$). Similar trends were identified at the 1-month follow up.

Inspection of the means of children's strategic knowledge, however, revealed that although children's initial strategic understanding was comparable across groups, by the posttest, performance on this measure diverged in the predicted direction across the two groups of children. Analyses revealed a significant main effect of the instructional unit, $F(1, 51) = 8.63$, $p < .01$, and a significant interaction between the instructional unit and time, $F(2, 51) = 10.68$, $p < .01$. Further exploration of the data showed that children's knowledge of strategic information differed significantly at the posttest assessment, $F(1, 52) = 9.32$, $p < .01$. Again, in this case, the children in the memory-rich instructional unit provided greater amounts of information regarding strategic information related to the instructional unit. These differences in performance continued to be evident 1-month later at the final assessment, $F(1, 52) = 6.01$, $p < .01$.

Table 32.

Knowledge as a Function of Instructional Style

	Memory Rich		Low Memory	
	M	*(SD)*	M	*(SD)*
Factual Knowledge				
Pretest	1.63	(1.44)	2.06	(1.21)
Posttest	11.61	(5.26)	11.21	(6.01)
1-Month	10.61	(4.32)	9.50	(5.33)
Strategic Knowledge				
Pretest	1.48	(1.48)	1.81	(1.60)
Posttest	9.04	(2.82)	6.42	(3.45)
1-Month	7.75	(2.35)	6.00	(2.88)

IV. DISCUSSION

The research reported here represents the first effort to experimentally manipulate teachers' instructional style in the service of further understanding the role of teacher-led instruction on children's skills for remembering. Although findings from observational work conducted in elementary school classrooms have clearly indicated that teachers do not explicitly teach skills that children use to remember in their classrooms (Moely et al., 1992; Coffman et al., 2008), it is also apparent that there are specific aspects of instruction that are important for children's mnemonic development.

By making use of examples of memory-relevant language used during classroom instruction, the experiment described here was designed to examine the extent to which there was a direct impact of teacher-led instruction on children's mnemonic skills. Combined, the converging findings from observational research and the experimental study reported here contribute important evidence on which to base further exploration of these instructional practices directly in the classroom setting. In addition, by investigating children's strategic behavior when "working to remember" everyday items and items linked to content covered during the course of instruction, the findings of this investigation also provide hints regarding the mechanisms by which teachers' memory-rich instructional style is impacting children's independent strategy use.

4.1 The Instructional Manipulation

Of critical importance to this investigation was the ability of teachers to make use of the two contrasting styles of instructional language. Coding of the videotaped lessons revealed that efforts to train the teachers in the use of memory-rich and low-memory modes of instruction were successful. Indeed, even though each teacher was asked to conduct the lessons during two sessions, once in each of the two contrasting styles, they were able to do so, and, on the whole they were incorporated the targeted techniques at rates comparable to those observed naturally occurring in the elementary school classroom (Coffman et al., 2008). This is particularly impressive given that, in addition to following the scripted lessons provided, it was often necessary for the teachers to improvise their use of memory-relevant language based on exchanges with the children.

It is interesting to note that across both conditions, the percent occurrence of *deliberate memory demands* made during lessons in the experimental investigation was about 10% less than the amount observed in language arts and mathematics lessons in first-grade classrooms (see Tables 1 and 5). This finding, contrasted with greater percentages of observed intervals during which teachers provided the children with general information (*general information giving*), suggests that there may be something unique about presenting an entirely new content unit that lends itself more easily to certain types of instructional language. This view is also supported by the amounts of metacognitive information requested and imparted by the teachers during the lessons. Lego building, in particular, provided numerous opportunities both in scripted lessons and one-on-one interactions to incorporate these types of techniques in instruction.

To this end, it is also worth noting that the greatest differences in the observed language of the teachers as they taught the lessons with high-memory and low-memory, were found in their use of *strategy suggestions*, *metacognitive questions*, and in the combined use of *deliberate memory demands* with *metacognitive instruction* or *cognitive structuring activities*. It is the case that teachers, regardless of mnemonic orientation, provide extensive amounts of information and task instructions. Similarly, teachers often ask their students to provide information from memory. Although both of these instructional techniques are common, it appears that children benefit in particular from instruction that includes the joint occurrence of memory demands and cognitive structuring activities and that is also metacognitively rich.

4.2 Child-level Performance on Measures of Mnemonic Skills and Content Knowledge

4.2.1 Performance on Memory Tasks

Gender and Grade Differences in Children's Memory Performance.

Overall, children's performance on measures of recall on the Object Memory task and strategic sorting, recall, and clustering on the Free Recall with Organizational Training task were comparable to results found in other investigations using similar tasks. As was expected, in advance of training on the Free Recall task, the second grade children outperformed the first graders, and the same was true when children completed the Object Memory task for the first time. Differences as a function of grade on strategy use and recall were no longer seen after the posttest assessment, indicating in general, all children, regardless of grade, were able to benefit from training in the Free Recall task as well as experience with the Object Memory task.

One unexpected finding involved gender differences that were seen at the pretest assessment in children's performance on the Free Recall and Object Memory tasks. Although overall children's scores were similar to what has been found previously, in this sample the girls outperformed the boys on recall on both of these tasks, as well as in their strategy use in the Free Recall task at each assessment point. Interestingly, these gender differences are not frequently seen in children's performance on deliberate memory tasks, and were not found on any of the other measures in the investigation. This is particularly surprising, given the nature of the materials that were presented in the other tasks (Legos for Lego Building, etc.), on which the girls might have been expected to perform less well than the boys.

Content Specific Sort Recall and Strategy Use in Free Recall.

Of greatest interest when considering children's memory performance were the relations between recall and strategy use within the Content Specific Sort Recall task, changes in children's strategic sorting in this task as a function of experiencing the instructional unit, and associations between children's strategic sorting in this task and their use of strategic sorting on the Free Recall task. Although the stimuli across the two groups of materials were very different, both tasks required children to make use of their knowledge of the semantic relations among the stimuli to create groups that would help them to remember. In the Free Recall task, children were explicitly trained to sort the cards presented that were drawn from four groups of easily categorized materials. For the majority of the participants, explicit instruction in sorting on this task boosted their use of the appropriate strategy on the task.

Strategic behavior on the Content Specific Sort Recall, however, was dependent on the children's newly-acquired knowledge of the materials. Indeed, after experiencing the 10-day instructional unit, greater numbers of participants made groups with the Legos that were based on semantic or functional relationships among the items, as opposed to information visually available, as was frequently the case at the pretest. This change between the pretest and posttest that was seen overall most likely reflects the exposure children had to the materials and new information they were able to draw upon about each of the items in the service of strategy use on this task.

Interestingly, children's use of sorting strategies on the Free Recall and Content Specific Sort Recall tasks were significantly correlated with each other at the pretest, posttest, and 1-month follow up. Moreover, linkages across measures of recall at each assessment were also related to one another. These data demonstrate that relations exist between children's ability to make use of strategic sorting of familiar items and stimuli that were specific to information that they gained during the instructional unit.

The Impact of Instruction on Children's Deliberate Memory Skills.

One primary goal of this investigation was to use experimental methods to evaluate the observations reported by Coffman and colleagues (2008) by demonstrating that children who participated in the memory-rich instructional unit would outperform their peers in the low-memory condition on the Free Recall and Object Memory tasks. The findings from this investigation did not support this hypothesis. Conversely, the only difference in performance on either of these tasks was identified in the children's Object Memory recall in favor of participants in the low-memory group.

There are many possible reasons why similar findings may not have been identified in this investigation. Although the children were randomly assigned across the two conditions, it was the case that the participants in the low-memory group began the investigation with greater knowledge of strategic sorting than those in the memory-rich condition. Thus, it is likely, that one of the reasons that instruction was not found to impact children's performance was that many of them were already very skilled in their use of strategies for remembering.

In addition, the instructional units that each of the children experienced was relatively short, in comparison with their day-to-day experiences in the classroom setting. Children in the classrooms of teachers observed by Coffman and colleagues (2008) had extensive exposure to the instructional styles of their teachers that cannot be replicated in a 10-day experimental project. Moreover, the children in this experimental investigation also were exposed daily to their own classroom teachers. It is likely that the exposure to instruction that they experience daily contributed to some extent not only to their initial strategic skills, but also their ability to generalize strategy training in the Free Recall task.

Given the lack of impact of the experimental condition on the children's strategy use and recall in the Free Recall and Object Memory tasks, it is even more interesting that their use of similar strategies when asked to remember content specific information varied as a function of the condition in which they participated by the end of the 2 weeks of instruction. As reported above, although there were no differences in the children's performance on the Content Specific Sort Recall task at the initial time point, after being exposed to the content over the course of the 10-day unit, children in the memory-rich condition were found to be using more sophisticated sorting strategies with the materials.

What could be driving these observed differences in strategy use? These findings provide an interesting glimpse into how children may be differentially approaching the information that they are exposed to in the classrooms of high mnemonic teachers. Specifically, children in the memory-rich instructional condition were more likely to make groups based on their knowledge of what the items were and how they might be used together. Based on the performance of their peers in the low-memory condition, it does not seem to be the case that these types of associations between the items were as easily recognized, and the children grouped the items instead on features such as color or shape.

The differences observed in grouping techniques map onto instructional practices in the contrasting experimental conditions. Indeed, in the memory-rich condition, instruction of the Lego items was focused on children understanding how the pieces might work together through the provision of strategy suggestions and requests for children to explain their building techniques. In addition, teachers explicitly drew connections between the materials through cognitive structuring activities. In contrast, scripted lessons in the low-memory condition emphasized imparting novel pieces of information, such as the names of the Lego pieces, through general information giving and requests of children's semantic knowledge.

That similar differences in children's recall performance on the Content Specific Sort Recall task were not identified as a function of instructional style is not surprising. At each assessment, children's recall was found to be increasingly related to their ability to correctly identify the Lego items (*r*s = .26, .61, and .76). These consistent linkages most likely reflect children's overall knowledge of the Lego items, and suggest that the recall for the task most likely is not a reflection of children's strategic efforts on the task.

Although it is impossible to determine from this experiment, it appears that children in the memory-rich condition came to think of content specific items presented in this task differently during the 10-day instructional unit than their peers in the low-memory condition and were better able to see the linkages between the items based on what they knew about how they could be used. It may also be the case that children exposed to greater amounts of discussion of metacognitively relevant information through these lessons are also learning more about different ways that one can strategically approach new tasks. Moreover, it is possible that some of the same factors, including the exposure to metacognitively rich language, that contributed to the success of children in the memory-rich group are similar to those that lead children in high-mnemonic classrooms to exhibit greater levels of strategy use when "working to remember" familiar objects.

4.2.2 Performance on Measures of Lego Building Skills and Knowledge

The Impact of Instruction on Lego Building Skills and Knowledge Acquisition.

Across both of the conditions and at each of the time points, the children were found to be very skilled Lego builders. Indeed, at the beginning of the experiment, many of the children were able to successfully complete the Lego build, and this continued to be the case with only small gains observed in successfully completed building steps at the posttest and 1-month follow up. The children's ability to talk strategically about their building process did not change after experiencing the instructional unit, but by the posttest use of this type of languages while working was related to building success.

The measure of children's strategy talk in the Lego Build used in this set of analyses was very basic in that it was designed only to capture the overall talk for each building step without focusing on the types of strategies that the children were describing. Coding of children's language was conducted, however, to capture the variability in the types of comments that children made with respect to both strategies and procedures. These detailed characterizations will be explored in future analyses to better understand the relations between children's strategy talk and building skills, and potential changes in the types of strategies that children describe as a function of experiencing the Lego instruction.

As was expected, children's knowledge of facts and strategies covered during the instructional unit increased greatly between the pretest and posttest. Preliminary evaluation of performance on the 1-month follow up suggested that children's strategy-related knowledge remained at near posttest levels. Conversely, by the 1-month assessment, their knowledge of the facts presented during the instructional unit decreased rather dramatically. Although it was anticipated that children would forget some of the information presented during instruction, it was not originally hypothesized that children would retain greater strategy-related knowledge over time.

In general, children's Lego building skills were not found to be related to their content related knowledge of facts or strategic information. It was the case, however, that children's understanding of strategies, as measured on the knowledge assessment at the posttest after experiencing the instructional unit, was significantly associated with their provision of strategic information while building concurrently at the posttest, and also at the 1-month measurement point. Similar linkages were seen between children's strategy knowledge at the posttest and their provision of strategy-related comments 1 month later at the follow up assessment. These associations make sense intuitively – it seems likely that children with greater understanding of strategies would be better able to make use of these same types of strategies, or be better at articulating them in applied tasks. Based on these preliminary linkages, it will be very interesting to explore further these relations with a more detailed characterization of children's talk during the Lego Building task.

Given the overall lack of change seen between the pretest and posttest measures of the Lego Building task, it is not surprising that no impact of instruction on the content-specific building skills were found. It was surprising, however, to find that although children's factual knowledge increased greatly during the 10-day unit, there appeared to be no impact of experimental condition on outcomes at the posttest assessment. In general, at this assessment, it appears that all children benefited from the instruction provided, and were able to learn basic content, regardless of the instructional style with which it was presented. Although this finding is different than what was originally hypothesized, it is encouraging that both groups benefitted from the instruction that was provided.

As hypothesized, differences as a function of instruction in children's knowledge of strategies were found at the posttest and at the 1-month follow up as well. Not only did the children in the memory-rich condition exhibit less knowledge of strategies in advance of the instructional unit than their peers ($M_{\text{Memory Rich}}$=1.48 vs. $M_{\text{Low Memory}}$=1.81), but by the end of the instructional unit they nominated significantly greater amounts of unique of content-specific strategic information ($M_{\text{Memory Rich}}$=9.04 vs. $M_{\text{Low Memory}}$=6.42). These findings indicate that the inclusion of memory-relevant language – and potentially metacognitively relevant instruction in particular – leads children to develop an increased understanding of this type of information.

4.3 The Role of Instruction in Children's Strategy Development

Although a direct impact of instructional condition on children's strategic memory performance was not found in this investigation, the observed influence of contrasting levels of memory-relevant talk on children's memory strategy use in the Content Specific Sort Recall task and knowledge of strategies may provide important information regarding the specific impact that this type of instruction has on children as they are developing independent strategic skills. In addition, these results provide insight into potential mechanisms that may be underlying the differences in the development of children's strategic skills reported by Coffman and colleagues (2008).

The results presented here indicate that exposure to novel information in a memory-rich instructional style may result in an increased ability to make use of that information when asked to do so when "working to remember." In addition, it is also clear that this type of instruction leads to superior understanding of Lego building strategies. Each of these outcomes represents a unique set of skills on the part of the child. Although stimuli in the Content-Specific Sort Recall task and the knowledge assessment both include Legos, the strategies utilized and described by children in each of these tasks varied considerably. In the Content-Specific Sort Recall task, for example, children were asked to sort pictures of Legos into groups that would help them to remember. The strategies nominated by children on the Knowledge Assessment, in contrast, reflected their understanding of the strategies that could be employed when facing a building challenge while working with Legos. In this way, the demands that each of these tasks place on children's understanding of the content presented differ.

Even though gains in children's strategic knowledge might be expected given the nature of the differences in emphasis across instructional conditions, it is not simply the case that the teachers focused singularly on direct instruction in the use of these strategies during these lessons (see Appendices E - I). What characteristics of memory-rich instruction might be driving these differences in strategy-related skills? It is interesting to note that although memory-rich instruction included extensive amounts of strategy-related talk, the teachers only made direct strategy suggestions to children during 10% of the observed intervals. Moreover, these strategy suggestions were not always directly made with regards to Lego building, but also to ways that children might process other types of information.

Importantly, the majority of metacognitively-relevant statements made by instructors in the memory-rich condition were delivered in the form of metacognitive questions ($M_{\text{Memory Rich}}$ =16.8% vs. $M_{\text{Low Memory}}$=2.3%). When asking metacognitive questions related to the Lego content, children were asked to share their strategies for building and remembering with the group. In addition, they were encouraged to reflect on why particular strategies might be more effective than others. By asking these types of questions, the teachers provided opportunities for the children to learn about the use of strategies for both building and remembering from their peers, without directly imparting them. In addition to providing increased opportunities to learn about strategy relevant information, presenting the content in this way also gave children the opportunity to learn about the processes that others use when evaluating and utilizing strategies.

Similar differences in the memory-rich lessons in the extent to which teachers presented information related to the linkages across the Lego pieces may have also contributed to children's abilities to strategically sort them in the Content-Specific Sort Recall task. Again, inspection of the lessons reveals that it was not the case that teachers directly explained to the children that they could sort the Lego pieces along a specified set of dimensions when sorting them in the service of remembering. Instead it is apparent that the children were able to generalize these skills from the way that the information was presented during the lessons. It is likely that similar processes are underway each day in the classrooms of the high-mnemonic teachers observed by Coffman and colleagues (2008), which result in observable differences in children's memory strategy use and academic skills.

4.4 Limitations and Future Directions.

Given that this was the first attempt to manipulate the use of memory-relevant instructional language, there are several things that could be improved upon in future investigations. For example, although the instructors were able to make use of the targeted language, the content that was selected impacted the ways in which this language could be implemented during the lessons. Comparison of the coded intervals of instruction in the experiment (Table 5) and those observed in the first-grade classroom (Table 1) reveals that experimental lessons included fewer requests of memory. Similarly, given the number of opportunities for discussing building and "engineering" strategies, it could be that Lego building in particular lends itself to greater metacognitive talk. This may or may not have made a great deal of difference in the overall experience for participating children, but it would be important to see if similar differences would be seen when scripting other types of content.

In addition, although the after school setting was a good fit for the length and goals of this investigation, it also introduced a number of challenges. Specifically, even though the majority of children were very engaged during the lessons, it was sometimes difficult to ensure the same level of attention that children might typically have during the regular school day. In addition, the setting in which the study was conducted imposed constraints on the length of the instructional manipulation. Although working with the children for even as few as 10 consecutive afternoons posed a number of scheduling challenges, it is possible that a longer instructional unit – and with it greater exposure to differential styles of instruction – might result in greater differences in children's performance. Moreover, building rapport with a new group of students quickly can be extremely challenging. Each of the teachers who led lessons in this investigation proved to be very skilled in working with the children under these circumstances, but it is likely that the ease of implementing these techniques during regular lessons would be much easier.

For these reasons, an important next step would be to conduct this type of investigation directly in the elementary school classroom. This could be done in the context of novel science units, as was the case in this investigation, or during regularly occurring mathematics or language arts lessons. In addition, it would also be ideal to move away from scripted lessons and toward training instructors more broadly in ways that they could make use of these techniques in their everyday lessons. Based on the teacher training that was conducted as part of this investigation, it is likely that this might be easier than might be suspected. Indeed, as mentioned above, in addition to being provided the scripted lessons, teachers were also trained in the use of specific techniques that could be used in each condition. Emphasis on these same techniques was the focus of daily feedback to the instructors, as well. In general, teachers were able to incorporate the use of memory-relevant instructional techniques into their lessons with little difficulty.

All in all, the findings presented here provide insight into how memory-relevant instruction relates to children's strategic performance and learning of new content in a fun and engaging science unit, but provides limited evidence that would directly related to children's school-based performance. Thus it would particularly interesting, for example, to conduct a similar investigation in the context of regularly occurring mathematics lessons. In this way, it would be possible to combine measures of memory strategies, the use of math strategies, and mathematics achievement. With this evidence similar linkages could be investigated, but would have greater relevance to children's academic performance in school.

The findings reported here demonstrate that it is possible to train teachers in the use of memory-relevant instructional techniques. Moreover, it is apparent that when teachers instruct children using these methods, children in turn exhibit more sophisticated use of memory strategies with content-related materials and demonstrate higher levels of content-related strategy knowledge than their peers exposed to low-memory instruction. Importantly, although additional research is still needed to better understand the underlying mechanisms and broader impact of instruction on children's memory development, the success of this manipulation provides further evidence for the importance of memory-relevant of language when teaching children.

Appendix A

Taxonomy of Classroom Behaviors
(3.25.10)

Coding with the Taxonomy of Teacher Behavior – The Taxonomy calls for the classification (in 30 second intervals) of each teacher's conversation into four broad categories: *instruction*, *cognitive structuring activities*, *memory requests*, and *metacognitive information*.

Codes:

Instructional		Cognitive Structuring		Memory Requests (Expressed or Implied)		Metacognitive Information	
BR	Book Reading	**MREP**	Massed Repetition	**SEM**	Semantic	**SUG**	Suggestion
GIG	General Informatio n Giving	**IDF**	Identifying Features	**EPI**	Episodic	**MQ**	Metacognitive Questioning
PS	Prospectiv e Summary	**CAT**	Categorization	**PRC**	Procedural	**MR**	Metacognitive Rationale
STI	Specific Task Instruction	**REL**	Identifying Relationships	**PRS**	Prospective	**SUP**	Suppression
		PEH	Personal Experiences Home	**ANT**	Anticipated	**REP**	Replacement
		PES	Personal Experiences School				
		INF	Drawing Inferences				
		IMG	Visual Imagery	NON	Non-Instructional/Non Memory Relevant (NON)		
		ATI	Instructional Goals				
		ATB	Behavioral Goal				

A. Instructional Activities:

Book Reading (BR): The teacher reads from a book or other source (e.g., a story written by the class, a poem, a letter, the words to a song, etc.)-- this code will carry through the reading of the book or other material, but will not preclude coding of other verbalizations (e.g., GIG, PES) that the teacher intersperses throughout the book. Note: the reading of a single sentence, word problem, etc. do not get coded as BR.

General Information Giving (GIG): The teacher presents ***new*** factual information to the children. In instances where a teacher repeats a child's answer, the GIG code is used only if she provides further elaboration or information.

***Examples*:**
- While showing children a frog, the teacher tells the children about the frog's wetland habitat and how the frog has adapted to living there.
- A homonym is a word that sounds just exactly like another word, but it's spelled differently and it means something else.
- The teacher shares information about a personal experience relevant to a lesson.

Prospective Summary (PS): The teacher describes upcoming events to the children. (Not to include narratives of what she is doing, but instead describing & organizing events, lessons, or days for the students).

***Examples*:**

• The teacher says, "This morning we will go to music and this afternoon we will work on our garden space."

• Today we are going to talk about dinosaurs.

• We are having a test tomorrow and then we'll go out and play kickball.

Specific Task Instruction (STI): The teacher gives the children instructions for performing a particular activity. Additionally, STI will be used to capture instances in which a teacher invites a child or children to complete a task through the use of statements or questions that serve to describe task itself.

***Examples*:**

• The teacher describes and demonstrates how to form the letter W.
• The teacher instructs the children where to place their completed work.
• The teacher shows the children the sequence of movements of a dance.
• The teacher tells the children the procedures for completion of the activities at each classroom center.

• Who wants to come up and find the word "and" in this sentence?

B. Cognitive Structuring Activities:

Massed Repetition (MREP): The teacher directs the children to perform an activity in unison. The activity may be a physical activity such as performing a series of movements demonstrated by the teacher or repetition of an utterance or phrase made by the teacher. The purpose of the activity is to cause the children to maintain conscious awareness of the current information. Note: This is not to be coded if a teacher merely poses a question and more than one child answers at a time.

***Examples*:**

• The teacher and children name the colors that comprise a pattern of unifix cubes.
• Children join in to sing a familiar song after the teacher begins to sing the first line.
• Let's all read this letter together.

Identifying Features (IDF): The teacher or children generate features of one semantic, biological, or conceptual category that is specified by the teacher. The presence of the category as it relates to other classroom activities must be obvious to the observer.

***Examples*:**

• When introducing a new unit on insects the teacher names and points to the parts of an insect.
• The teacher says, "Circle the 'it' family words." or "Underline the contractions."

Categorization (CAT): The teacher or children place presented conceptual or material items verbally or motorically into at least two categories. The children may be required to decide which of several categories is most appropriate for specific items. It must be obvious to the observer that the activity includes and specifies the use of at least two categories.

***Examples*:**

• To demonstrate that animals can live in different environments, the teacher sorts cards with
pictures of animals based on the animals' natural habitat.
• After reminding children of a previous lesson about vowels and consonants, the teacher points to
letters and asks whether each letter is a consonant or a vowel.
• Teacher calls out numbers and the children decide if each is odd or even

Identifying Relationships (REL): The teacher or the children compare or contrast at least two objects or concepts, emphasizing their similarities and differences.

***Examples*:**

• The teacher begins a phonetics lesson about "silent e" by showing children word pairs that are identical except for the "e" at the end of the second word of each pair (can and cane). She compares the words and points out the difference.

• The teacher shows the children two numbers and asks, "Which number is greatest?"

• After several lessons about insects, a child is asked to identify the similarities or differences between a butterfly and a beetle.

• Squares and rectangles both have four sides but in a square all the sides are the same length.

Making Connections with Personal Experiences (PEH or PES): The teacher asks the children to associate a prior experience within the classroom or outside of school to a current classroom activity.

***Home*: PEH**

***Example*:**

• The teacher asks for names of objects from home to include in a poem.

• The teacher tells children to write about their weekend in their journals.

***School*: PES**

Example:

• The teacher reminds the children of the previous week's lesson about fossils presented by a visitation teacher from the Museum of Natural History as she begins a lesson about Dinosaurs.

• The teacher says "Yesterday we talked about..."

Drawing Inferences (INF): The teacher asks the children to predict an outcome that has not yet been materialized, or to assume the intentions, desires, or motivations of others from their actions.

***Examples*:**

• After reading the beginning of a story and examining its illustrations, a child is asked to predict what will happen next.

• The teacher asks "What do you think will happen when I mix salt with water?"

• The teacher asks the children to think about why a character did something or how that character might have been feeling.

• After writing a story, the teacher asks "what would your first reaction be to that situation?"

Visual Imagery (IMG): The teacher asks the children to create visual mental images that relate to presented material.

***Examples*:**

• The teacher says, "Imagine yourself as an animal, what animal are you?"

• The teacher tells the children to make a picture of their favorite place in their mind.

Attention Regulation (ATI or ATB): The teacher directs or focuses the attention of children. This direction may be employed for the sole purpose of behavioral control or in the service of *imminent* instructional goals. In unusual circumstances with multiple utterances, both ATI and ATB could be coded, such as when a teacher tells a child to sit down and then refocuses her attention on a visual aid.

***Instructional goal*: ATI** is coded when a teacher initiates attention regulation either providing directions for following along or focusing attention prior to the start of an instructional activity. ATI is always used to code something in the *here and now* (**not** "think about something in the past.")

***Example*:**

• The teacher asks the children to look at the class calendar to calculate the number of
Fridays left in the month.

• "Think about the parts of a story."

• "Sit on your knees if you can't see the chart."

• The teacher facilitates increased involvement in a class activity ("let's hear it," "it moves quickly, keep up")

***Behavioral goal*: ATB** is coded when the teacher is regulating student behavior, usually in response to student actions.

***Example*:**

• The teacher reprimands student for speaking loudly and disrupting the class during a lesson.

• If a student walked through a group of children and the teacher told him to walk around.

C. Memory Requests

The teacher expressly asks the children to remember an event, fact, procedure, or activity. The memory demand may be explicit or implied in the form of either a question or command. Each memory request should be categorized first by the type of question (SEM, EPI, PRC, PRS, or ANT) and then the nature of the memory demand (expressed vs. implied).

Deliberate memory demands

Expressed Deliberate: Requests in which memory is explicitly stated. Can be instances where the teacher uses key words to ask children to:

- remember,
- don't forget,
- put it in your brain
- remind me to
- know/learn this

Implied Deliberate: Requests that do not explicitly reference memory. Can be activities in which the teacher asks students to:

- recall details of an episode,
- retrieve previously presented instruction,
- recall a series of instructions required to accomplish an assignment
- fulfill a request at a later point in time

Semantic (SEM): The teacher requests that a child or children retrieve an already learned fact, idea, or object. The information requested is generic in nature, with no specific input (event, situation, or circumstance) referenced.

***Examples*:**

• "Do you remember what 4+4 equals?"

• "Hold up the number of fingers to show what 2+2 equals."

• "How do you spell 'Dear'?"

• "Change one letter to make 'bead' into 'bear'.

• "Step on a shape that has three sides."

Episodic (EPI): The teacher requests that a child or children retrieve a specific past event that occurred inside or outside of the classroom.

***Examples*:**
- "Do you remember what happened at your third birthday party?"
- "Tell me what you did at your birthday party."
- "Do you remember what we did the last time the weather was nice?"
- "Where did we go last Tuesday when the weather was nice?"

Procedural (PRC): The teacher requests that a child or children recall how to perform a series of related activities which, when performed in order, combine to achieve a specific goal.

***Examples*:**
- "What is the first step in solving this problem?"
- "Who remembers how to make modeling dough?"
- "How do you make modeling dough?"

Prospective (PRS): The teacher assigns a non-instructional task to be completed by the child for a future purpose. The request is often phrased as an imperative that implies a ***behavioral*** goal.

***Examples*:**
- "Don't forget to skip lines when you are writing."
- "Bring your lunch money tomorrow!"
- "Remember to have your parents sign the permission form for our field trip."
- "Have your parents sign the permission form for our field trip!"

Anticipated (ANT): The teacher states his or her expectation that the child is to remember some material or presented information, implying that study should be done, but not specifying the nature of study or strategy use at all. The request implies a ***learning*** or ***studying*** goal.

***Examples*:**
- "I expect you to learn these for the test on Friday."
- "I want you to remember this set of numbers."
- "Remember that this is just a draft and we will do editing."
- "When you are writing a story, always think about your audience."

D. Metacognitive Information:

The teacher provides or solicits metacognitive information. This can be accomplished in the form of direct instruction, through suggesting a way for students to improve future recall of current information or general instruction, or through providing rationale for the use of a particular strategy. Alternatively, the teacher may solicit metacognitive information from the students. Such instruction might be designed to increase students' planning, organizing, or self-regulation.

Suggestion (SUG): The teacher recommends that children adopt a method or procedure for remembering or processing information. Include content specific strategy suggestions (e.g., counting on, looking at the picture to figure out a word).

Examples:
- "If you make a picture in your mind it will help you to remember (w/rationale)."
- "Look up here at our chart and see if it gives you a clue to the answer (w/rationale)."
- "See if that makes sense."

Metacognitive Questioning (MQ): The teacher asks a child to provide either a potential strategy, a utilized strategy, or a rationale for a strategy they have indicated using. This could be double coded with a deliberate memory demand.

Examples:
- "How did you study those words?"

• "What are some strategies you could use to help you figure that out?"
• During a lesson on highlighting, the teacher asks, "Would it help to highlight everything?"
• "How do I prove that the answer is 15?"
• "How do you know you were supposed to add/subtract?"

Metacognitive Rationale (MR): The teacher provides a rationale for a strategy, making clear that it will serve a memory or learning function for the child. This can occur with or without a specific suggestion.

Examples:

• "Using a weekly planner will help you organize your assignments so you can remember all of them."
• "If you don't know that word, you can read the rest of the sentence to see what could make sense there and it may help you figure it out."

Suppression (SUP): The teacher recommends that children refrain from using an unhelpful or inappropriate method or procedure.

***Example*:**

• "Don't count on your fingers."
• "Don't just guess."
• "Don't erase your mistakes."

Replacement (REP): The teacher recommends a more effective alternative method or procedure to the children.

***Example*:**

• Instead of just guessing about what will happen next, look carefully at the pictures and think about what they tell you about the story."
• "Don't erase your mistakes. Just cross them out."

Note: When a replacement occurs, it will usually be preceded by suppression. Both should be coded.

E. Non-Instructional/Non Memory Relevant (NON)

The non-instructional code will be used to capture instances in which the teacher is not engaged in a memory or instructionally relevant activity. The NON code will be used when there is a teacher-driven non-instructional period or when there is a continuation of an activity with no new verbal instruction (the coder will note intervals of this second type). NON will also be used as the default code, such as when a verbal interruption spans an entire interval.

General Taxonomy Notes:

1. Only code teacher-led instruction (e.g., do not code aide teaching)

2. Avoid Double coding except in special circumstances:
   a. Metacognitive Questions can be double coded with other memory requests
   b. Memory Requests can be double coded with some cognitive structuring activities (e.g., PES and PEH, IDF or REL)

3. The question of "Are you ready?" or similar attention getting devices can sometimes be captured with an ATI code. This should only be the case when the teacher is using the question to focus attention before the start of an activity.

4. INF will never be a deliberate memory demand in and of itself.

Appendix B

Sample Instruction from High Mnemonic Classrooms in Mathematics and Language Arts

High Mnemonic Language Arts Example	High Mnemonic Math Example
In this example, a first-grade teacher is leading students in a word game, in which the students have been asked to guess the words that are covered up in several sentences. She wants them to use the context of the surrounding words to make informed guesses as to what the covered word could be. As the teacher pulls the names of students out of her "magic bag, she asks each one to provide a word that will make sense in the sentence and that follows the theme of "In my classroom." ***T:*** Let's see if you guys can help me figure out what the covered up word is . . . So let's see, let's choose four words for each sentence, and see if you guys can make it make sense, because this is why we learn to read. These words have to make sense or they don't mean anything to us. So let's read it together. ***All:*** On the teacher's desk, there are . . . ***T:*** OK what could be on the teacher's desk? Just look back there and see what's back there. Looking away…what could be back there on that teacher's desk? ***S1:*** Pencils. ***T:*** Pencils! Ok, on the teacher's desk, there are *pencils*. P-E-N-C-I-L-S. Does that make sense in the sentence? Let's see if it makes sense. *The teacher and students all read the sentence again together.* ***All:*** On the teacher's desk, there are *pencils*. ***T:*** Would that make sense? *Students:* Yes!	*The teacher is standing in front of the chalkboard teaching a lesson about place value and how numbers can be demonstrated visually using tally marks. On the overhead are math manipulatives (rods and squares where the rods equal 10 and the squares equal one). She tells the class that each individual tally mark equals one, and each "box" of tally marks equals five. There is a student at the overhead demonstrating how to write a number using tens and ones. The teacher asks the class if the student will need to make another "box" to complete the number.* ***T*:** And each box is worth how much? ***S1*:** Five. ***T*:** Five, so each tally mark is worth one, each box is worth five. And she's doing a wonderful strategy of putting the amount underneath, counting by fives. Five, ten, fifteen and now she's going to add the rest. Will she make another box? ***S2*:** No. ***T*:** No, she does not have enough to make a box, but she has her amount. Beautiful! That's how your tally boxes should look for that number. Five, ten, fifteen, and then sixteen, seventeen. *(The teacher is showing the students each box/tally on the board as she calls out the numbers.)* Who will take a risk, and show us that number using place values? *The students raise their hands. The teacher looks around and calls on a student, and he comes up to the overhead.* ***T*:** You have two choices, you can use the overhead rods if you'd like, or you can draw them if you'd like. What's a good strategy to do with the number 17 before he even starts with the place values? Is there a good strategy? ***S3*:** Yes. ***T*:** Yes. What's a good strategy? ***S3*:** You…do the tens and then the ones.

Appendix C

Sample Instruction from Low Mnemonic Classrooms in Mathematics and Language Arts

High Mnemonic Language Arts Example	High Mnemonic Math Example
In this example, a teacher is leading students in a lesson in which she is asking them to assist her in making sentences on the board. As the teacher writes sentences on the board she intentionally leaves out letters for the students to fill in. ***T:*** Okay, let's see. *Last October, ws my birthday. i had so much fn.* What's wrong? ***S1:*** There should be a *u* in *fun*. ***T:*** A *u* in *fun*? Are you sure? ***S1:*** Yes. ***T:*** Alright, before we fix anything else, what happened to my words though? What did I do? ***S2:*** You were going too fast. ***T:*** I was going too fast, *and* what did I do? ***S3:*** You messed up on getting letters. **T:** But what did I forget in general? We talked about it yesterday, what did I forget? I forgot to always take my time, and I forgot what*?* ***S4:*** The vowels. ***T:*** I forgot the vowels! Because without the vowels, do you know what it sounds like? *The teacher tries to say the sentence using no vowels. The class giggles when she reads "ws".* ***T:*** *A*, I'm just going to squeeze it in. O-c-t-o-b-e-r. You hear how that opens it up? Last October was my b-i-r-t-h-d-a-y, and I can be excited about that. I couldn't be excited without the vowels. I need the vowels to be excited. Last October was my birthday!	*In this lesson, a first-grade teacher is leading her students in addition problems involving two-digit numbers. The teacher presents the problems to the class on the overhead projector and the students are called on to answer them.* ***T:*** Let's count again, let's do 92 + 8. We have 92, we have 93 . . . ***All*:** 94, 95, 96, 97, 98, 99, 100. 100. You got close Mara, good job, but the answer is 100. Now, who had number two? *The teacher moves on to the next problem.* ***T:*** 89 + 9 equals 98. How about this, is this correct? ***S:*** Yes. **T:** Alright, good job. Just look at number three. 54 + 10 equals 64. ***All*:** *64* ***T*:** Who had this one? Is this correct? *Some students respond with yes and some with no.* ***T*:** Class, do we agree? *Students again respond with yes and no.* ***T*:** Let's see, we have 54 and plus 10 more, 5 plus 1 is what? ***S*:** 64. ***T*:** 64 is correct, good job.

Appendix D

Sample Instructional Techniques

Instructional Techniques	Definitions	Example
Categorization	Verbally or physically putting material into categories	"Let's make groups of vehicles based on if they broke or survived the drop test."
General Information Giving	Presentation of factual information	"This gear has 40 teeth."
Identifying Relationships	Comparison of at least two objects or concepts	"Both wheels and gears are circular, but gears have special teeth."
Metacognitive Questions	Requesting that a child provide a potential strategy, a utilized strategy, or a rationale for a strategy they have indicated using	"How did you figure out which pieces you would need to build a sturdy structure? How did you know that would work?"
Procedural Request	Recollection of how to perform a series of activities to achieve a goal	"When we make our Lego cars, what is the first step?"
Prospective Summary	Describing upcoming events to the children.	"Today we will be building our own cars with wheels and axles."
Referencing Personal Experience	Associate a prior experience at home or at school to a current classroom activity	"What is an example of a gear that you might find in your house?"
Semantic Question	Retrieval of an already learned fact, idea, or object	"What is the name of this Lego piece? What does it do?"
Strategy Suggestions	Recommending that a child adopt a method or procedure for remembering or processing information	"If you are having trouble thinking of ways to connect the wheel and axle, you can look at the diagram to help you."
Metacognitive Rationale	Providing a rationale for strategy use of for students' planning, organizing, or self-regulation	"If you keep the items organized in their groups, you will be able to remember where they go and find them more easily later."

Instructional Techniques	Definitions	Example
Strategy Suggestions	Recommending that a child adopt a method or procedure for remembering or processing information	"If you are having trouble thinking of ways to connect the wheel and axle, you can look at the diagram to help you."
Metacognitive Questions	Requesting that a child provide a potential strategy, a utilized strategy, or a rationale for a strategy they have	"How did you figure out which pieces you would need to build a sturdy structure? How did you know that

indicated using	would work?"
Instructional Techniques Co-Occurring with Memory Questions	
Requests for information from memory **and** the presentation of instructional information by the teacher	"Today we will be building our own cars. Who knows the first step we take when building a new structure?"
Requests for information from memory **and** teacher instruction that could impact the encoding and retrieval of information, such as focusing attention or organizing material	"All of these modes of transportation have wheels. What is another vehicle that you have seen around town that also has wheels?
Requests for information from memory **and** the provision or solicitation of metacognitive information	"What kind of gear is this? What clue did you use to help you figure that out?"

Appendix E

Sample Instructional Techniques

Instructional Techniques	Definitions	Example
Categorization	Verbally or physically putting material into categories	"Let's make groups of vehicles based on if they broke or survived the drop test."
General Information Giving	Presentation of factual information	"This gear has 40 teeth."
Identifying Relationships	Comparison of at least two objects or concepts	"Both wheels and gears are circular, but gears have special teeth."
Metacognitive Questions	Requesting that a child provide a potential strategy, a utilized strategy, or a rationale for a strategy they have indicated using	"How did you figure out which pieces you would need to build a sturdy structure? How did you know that would work?"
Procedural Request	Recollection of how to perform a series of activities to achieve a goal	"When we make our Lego cars, what is the first step?"
Prospective Summary	Describing upcoming events to the children.	"Today we will be building our own cars with wheels and axels."
Referencing Personal Experience	Associate a prior experience at home or at school to a current classroom activity	"What is an example of a gear that you might find in your house?"
Semantic Question	Retrieval of an already learned fact, idea, or object	"What is the name of this Lego piece? What does it do?"
Specific Task Instruction	Providing instructions for performing a particular activity	"Fill out your engineer logs and put them into the file folders."
Strategy Suggestions	Recommending that a child adopt a method or procedure for remembering or processing information	"If you are having trouble thinking of ways to connect the wheel and axle, you can look at the diagram to help you."

Day 2: WHEELS AND AXLES

Goals:

- Learn about the simple machine wheels and axles
- Build basic Lego structures and use toy cars to test the importance of wheels in decreasing work and effort

Background Information on Wheels and Axles

- *Yesterday we talked about all sorts of different things that move.*
  - *Who remembers what specific moving things we are going to focus on for the rest of this week?*
    - *We talked about three types of things that move including things that move by air, by land, and by sea.*
  - *What did all of the vehicles that we talked about have in common?*
- Pull out the table of vehicles from the day before and refer to the nominated items again.
  - *Each of these vehicles has a wheel and an axle.*

Wheels and axles as simple machines:

- *The wheel and axle are a simple machine.*
- *Simple machines make work easier by allowing us to push or pull over increased distances.*
  - *There are 6 types of simple machines, and the wheel and axle is one.*
  - *Simple machines, when combined, are the building blocks of which all complicated machines are composed.*
    - *Does anyone remember what we call those more complicated machines?*
      - *When many simple machines are combined we call them compound machines*
    - *Did anyone remember to look out for simple or compound machine last night at home or today while you were in school? What types did you see?*

The wheel and axle can consist of a wheel that turns an axle or an axle that turns a wheel.

There are two ways to use a wheel and axle:

1. *To roll things* (e.g. a car) – *the wheels move independently of the axles*
2. *In the round* (e.g. a door knob) – *force is exerted on the wheel (by you) and the axle turns. In this case, the simple machine aids in work.*

Wheels and axles can be found all around us – even in everyday objects that you may not expect.

Book Reading Activity: Wheels, Axles, Spokes, and Sprockets

Now I am going to read you a book that is all about the wheels and axles that we encounter every day. As I read I want you all think about examples that we can share later of wheels and axles.

As you read the book, ask the questions prompted on each page.

After reading the book:

- *Now that we have read the book, can anyone think of examples of wheels and axles?*
  - *How would you be able to identify if something is a wheel and axle?*
  - *How do wheels and axles help decrease work that people have to do?*
  - *What are some things that we may not have thought of before that wheels and axles help us do?*

- *When we are thinking of different types of wheels and axles, let's think about them in terms of examples of ones that roll and ones that are used in the round. What is the wheel and what is the axle?*

Remember that the wheel and axle can consist of a wheel that turns an axle or an axle that turns a wheel.

There are two ways to use a wheel and axle:

1. *To roll things* (e.g. a car) – *the wheels move independently of the axles*
2. *In the round* (e.g. a door knob) – *force is exerted on the wheel (by you) and the axle turns. In this case, the simple machine aids in work.*

  - *What are some ways that you can recognize and remember the differences? How might an engineer remember how these two are different?*
  - Make a Venn diagram of the ideas that the children generate.
- *What other types of wheel and axle combination can you think of that might be in a car aside from the obvious? What are some that were mentioned in the book?*
- *Some examples to continue the conversation:*
  - *The potting wheel is one example of using a wheel in the round.*
  - *Simple wagons or carts are examples of wheels and axles that are used to roll.*

Examples of wheels and axles:

Merry-go-round
Screwdriver (in the round)
Hinges
Faucet (in the round)
Door knobs (in the round)
Hand drill
Steering wheel (in the round)
Yo-yo
Windmills (in the round)

Other important piece of information to incorporate:

- The types of wheels you choose when building a vehicle depend on what you want your vehicle to do.
  - Tires with larger diameter will make the car move faster.
  - Tires with smaller diameter will provide more power.
  - Thinner tires are also faster

<u>Lego Building – Sturdy Cars & Sliding vs. Rolling</u>

Yesterday when we built we used regular Legos. Today we will be working with special Lego sets. Before we get started building today, I want to show you all how to use these sets like engineers.

  - Hand out sets to each group of students. Have the student open the sets and ask them to inspect them first along with you.
- *Look at the Legos, there are lots of additional pieces. Let's talk about them.*
- Label each of the main pieces and describe them – they will be readdressed as needed, but describe their name and function as they related the previously identified features of moving vehicles.
  - Identify the specific pieces (using pictures and pieces) and the children pull out those specific pieces, map on names, etc. As you show the students each piece, ask them occasionally:
    - *Who can tell me what the name of this piece is? How did you figure that out?*
    - *What could these be used for?*
  - Introduce the sets:
    - Describe what each piece is used for while presenting them to the group.
    - Show the children where these pieces are located on the model truck. Point out wheels, axles, hubs, etc.

- Plates and blocks
    - Who remembers how an engineer might label these to make sure that they were using the correct one? Can anyone find a 2 x 3 plate?
- Beams
    - Beams are going to be very helpful to us when we are building. There are three types of beams. One is the studded beam. Do you think that we could identify these in the same way that we would a plate or a beam? Why or why not? The other is also straight beam, but it has smooth sides. How could you count the length of these? The third type is an angular beam.
- Wheels
    - You will notice that there are many different types of wheels in these sets. What are some of the types of wheels you see? What are some of the ways that we talked about yesterday that you might be able to make sure that you have found the correct wheels when we are trying to build something specific?
- Axles
    - Look at the different wheels and axles. Some of them are really short, and others are very long. These axles don't give us any way to count how long they are like the bricks and plates do . . . how do you think that you could tell that you are using the right axles when you are building?
- Bushings
    - These bushings are really small, but in the next few days you will learn that they do a really big job when we are building. How many different types do you see? How are these different than the other pieces that you see? What do you think that they do?
- Hubs
    - There are several different types of hubs, and each works with a specific wheel. When you are building with wheels and hubs, you have to make sure that you match the right ones together.

- These Lego boxes will be really helpful to us while we are building.
    - Can anyone think of why these boxes might make it easier for us to find and organize the pieces that we need?
    - When we are building with our partners it helps to be able to use Lego names for the pieces we want to use. How might we be able to use these boxes to help us remember the names of the pieces?

When we are building with these Legos, there are some special things we need to remember about how to take care of them. Open your engineer notebook and turn to the third page. Let's go over them together first, but if you ever forget them just remember that you can look them up in your notebook.

General Rules of Legos

- Lego engineering is different than playing with Legos at home. We need to make sure that we do not lose these Legos, and we must put them away in their kits at the end of the day.
- Only pull out the pieces that you think you will need for what you are doing right now.
- The Lego pieces must be used in a contained area.
- We all have to share the pieces, and if you are not using them you have to put them back or share them with another builder.
- If you are already finished with you project you may ask if others need help problem solving as well – troubleshoot with another group.

- If the Legos get stuck together and you can't get them apart, find a Lego separator!

Introduction

Next we are going to test out the importance of wheels using our Legos. Who remembers some of the rules that we discussed about how to use the Legos?

- Recap the rules of Lego building – specifically only using the pieces designated for this particular build
- *Look at the Lego building guide. What pieces do we need to get started? How did you find which piece you would need to use first? What is it called?*
    - Continue to label each piece for the students and ask how it is used.

1. Provide time for the children to build a model of the base of a car.
2. Slide it across different surfaces. What does it do?
3. Add wheels and axles to the vehicle. Slide it again. What is the difference?
4. Slide the car down a ramp and measure the distance.
5. Change two wheels for larger ones. Slide the car down the ramp and measure the distance again.

Summary:

- What did we find out today about the importance of wheels?
- As good engineers, how do we best set up a test of the different wheels? What things do we need to think about when we are comparing different parts of the things that we have built like we did today?
- How might an engineer have tested out different types of wheels and compared them to one another?

Wrap up

Sort all of the pieces back into the appropriate bins.

- Please put all of the pieces back into the boxes and make sure that each of them ends up in the right spot. If we sort all of them now, it will make it much easier to find everything tomorrow!

Day 3: STURDY CARS

Goals:
Present the idea of sturdy structures and three ways to build sturdy walls
Build and test a sturdy wall
Build a simple sturdy car base that can survive the drop test
Introduce the utility of connector pegs

Begin with a general discussion of study structures:

- *Yesterday and the day before we talked about the importance of simple machines.*
  - *What are the different types of simple machines?*
  - *Who remembers what a simple machine and a compound machine are?*
    - *What is the difference between the two? How can you tell?*
  - *Why are simple machines are so important?*
- *So who thinks that simple machines are important to the types of vehicles that we will be building together? Why do you think so?*
- *Who remembers what Lego pieces we worked with yesterday?*
  - *What were the names of the pieces?*
  - *Why were _________ important when we were building?*

    Items used:

Plate	Axle	Tire	Hub
Bushing	Beam	Brick	

  - *What are some of the strategies that we talked about yesterday that will help us with Lego selection?*

- *We know that simple machines are important in everyday things we do, but another very important part of building that I want you to remember each time you think of what you are going to build is making sure that the things we build are sturdy.*
  - *Who knows what sturdy means?*
  - *Why might it be important if the things we build are sturdy?*
- *Does anyone remember the story of the Three Little Pigs?*
- *I am going to read the story to you again, and while I am reading I want you to be thinking about building things that are sturdy. When the story is done we are going to talk about ways that we can build things that are sturdy, so pay attention while I am reading so you will remember what makes some buildings stronger than others!*

Read the story to the children. While reading, ask questions throughout:

- *Look at this picture . . . why do you think that this house was not strong enough?*
- What should this pig have done to make his house stronger? Why do you think that would have helped?

After the story is done, ask the children:

- What were the three materials that the three pigs used?
- Why do you think that the bricks saved the pigs and the other materials didn't?
- Do you think that any of the building techniques we heard about in the story would help us make our Lego structures sturdier?
  - Why or why not?

Engineer's Challenge 1: Sturdy Wall

The first engineering challenge today is to build a sturdy wall. The students may use only the Lego pieces that have already been discussed, and the resulting wall must be able to pass the "flick test". Before the students begin building, demonstrate the "flick test" to them, so that they understand the challenge. Corresponding worksheets will be found in their engineering journals that will allow for a brief follow up activity. Begin by saying:

Today our first engineering challenge will be to build a sturdy wall just like the walls of the houses we learned about in the Three Little Pigs. You can use any of the pieces in your box that we have already talked about, and you may want to use some extra beams or blocks. I want you to try to make a wall that is at least 7 blocks tall.

- *Remember while you are working that your structure will have to pass the "flick test".*
    - *What is the first engineering step that you need to think about before you begin?*
    - *If you can't remember the steps, make sure to look in your engineering notebooks!*
- *When you and your partner have completed your wall, bring it to me and I will test it for you.*
    - *Before you begin, can anyone tell me what types of things do you think that you will need to consider while you are building?*
    - *Remember while you are building to think about what we have learned from the 3 Little Pigs!*
- *Before we begin, open your Engineers Log to the page that says "Sturdy Wall" at the top. Once you have tested a sturdy wall, I want you to draw in the right box a picture of what a wall would look like that would not be sturdy. Next to that, I want you to draw your successful wall. While you are drawing, focus on the way the bricks are connected. Think about what is similar about the way the bricks work together and what is different while you are working.*

Allow the children time to build. As they complete their walls, conduct the flick test for those that have finished. If the wall fails to pass the flick test, ask them:

- *Look at the wall you have made. Why do you think that it did not pass the flick test? What can you do to fix the problem? Try it, and bring it back to me to test!*

Once everyone is done building at least one wall, have them come together as a group and bring their walls, and begin discussing the structures:

- *What building techniques did you all find made the best sturdy wall?*
- *What were some of the building challenges you faced? How did you solve them?*
- *What building tips can you think of that would help another person build a sturdy wall?*
    - Make a list of the children's suggestions. Make sure that the following are discussed and written on the large pad and ask the following questions if the answers do not come up:
        1. Overlapping beams and bricks are stronger than non-overlapping ones.
            a. *How can we tell if the bricks are overlapping?*
            b. *How does that help make things sturdy?*
        2. Three stacked plates are the same height as one beam or one brick.
            a. *Do you think that this is something that we want to make sure to remember while we are building other structures?*
            b. *How could this help us?*
        3. Breaks usually occur where there are double cracks.
            a. *What do you think that means?*

All of these building strategies will be very important to remember for when we are building other things. Please write these three strategies in your Engineer Journals. If you need to remember them, you can look in your journals for helpful tips when you are building in the future!

Engineer's Challenge 2: Strongest Shape

Now that we have all learned ways to build a sturdy wall, I want to talk with you about how to make other things that we build with Legos strong.

- Why do you think that it is important that we make what we are building strong?
- Is something that is strong also sturdy?
    - How are they similar or different? Why do you think so?
- What are the names of some shapes?
    - Do you think that a _______ could be strong? Why or why not? (ask this of some the shapes the children nominate).

Our next challenge it to use some of the newer Lego pieces to make strong shapes. The things that we build will need to be able to pass the "push test". Before we begin building, I want to introduce the Lego pieces that you will be able to use on this challenge. Look at the pictures that I have here.

- Show the pictures to the students and ask them, *"Can anyone tell me what type of Lego piece this is? If you can't think of what it is, look in your boxes so that you can match the piece with its name."*
- Ask the students what they think that each piece is used for and talk about them together. Have them pull each out of their boxes for closer inspection.
- Continue by asking the students what the similarities and differences between the pieces are:
  - *How are these pieces similar? What is different about them?*
  - *Do these pieces work differently? How would an engineer know when to use one of these instead of the other?*
    - *When you are building it is important to remember that these two types of pieces can be used for different things:*
      - The BLACK pegs are used for a snug fit
      - The GREY pegs are used for a when you want things to be able to rotate and move
- Use the pegs to connect two beams, and show the children how they work differently.
    - *What is a way that we could remember what each is used for?*
      - *One thing that we could do would be to write it in our engineer's notebook so that we could remember it later.*

Continue to describe the challenge.

- *I want you all to think of some basic shapes. What are some shapes that you might be able to build?*
  - Have the children generate shapes such as a triangle, circle, rectangle etc. Tell them that they can decide to build whatever shapes they want, and that they should pick one to start with.
  - *The "push test" is a little different from the "flick test". To pass the "push test" your structure will have to be stable enough to keep its shape if I push on it from the top down.* (Demonstrate what this means.)

Have the students begin building, and test their structures as they finish.

- As they build, if their shape does not pass the push test remind them of the steps of engineering and ask them what other ways that they can think of to make the structure stronger. Have them rebuild and try the test again.

Summary

If time allows, after the children have had the opportunity to build some shapes, come together as a group. Ask the children about the building process, and the structures that turned out to be the strongest.

- *Did anyone find a shape that was very strong? Can you tell us what shape it was, and what pieces you used? Why do you think that it was strong?*
- *Did anyone encounter any challenges while building? What were they? How did you work around the challenge?*
- *Where there any building strategies that we have talked about before that you thought were really helpful when you were working on this? What did you do, and how did it help?*

Day 7: GEARS

Introduction to Background Information on Gears

- *Who remembers what we talked about most of yesterday? Can anyone remind me what a gear is?*
- *What do wheels and gears have in common? How are they different?*
  (Both wheels and gears are circular, but gears have special teeth.)
- *What is special about gears that makes them different from wheels? What do they have that wheels do not?*
- *Who remembers what gears are used for? Where could we look to help us remember? How are they helpful to us?*
  - **Gears are used to:**
    1. **Reverse the direction of rotation**
    2. **Increase or decrease the speed of rotation**
    3. **Move rotational motion to a different axis**
    4. **Keep the rotation of 2 axes synchronized**
- *Who remembers why gears are important in machines? Can you think of the two ways that we talked about yesterday?*
  - **They prevent the gears from slipping – axles connected by gears are always synchronized with one another**
  - **They make it possible to determine exact gear ratios. You can count the number of teeth to figure it out!**
- *Today I want us to test out our knowledge of gears by building our own gear trains with Legos.*

Vocabulary refresher:

- *Yesterday we talked about what we call it when we put several gears together too. What two words do we already know to use to describe gears? (gears and teeth)*

- *Who can remember what the three terms we used to talk about gears together?*
  - *If you need help, remember that they go together like a train!*
- *The three other words that are important are Driver, Follower, and Idler. These three apply when there are gears in a row together. When gears are in a row together like this, it is called a gear train.*
  - Show diagram of gear train and label the items.
  - *What are some ways that you could remember these terms?* (As the children provide items, write them on a sheet of paper that can be hung in the room.)
    - *To remember these terms you can think of the driver as the driver of the train.*
    - *The follower is like one of the cars that follows the direction of the driver of the train.*
    - *The idler can refer to all of the gears in the middle.*

Gearing up with Legos

Activity (Alternative building plans can be found on p. 102 of the Legos binder)

1. Build a model (p. 16 of Gears) using a 40-tooth gear an 8-tooth gear.
2. Predict what happens when you turn a handle on the 40-tooth gear.
3. Build another model with the handle on the other gear.
4. Predict what will happen now.
5. Build a model (p. 17 of Gears) with an idler.
6. Build a model with more gears on your own.

- *Do you all remember yesterday we talked briefly about gear trains? For our discussion today, it will be important for you to remember a few terms that are special to gears. What* *two words do we already know to use to describe gears? (gear and teeth). Who remembers what other words we used to describe gears that work together?*

- *Look at this picture of a gear train. Does the phrase "gear train" give you a hint? Who remembers what the words for each of these pieces are?*
    - *The three other words that are important are Driver, Follower, and Idler. These three apply when there are gears in a row together. When gears are in a row together like this, it is called a gear train.*
- Show diagram of gear train and label the items.
- *What are some ways that you could remember these terms?* (As the children provide items, write them on a sheet of paper that can be hung in the room.)
    - *To remember these terms you can think of the driver as the driver of the train.*
    - *The follower is like one of the cars that follows the direction of the driver of the train.*
    - *The idler can refer to all of the gears in the middle.*

Background information

Today we will be building our own gear trains. Open up the guide books in front of you to B which is on page 7. We are going to work to build these gear trains, and once the gear train is built we will be able to test out how different gears work together. Before we begin, let's all look at the first picture together.

- *What do you think our first building step should be today?*
- *While you are working, remember to only take out the pieces that you need to use at that time so that none of them gets lost!*
- *What is the first piece we need to find? How can I check to make sure that I have the right ones?*
- *Continue building, but while you are building until you have made your gear train structure (until step 5) make sure that you are paying special attention to using the right Legos AND counting. Why do you want to make sure that you are being careful with your counting?*
    - *Describe why they will need to count both the number of wholes on each beam to make the two side of the structure similar, and then also to make sure that they have the correct gears.*

Main Idea:

Gears are wheels with teeth that are used to pass on motion and force.
Two meshed gears turn in the opposite direction.

Allow the children to finish the basic gear train structure.

- *Turn the page to **page 8**. Look at **B1**. Using your gear train structure, I now want you to add some gears so that we can test out how the gears can work together. Look at the bottom left hand corner of the page – who can think of how that will help you decide which size axle you are supposed to use?*
- *Once you have finished building it, open up your engineer's notebook to document what you have done. You will write down the size of each gear, and then the gear ratio. For example, if the first gear has 8 teeth and the second gear has 40 teeth, the gear ratio would be 8 to 40. Go ahead and build only **B1, B2**, and **B3**. When you are finished, we will talk about them.*
- *While you are working, remember to think about the gears in these terms:*

  Main Idea:

  Gears are wheels with teeth that are used to pass on motion and force.
  Two meshed gears turn in the opposite direction.
  A **large driver** makes a small follower gear turn faster – this is **gearing up**.
  A **small driver** makes a large follower gear turn slower – this is **gearing down**.
  An **idler** gear makes adjacent gears turn in the same direction.

- For Each Set of Gears:

B1:

  - *Count the number of teeth on each gear in B1. How many teeth are on each gear on your gear train?*
  - *We use the number of teeth on the gear to determine the gear ratio between the two.*
- *Who can tell me how many teeth are on one of your gears?*
  - Write the ratio on the white board.
- *If the crank is attached to the 8 tooth gear and the other gear has 24 teeth, how many times would you have to turn the crank for the other gear to rotate all of the way around?*
- *If this gear one is our driver, how can we use the numbers in an equation in this way to set up a math problem? What kind of problem would this be like?* Another way to think about it would be to ask how many times 8 goes into 24. *How can you solve that problem?*

Before B2

- *Look at the steps for the next gear train. What do you see that is different? Based on what we just observed, how do you think that the gear ratio will change? How do you know? How can we test that?*

Before B3

- *What do you think will happen if both of the gears are equal? What information do you know about gears that you can use to solve that problem?*
- Continue this for the rest of the gear train ratios.

Have the children continue to build through **B4** – reiterate the idea of a gear train by showing them the pieces of the gear train they have built and labeling them.

Conclusion - Group Discussion

- Can you turn one gear and make another turn?
- Can you turn one gear and make more than one other gear turn?
- How many gears can you use in one system?
- What happens when a smaller gear turns a larger gear?
- What happens when a larger gear turns a smaller gear?

Summary:

Once the children are done building, gather as a group to talk about the gears covered today. Start the discussion by asking:

- *What types of things did we learn about gears today? Sometimes gears can be challenging to work with - what are some of the building strategies we might want to add to our list that are specific to gears?*
- *What are some of the benefits of using gears? What are some of the problems that might come up?*
  - Ask them to generate ideas and write them on the board or pad of paper and ask them to do the same. Add the following if they do not generate them.

Pros and Cons of Gears:

- **All gears must be carefully meshed to work.**
- **Spur gears are excellent for sending energy of motion from one place to another.**
- **Gears can speed up or slow down motion, change direction of motion, and they do not slip and are very efficient.**
- **Bevel gears can change the angle of motion.**
- **Worm gears change the angle of motion.**

- **Worm gears can ONLY reduce speed but at the same time significantly increase force.**
- **Worm gears also are self locking, which provides a safety feature for when the user is not interested in cranking anymore.**

Summary: Adding Gear Trains to Lego Cars

Now that we have learned to use gears with our Legos, I want you to think of some ways that you can connect gears onto the cars, which is what we will be doing tomorrow. How might these gears be included with the basic cars?

- *How would that work?*
- *What pieces would you use, and why would you use them?*
- *How did you know from this example that you could use them together that way?*
- *How will we remember what each gear is used for? What can we look at?*

Day 10: WRAP UP

Introduction

Allow the children to complete their cars. Have them all gather near the ramp, and test each of their cars first for speed and then for how far they can go over bumpy surfaces. As they test their cars, have the children help measure the distance and keep track of car performance on the board or big paper. Follow up the activity by having the kids all come back to the group and talking about their cars:

- *Everyone did an amazing job with that! Let's talk about our results . . . who remembers which car went the furthest?*
- *Why do you think that car went the farthest on the ramp?*
  - *Let's all look at it together . . . what do you see that might have made it go faster?*
  - *What building tips about making fast cars could we get from this one?*
- *Who else would like to share their car?*
- *Let's think about which cars did best on the bumpy surface? Why do you think that this car did well?*
  - *What can we learn from how this one was built?*

Summary Letter Writing Activity

- *Now that we have built and tested our cars, I think that we are real engineering Lego experts! To wrap everything up, I want you all to help me write a letter so that we can share with our families what we have done so far while working together with the Legos.*
  - The letter will be written on a large pad of paper in the front of the room. All of the children will help in writing the letter. The goal is to describe to the parents what they learned about things that move, simple machines, and Lego building.
- *Does anyone know how we start off a letter? What do we need to do first?*
  - *Who are we going to address it to?*
  - *What do I need to put after the name of the person?*
  - *Is there anything else that I need to include?*
- *What should our first sentence be? Our goal is to tell our families about what we have worked on over the past several days, so when developing a good first sentence we should think about what our goal is to help us come up with what we will write.*

  - Write up the introduction and the first sentence. Next start on filling out the letter with information about the things that we have done. As the children generate text work on writing the letter together calling on children to participate if necessary. As you are writing, ask for the children's help:
    - *How do I spell ________?*
      - *How did you know that? What did you use to help you spell that word?*
      - *If you don't know how to spell a word, what are some ways that you could figure it out?*
    - *We have already used __________ above. What is another good word that we could use?*
    - *How do I know what punctuation to use here? Should I use an exclamation (or period, comma, etc.)? Why?*
- *Next we should tell the reader what we have done. First we should tell people what we focused on while we were working, starting with what we did on our first few days together.*
  - *Who remembers how we started our activities together? What did we talk about first?*
    - *Does anyone remember what types of vehicles we talked about?*
    - *What groups of vehicles did we have?*
    - *What specific types of vehicles did we focus on?*
  - *We also talked about simple machines.*
    - *Who remembers how many types of simple machines there are?*

      - There are five types of simple machines. They are a lever, pulley, inclined plane, screw, and the wheel and axle.
    - *How do they help us?*
    - *What are a few of them called?*
    - *Simple machines are all around us, even in places we do not expect. What are some of the ways that we talked about identifying simple machines? Let's share them in our letter.*
    - *Who can tell me something about compound machines? How are they similar or different than simple machines?*
  - *How can we write that in a sentence?*
  - *Who remembers what many simple machines working together are? Should we tell our reader about the compound machines? What should we say?*
- *Last week we talked about one a specific type of simple machine. What simple machine did we focus on the most?*
  - Allow the children to nominate wheels, axles, and gears.
    - *What are some of the things that are important about wheels and axles? How do they help us?*
      - Wheels and axles help us by making our work easier.
    - *What are the two types of wheels and axles? How can we tell which is which?*
      - Axles that turn wheels and wheels that turn axles (in the round).
    - *Can you all think of examples of wheels and axles?*
  - Write in a few sentences about gears, and open up the conversation to include gears.
    - *Who remembers why gears are helpful? What are some examples of machines that use gears?*
    - *What example did we talk about that you might have at home?*
      - *What do we know about how to make riding uphill easier? What gear setting should we put our bike on? Why is this?*
      - *We should put our bikes on the lowest setting to go uphill. How did we decide we could remember this?*
    - *What are some special words that we learned that help us talk about gears. How did you remember them?*
- *Before we finish the letter we should tell the reader about our Lego building and engineering. What should we tell them about Lego building?*
  - *What are some things that we made with Legos?*
  - *Who remembers the names of some of the special Lego pieces that we used?*
  - *What were some challenges that we faced?*
    - *How did we work around them?*
  - *What else should we tell the reader about the Legos?*
  - *What else can we tell them about how to build and take on challenges like an engineer? How were the steps helpful to us while we were building?*
    - **Identifying the engineering challenge –** Think about the challenge. What is the problem that needs solving?
    - **Researching possible solutions –** Think of all of the ways that you can try solve the problem. Share your ideas with your partner.
    - **Picking the best solution –** Decide which idea is best!
    - **Build and test –** Build what you think will work best, and test to see if it meets the challenge.
    - **Repeating any steps needed to improve the design –** If your design does not work the way that you want it to, try to figure out what should be fixed, make a change, and repeat step 4!
  - *Can we tell the reader about how these steps made our work easier? What should we say?*

- *Now we need to close the letter. What should we say? What are some different ways that we could end it?*

Appendix G

Wheels, Spokes, and Sprockets Book Reading Prompts

Page 4 – Look at this picture – the wheels are made in the shape of a circle. Why do you think that circles are the best shapes for wheels? Would triangles make good wheels? Why or why not?

Page 6 – Who remembers how simple machines help us? Do you think that the wheels on this fire truck make the job of moving the truck easier?

Page 9 – Who can point to the axles on this skateboard?

Page 11 – What determines the size and sturdiness of a wheel? Have you all ever seen a tractor? Are they large machines? Do they have big wheels? Why might this be?

Page 13 – How do you think that gears and axles are different from one another? How are they similar?

Page 15 – What does it mean for two gears to turn in opposite directions?

Page 17 – What kind of a simple machine do you think that a crank is? Why?

Page 18 – How is a belt like a wheel? Are they similar?

Page 19 – How are the wheels helping the people in the picture do work?

Reading Prompts for the Three Little Pigs

Experimental:

Page 1 - How many of you have heard the story of the three wolves? Have you heard this version? Well listen closely because we are going to try and learn something new from this story today!

Page 5 – What do you suppose he means by saying that we have not heard the real story? What two things did he say were important to this story?

Page 7 – Look at this picture. What types of things do you think that he is putting in his cake?

Page 9 – Why might it not be a good idea to build your house out of straw? What do you think will happen next?

Page 15 – What might be one problem with building your house of sticks? Would walls of sticks be more or less strong than walls of straw?

Page 17 – In this picture the sticks fell around the pig to look like utensils. What do you think he was trying to tell the reader with that picture? How is he using this picture to tell us something about the wolf?

Page 19 – Why might the bricks be stronger than the straw and the sticks?

Page 21 – Look at these bricks. What do you notice about the way that they are built that might make this wall so strong?

Page 23 – Why do you think that the wolf could not blow the wall down?

Page 25 – That was a pretty silly ending right? Why do you think that the author chose to narrate the story as the Wolf?

Appendix H

Day 2: WHEELS AND AXLES

Goals:

- Learn about the simple machine wheels and axles
- Build basic Lego structures and use toy cars to test the importance of wheels in decreasing work and effort

Background Information on Wheels and Axles

- *Yesterday we talked about all sorts of different things that move.*
  - *We talked about three types of things that move including things that move by air, by land, and by sea.*
- Pull out the list of vehicles from the day before and refer to the nominated items again.
  - Review the list that was generated.
  - *Each of these vehicles has a wheel and an axle.*
  - *What is a wheel? Does anyone know what an axle is?*

Wheels and axles as simple machines:

- *The wheel and axle are a simple machine.*
- *Simple machines make work easier by allowing us to push or pull over increased distances.*
  - *There are 6 types of simple machines, and the wheel and axle is one.*
  - *Simple machines, when combined, are the building blocks of which all complicated machines are composed.*
    - *When many simple machines are combined we call them compound machines.*
    - *Simple machines are very useful and help make our work easier everyday!*

The wheel and axle can consist of a wheel that turns an axle or an axle that turns a wheel.

There are two ways to use a wheel and axle:

1. *To roll things* (e.g. a car) – *the wheels move independently of the axles*
2. *In the round* (e.g. a door knob) – *force is exerted on the wheel (by you) and the axle turns. In this case, the simple machine aids in work.*

Wheels and axles can be found all around us – even in everyday objects that you may not expect.

Book Reading Activity: Wheels, Axles, Spokes, and Sprockets

Now I am going to read you a book that is all about the wheels and axles that we encounter every day. Please follow along with me as I read. Who can tell me what the title of this book is?

After reading the book:

- *Now that we have read the book, can anyone think of examples of wheels and axles?*
  - *What are the two types of wheels and axles?*
  - *Can you think of any new ways that wheels and axles would have been important in the past?*

- *Yesterday we made a list of all sorts of different things that move. Today let's make a list of wheels and axles that we can think of. They don't have to just be found on cars.*
- *Can anyone think of wheels and axles? Which part is the wheel and which is the axle? What else can you think of? What else?*

Like I mentioned before we read the book, the wheel and axle can consist of a wheel that turns an axle or an axle that turns a wheel.

There are two ways to use a wheel and axle:

1. *To roll things* (e.g. a car) *– the wheels move independently of the axles*
2. *In the round* (e.g. a door knob) *– force is exerted on the wheel (by you) and the axle turns. In this case, the simple machine aids in work.*

- *The wheel and axle is one of the oldest and most important inventions. Historians believe that the wheel may have been invented first for two reasons:*
  - *The first use was the potting wheel. Have you ever seen a potting wheel? Do you think that it is an example of a wheel and axle?*
    - *This is an example of using a wheel in the round.*
  - *The second was to make basic wheeled vehicles like simple wagons or carts.*
    - *This is an example of wheels and axles that are used to roll. Can you think of reasons that this invention might have been really important?*
- Using the list of items that have a wheel and axle, ask the children to come up and circle examples of wheel and axle combinations that they can identify on the list. Use the following for more examples if needed:

Examples of wheels and axles:

Merry-go-round
Screwdriver (in the round)
Hinges
Faucet (in the round)
Door knobs (in the round)
Hand drill
Steering wheel (in the round)
Yo-yo
Windmills (in the round)

Other important piece of information to incorporate:

- The types of wheels you choose when building a vehicle depend on what you want your vehicle to do.
  - Tires with larger diameter will make the car move faster.
  - Tires with smaller diameter will provide more power.
  - Thinner tires are also faster

Lego Building – Sturdy Cars & Sliding vs. Rolling

Yesterday when we built we used regular Legos. Today we will be working with special Lego sets. Before we get started building today, I want to show you all how to use these sets like engineers.

- Hand out sets to each group of students. Have the student open the sets and ask them to inspect them first along with you.

- *Look in your boxes, there are lots of additional pieces. Let's talk about them.*
- Label each of the main pieces and describe them – they will be readdressed as needed, but describe their name and function as they related the previously identified features of moving vehicles.
    - Describe what each piece is used for while presenting them to the group.
    - Show the children where these pieces are located on the model truck. Point out wheels, axles, hubs, etc.
  - Identify the specific pieces (using pictures and pieces) and the children pull out those specific pieces, map on names, etc. Ask the students as you pull each one out ask occasionally:
    - Can you all tell me what this one is?
    - Has anyone seen one of these before?
  - Introduce the sets:
    - Plates and blocks
      - We can use any of the blocks and plates that we have in our building. There are so many colors that we could build some pretty good looking things, don't you think?
    - Beams

    - Beams are going to be very helpful to us when we are building. There are three types of beams. One is called a studded beam. Can you find one that has studs on the top? The other is also straight, but it has smooth sides. The third type is an angular beam. These are pretty cool. Can anyone find one and hold it up?
- Wheels
    - *In each of these sets there are lots of different types of wheels. I see skinny wheels. Who sees the skinny wheels? I see some really big wheels. Can you all find those too? What else is cool about some of these wheels?*
- Axles
    - Look at the different wheels and axles. Some of them are really short, and others are very long. What colors do they come in? What shape are they?
- Bushings
    - These bushings are really small, but they are helpful for building. How many different types do you see? We need to be extra careful not to drop these, because they can get lost really easily!
- Hubs
    - Hubs are used with the wheels, and different sized hubs work with different wheels. How many types of hubs can you find? Are there the same amount of different types as there are wheels?

When we are building with these Legos, there are some special things we need to remember about how to take care of them. Open your engineer notebook and turn to the third page. Let's go over them together first. Can anyone read me the first Lego rule?

General Rules of Legos

- Lego engineering is different than playing with Legos at home. We need to make sure that we do not lose these Legos, and we must put them away in their kits at the end of the day.
- Only pull out the pieces that you think you will need for what you are doing right now.
- The Lego pieces must be used in a contained area.
- We all have to share the pieces, and if you are not using them you have to put them back or share them with another builder.
- If you are already finished with you project you may ask if others need help problem solving as well – troubleshoot with another group.
- If the Legos get stuck together and you can't get them apart, find a Lego separator!

Introduction

Next we are going to test out the importance of wheels using our Legos. Who remembers some of the rules that we discussed about how to use the Legos?

- Recap the rules of Lego building – specifically only using the pieces designated for this particular build
    - *Look at the Lego building guide. What are the names of the pieces that we need to get started?*
    - *That's right, this piece is a ___________. We will use this piece to _____________.*

6. Provide time for the children to build a model of the base of a car.
7. Slide it across different surfaces. What does it do?
8. Add wheels and axles to the vehicle. Slide it again. What is the difference?
9. Slide the car down a ramp and measure the distance.
10. Change two wheels for larger ones. Slide the car down the ramp and measure the distance again.

Summary:

- What did we find out today about the importance of wheels?
- Is that what you expected? Which wheels do you like to build with the most?
- Today I liked how well we planned out what we were working on. Engineers are very planful when they are working and pay a lot of attention to detail, and you all did that today. This really helped us learn a lot about wheels!

Wrap up

Sort all of the pieces back into the appropriate bins

Please put all of the pieces back in the boxes in the correct spots. Tomorrow we will work with the Legos some more, and start a new building project!

Day 3: STURDY CARS

Goals:
Present the idea of sturdy structures and three ways to build sturdy walls
Build and test a sturdy wall
Build a simple sturdy car base that can survive the drop test
Introduce the utility of connector pegs

Begin with a general discussion of study structures:

- *Yesterday and the day before we talked about the importance of simple machines.*
  - *What are simple machines?*
    - *What are some examples?*
    - *What is a compound machine?*
  - *What type of simple machine did we make yesterday? What were the most important pieces that we used?*
  - *What other pieces did we work with?*
    - *What color were the __________?*
    - *Were there a lot of different types of _________?*

    Items used:

Plate	Axle	Tire	Hub
Bushing	Beam	Brick	
  - *What are some of the pieces that you are looking forward to building with today?*

- *From what we worked on yesterday it is pretty clear that simple machines are important and help us every day, right? Well today we are going to talk about another important part of building. We are going to talk about making sure that things we build are sturdy.*
  - *Who knows what the word sturdy means?*
  - *Engineers have to make sure that all of the things that they build are sturdy so that they don't fall apart.*
- *A great example many of you all might know that shows us about the importance of sturdy structures is in a story that you all have probably heard before.*
  - *How many of you have read Three Little Pigs?*
- *I am going to read the story to you again. Follow along with me while I read, and when I am all done reading we will talk more about sturdy buildings. Let's begin . . . who can tell me what this is a picture of?*

Read the story to the children. While reading, ask questions throughout:

- *Look at this house? Does it look sturdy?*
- *Can anyone tell me what this word is?*
- *What is this a picture of?*

After the story is done, ask the children:

- What were the three materials that the three pigs used?
- What pig had the house that was the strongest of all? Which house was the least strong?
- What was the strongest house made of? Was that house the strongest because it was made of bricks, or were there other reasons?

Engineer's Challenge: Sturdy Wall

The first engineering challenge today is to build a sturdy wall. The students may use only the Lego pieces that have already been discussed, and the resulting wall must be able to pass the "flick test". Before the students begin building, show demonstrate the "flick test" to them, so that they understand the challenge. Corresponding worksheets will be found in their engineering journals that will allow for a brief follow up activity. Begin by saying:

Today our first engineering challenge will be to build a sturdy wall just like the walls of the houses we learned about in the Three Little Pigs. You can use any of the pieces in your box that we have already talked about, and you may want to use some extra beams or blocks. I want you to try to make a wall that is at least 7 blocks tall.

- *The engineering challenge you have today is to build a sturdy structure.*
  - *Who can tell me what the goal of the challenge is?*
  - *What are you going to do next?*
- *When you are completely finished building your structure, it will have to pass the "flick test". When you and your partner have completed your wall, bring it to me and I will test it for you.*
  - *Before you begin, can anyone tell me what Lego pieces I would like you to be using for this activity?*
  - *What will you do when you finish building?*
- *Before we begin, open your Engineers Log to the page that says "Sturdy Wall" at the top. Once you have tested a sturdy wall, I want you to draw in the right box a picture of what a wall would look like that would not be sturdy. Next to that, I want you to draw your successful wall. Try to make sure that you make it look just like your wall that you built does.*

Allow the children time to build. As they complete their walls, conduct the flick test for those that have finished. If the wall fails to pass the flick test, ask them to:

- *Go back to your Lego kits and try make some changes to your structure. When you are done bring it back and I will test it again!*

Once everyone is done building at least one wall, have them come together as a group and bring their walls, and begin discussing the structures:

- *Was building a sturdy wall an easy or a hard challenge?*
- *What pieces did you use while you are building?*
- *What rules about sturdy structures did we learn today while working?*
  - *Make a list of the children's suggestions. Make sure that the following are discussed and written on the large pad and ask the following questions if the answers do not come up:*
    4. *Overlapping beams and bricks are stronger than non-overlapping ones.*
       a. *Do you know what overlapping means?*
       b. *Who has a wall with overlapping bricks?*
    5. *Three stacked plates are the same height as one beam or one brick.*
       a. *Did anyone do this when they were making their wall?*
    6. *Breaks usually occur where there are double cracks.*
       a. *What do you think that means?*
       b. *Does anyone have a wall with double cracks? Was that something that made anyone's walls less sturdy?*

Now that we have made this list I want you to copy it down in your Engineer Journals. We will continue to add other building tips in your journals while we are building other things as well!

<u>Engineer's Challenge 2: Strongest Shape</u>

Now that we have all learned ways to build a sturdy wall, I want to talk with you about how to make other things that we build with Legos strong.

- Do you think that houses are strong?
- When things are sturdy they can withstand the flick test.
- When I say that something is strong, what do I mean by that?
  - When we talk about building things, the word refers to things that are solid or stable, just like the sturdy wall we built.
- What are the names of some shapes?
  - Does the __________ seem like a strong shape you to? (ask this of some the shapes the children nominate).

Our next challenge it to use some of the newer Lego pieces to make strong shapes. The things that we build will need to be able to pass the "push test". Before we begin building, I want to *introduce the Lego pieces that you will be able to use on this challenge. Look at the pictures that I have here.*

- Show the pictures to the students and ask them:
- *Can anyone tell me what type of Lego piece this is? Can find it in your box? Look for it in your box and pull it out so that you can look at it with me.*
- Ask the students what they think that each piece is used for and talk about them together. Have them pull each out of their boxes for closer inspection.
- Continue by asking the students what the similarities and differences between the pieces are:
  - *What do you notice about these pieces? What color are they? What shape do you think that they are?*
  - *These pieces are different from one another.*
    - *This one is BLACK and it is used if you want things to fit snugly together.*
    - *This one is GREY and it is used when you want things to be able to rotate and move.*
    - *Please open your engineer notebooks and write down this information – we want to keep a log of all of the things we learn about the pieces*
      - Have them write:
      - The BLACK pegs are used for a snug fit
      - The GREY pegs are used for a when you want things to be able to rotate and move
- Use the pegs to connect two beams, and show the children how they work differently.

Continue to describe the challenge.

- *I want you all to think of some basic shapes that you could build. You could build anything you wanted – you could make a rectangle, circle, triangle or other shape that you wanted.*
  - Have the children generate shapes such as a triangle, circle, rectangle etc. Tell them that they can decide to build whatever shapes they want, and that they should pick one to start with.
  - *The "push test" is a little different from the "flick test". To pass the "push test" your structure will have to be stable enough to keep its shape if I push on it from the top down.* (Demonstrate what this means.)

Have the students begin building, and test their structures as they finish.

- As they build, if their shape does not pass the push test remind them of the steps of engineering and ask them what other ways that they can think of to make the structure stronger. Have them rebuild and try the test again.

Summary

If time allows, after the children have had the opportunity to build some shapes, come together as a group. Ask the children about the building process, and the structures that turned out to be the strongest.

- (Name of child) _______, tell us what you have built.
  - What did you make?
  - Tell us about it!
    - What types of pieces did you use?
    - What connector pegs did you use?
    - Is it easier to use the black or grey connector peg, or were they about the same?
    - If you were to build another structure, what else would you have added?

Day 7: GEARS

Introduction to Background Information on Gears

- *Yesterday we talked all about gears. As we learned yesterday, gears are a special type of wheel and axle.*
- *Today we will be talking some more about special types of gears and we will build our own gear trains. I think that you all will enjoy it a lot!*
- Both wheels and gears are circular, but gears have teeth.
- Before we begin working today, I wanted to remind you about what gears do. *Gears are used for a number of reasons. They can be used in bigger machines to:*
    1. Reverse the direction of rotation
    2. Increase or decrease the speed of rotation
    3. Move rotational motion to a different axis
    4. Keep the rotation of 2 axes synchronized
- *Because gears do so many different things, they are important to many machines. What special feature of gears do you think helps them do their work?*
    - They prevent the gears from slipping – axles connected by gears are always synchronized with one another.
        - Can anyone point out the teeth on this gear?
    - They make it possible to determine exact gear ratios. If you want to determine gear ratios, you first need to count the teeth on each of the gears.
        - If a gear has 24 teeth, what would we call it?
- Today we will do some gears building with our partners.

Vocabulary refresher:

- *There are few terms that are special to gears and to how gears work together that we will talk about before we begin. We already know two of the words: gear and teeth.*
- *The three other words that are important are Driver, Follower, and Idler. These three apply when there are gears in a row together. When gears are in a row together like this, we call it a gear train.*
    - Show diagram of gear train and label the items.
        - *The driver is the gear that starts the motion.*
        - *The idler is in the middle.*
        - *The follower is at the end of the row, and ultimately follows the driver.*

Gearing up with Legos

Materials:

8-tooth spur gears
40-tooth spur gears
Round bricks
Axles
Bushings
Cranks

Activity (Alternative building plans can be found on p. 102 of the Legos binder)

1. Build a model (p. 16 of Gears) using a 40-tooth gear an 8-tooth gear.
2. Predict what happens when you turn a handle on the 40-tooth gear.
3. Build another model with the handle on the other gear.
4. Predict what will happen now.
5. Build a model (p. 17 of Gears) with an idler.
6. Build a model with more gears on your own.

Vocabulary building:

- *Before we begin building, I want to tell you about the gear trains that we talked about yesterday again. There are few terms that are special to gears and to how gears work together that we will talk about before we begin. We already know two of the words: gear and teeth.*
- *The three other words that are important are Driver, Follower, and Idler. These three apply when there are gears in a row together. When gears are in a row together like this, we call it a gear train.*
    - Show diagram of gear train and label the items.
        - *The driver is the gear that starts the motion.*
        - *The idler is in the middle.*
        - *The follower is at the end of the row, and ultimately follows the driver.*

Background information

Today we will be building our own gear trains. Open up the guide books in front of you to B which is on page 7. We are going to work to build these gear trains, and we will use the gear trains to see how different gears work together. Before we begin, let's all look at the first picture together.

- *What pieces do you see in the picture? Which pieces do you need to find?*
- *Make sure that you only take out the pieces that you need at a time.*
- *What do you see in the second picture? Do you know what the black piece is called?*
- *Continue building until you have finished your gear train structure at step 5, but while you are building make sure that you are paying using only the Legos that you need. Follow along with the pictures carefully.*

Main Idea:

Gears are wheels with teeth that are used to pass on motion and force.
Two meshed gears turn in the opposite direction.

Allow the children to finish the basic gear train structure.

- *Turn the page to page 8. Look at **B1**. Now you and your partner are going to make the first gear train. Make sure that you are using the axles that are the correct size.*
- *Once you have finished building it, open up your engineer's notebook to document what you have done. You will write down the size of each gear, and then the gear ratio. For example, if the first gear has 8 teeth and the second gear has 40 teeth, the gear ratio would be 8 to 40. Go ahead and build only **B1**, **B2**, and **B3**. When you are finished, we will talk about them.*

While you are working, think of these terms:

A **large driver** makes a small follower gear turn faster – this is **gearing up**.
A **small driver** makes a large follower gear turn slower – this is **gearing down**.
An **idler** gear makes adjacent gears turn in the same direction.

Conclusion - Group Discussion

Can you turn one gear and make another turn?
Can you turn one gear and make more than one other gear turn?
How many gears can you use in one system?
What happens when a smaller gear turns a larger gear?
What happens when a larger gear turns a smaller gear?

- For Each Set of Gears

B1

- *Count the number of teeth on each gear of your gear train. How many are there?*
    - *We use the number of teeth on the gear to determine the gear ratio between the two.*
- *Who can tell me how many teeth are on one of your gears?*

    - Write the ratio on the white board.
- *If the crank is attached to the 8 tooth gear and the other gear has 24 teeth, it would take 3 turns of the crank to get the other gear to move all of the way around in a circle. 3 times 8 equals 24.*
- *If this gear one is our driver, we can use the numbers in an equation in this way to set up a math problem. We solve this problem by using division. Have any of you all used division yet in school? Let me show you how to solve this one.*
    - Work through the problem and tell the children what you are doing step by step.

Before B2

- Look at the next gear train on B2. In this gear train you will change out the 8 and 24 tooth gear. This sets up a different problem for us to complete. How many times will the 8-tooth gear turn for each turn of the crank?

IF THERE IS TIME CONTINUE WITH B3 and B4 – IF NOT, IT IS NOT A PROBLEM!

Before B3

- Look at the gear train on B3. Both of the gears are equal. Who can tell me the gear ratio.

Have the children continue to build through **B4** – reiterate the idea of a gear train by showing them the pieces of the gear train they have built and labeling them.

Conclusion - Group Discussion

- Can you turn one gear and make another turn?
- Can you turn one gear and make more than one other gear turn?
- How many gears can you use in one system?
- What happens when a smaller gear turns a larger gear?
- What happens when a larger gear turns a smaller gear?

Summary:

Once the children are done building, gather as a group to talk about the gears covered today. Start the discussion by asking:

- *Did you all like working with the gears today? Was it hard or easy to build with the gears?*
- *What was the neatest part?*
- *There are some pros and cons of working with gears. Lets write them down in our notebooks.*
    - Write the following on the board or pad of paper and ask them to do the same.
    - Have the children add the information to their journals when appropriate.

Pros and Cons of Gears:

- All gears must be carefully meshed to work.
- Spur gears are excellent for sending energy of motion from one place to another.
- Gears can speed up or slow down motion, change direction of motion, and they do not slip and are very efficient.
- Bevel gears can change the angle of motion.
- Worm gears change the angle of motion.
- Worm gears can ONLY reduce speed but at the same time significantly increase force.
- Worm gears also are self locking, which provides a safety feature for when the user is not interested in cranking anymore.

<u>Summary: Adding Gear Trains to Lego Cars</u>

Now that we have learned to use gears with our Legos, we will be able to add some of them to our cars! Tomorrow I will show you some more gears, and we will talk about ways that you can connect gears onto the cars that you will build.

Day 10: WRAP UP

Introduction

Allow the children to complete their cars. Have them all gather near the ramp, and test each of their cars first for speed and then for how far they can go over bumpy surfaces. As they test their cars, have the children help measure the distance and keep track of car performance on the board or big paper. Follow up the activity by having the kids all come back to the group and talking about their cars:

- *Everyone did an amazing job with that! Let's talk about our results . . . who remembers which car went the furthest?*
- *What pieces did they use on this car?*
    - *What do you call this one?*
    - *Is this car different from the others that you see? What is different about it?*
- *Who else would like to share their car?*
- *Let's think about which cars did best on the bumpy surface?*
    - *What type of wheels did they use on this car?*
    - *Did anyone else use the same types of wheels?*
    - *What other pieces did they use?*
    - *What can we learn from how this one was built?*

Summary Letter Writing Activity

- *Now that we have built and tested our cars, I think that we are real engineering Lego experts! To wrap everything up, I want you all to help me write a letter so that we can share with our families what we have done so far this week.*
    - The letter will be written on a large pad of paper in the front of the room. All of the children will help in writing the letter. The goal is to describe to the parents what they learned about things that move, simple machines, and Lego building.
- *First we need to write a greeting. When I am writing a letter I like to start off with a nice greeting. Because this is for our parents, I think that we should start with the word "Dear." Does that sound nice?*
    - *Who are we going to address it to?*
    - *What do I need to put after the name of the person?*
    - *Is there anything else that I need to include? What else?*
- *The first sentence we write should tell our families about what we have worked on over the past several days. Our theme this week has been things that move, so let's start with that. Who can tell me a sentence that says that?*
    - Write up the introduction and the first sentence. Next start on filling out the letter with information about the week. As the children generate text work on writing the letter together calling on children to participate if necessary. As you are writing, ask for the children's help:
        - *What word should I use next?*
            - *Can you spell it?*
            - *Who else knows how to spell it?*
        - *I also like to use [inset alternative word here] when writing. Let's try and use it in this sentence.*
        - *Do we need a period at the end of this sentence?*
- *Next we should tell the reader what we have done. First we should tell people what we focused on this while we were working, starting with what we did on our first few days together.*
    - *The first day we talked about things that move and simple machines.*
        - *Tell me some of the things that move that we discussed.*
        - *What specific types of vehicles did we focus on?*
    - *We also talked about simple machines.*

        - *There are six types of simple machines. They are a lever, pulley, inclined plane, screw, wedge, and the wheel and axle.*
        - *It would be really interesting to share some examples of simple machines with our parents right? Let's share some examples of simple machines in our letter. Give me an example of a lever. What other examples are there?*
        - *Let's also talk a little bit about compound machines. Who can share something they know about compound machines?*
    - *What is a good way to say that in a sentence?*
- *Last week we talked about one a specific type of simple machine the most. It was the wheel and axle right? What else?*
    - Allow the children to nominate wheels, axles, and gears.
        - *We should write about how wheels and axles make work easier. Can you think of an example?*
        - *Can you all think of examples of wheels and axles?*
    - Write in a few sentences about gears, and open up the conversation to include gears.
        - *What are some examples of machines that use gears? Who had fun working with the gears the most?*
        - *What are the names of the gears and other pieces on a gear train?*
        - *Was it hard or easy to build out gear trains? Let's write about it!*
        - *Who knows about gears on a bike? The bike we saw had lots of gears didn't it. What speed bike was it? Does anyone know?*
        - *We learned that when you are riding your bike uphill, you should have it on what setting?*
            - *We should have it on a low setting.*
- *Before we finish the letter we should tell the reader about our Lego building and engineering. Lego building was lots of fun, and I think that they should know about it.*
    - *What are some things that we made with Legos?*
    - *What pieces did we use the most?*
    - *Lego building can be challenging, but you all did a great job! Let's tell them about how we became Lego experts. Do you all think that you are Lego experts now? Were you before?*
    - *What else should we tell the reader about the Legos?*
    - *What else can we tell them about how to build and take on challenges like an engineer would? What are the steps?*
        1. **Identifying the engineering challenge –** Think about the challenge. What is the problem that needs solving?
        2. **Researching possible solutions –** Think of all of the ways that you can try solve the problem. Share your ideas with your partner.
        3. **Picking the best solution –** Decide which idea is best!
        4. **Build and test –** Build what you think will work best, and test to see if it meets the challenge.
        5. **Repeating any steps needed to improve the design –** If your design does not work the way that you want it to, try to figure out what should be fixed, make a change, and repeat step 4!

- *We should also tell everyone how helpful these steps were. How can we say that?*
- *Now we need to close the letter. What should we say? What are some different ways that we could end it?*

Appendix I

Wheels, Spokes, and Sprockets Book Reading Prompts

Page 4 – How many wheels are on a motorcycle? How about on a bike?

Page 6 – Look at this fire truck! Do you think that it is really heavy? Would it be hard to move without wheels?

Page 9 – Who here has been on a skateboard?

Page 11 – Look at this tricycle! It has big AND small wheels!

Page 13 – Have you all ever seen gears? We will be talking about gears more in the next few days.

Page 15 – Have you ever seen a clock with gears?

Page 17 – What other machines have cranks?

Page 18 – Have you ever seen been to an airport and seen a baggage carousel?

Page 19 – What are these people doing? Do you think that they are having fun?

Reading Prompts for the Three Little Pigs

Page 1 – How many of you have heard this story? Do you like this story? Have you seen this one before?

Page 5 – Look at this. This says “This is the real story”. Let’s get ready to hear it!

Page 7 – What types of things go into a making a cake? Who here likes cake?

Page 9 – I bet that a house made of straw would not be very strong. What do you think will happen next?

Page 15 – Look at this picture. You can see here that the pig cut all of the sticks for his house out of his yard. Let’s see what happens next!

Page 17 - Do you think that the wolf was really after sugar or the pigs?

Page 19 – Look at the wolf in this drawing. He looks like he is very full!

Page 21 – Are the bricks stronger than the straw and the sticks? Does anyone know what are bricks made of?

Page 23 – What is the Wolf doing in this picture? Do you see the microphone? Who might be holding it?

Page 25 – That was a pretty silly ending. What did you think about that book? Did you like it?

Appendix J

Content Specific Sort Recall Task

Sorting Score Coding Protocol

Scoring Sorting Patterns:

Score	Description
0	Sorting was done at random, with no apparent order.
1	Sorting was based on visual aspects of the pictures. This includes sorts based on color, shape or size. At least **half** of the groups must meet these criteria in order to receive a score of 1.
2	Low semantic organization. At least **one** group was constructed based on a semantic or functional association. "Legos" does not meet this criterion.
3	Medium semantic organization. At least **half** of the groups were organized semantically or functionally, with at least one of these groups containing **more than 2** items. In addition, there must be at least **one "good" group** that goes beyond general associations (such as "inside", "outside" "things I like", etc.)
4	High semantic organization. At least **half** of the groups were organized by **strong** semantic or functional associations (and at least one of these groups must contain **more than 2** items). No more than **one** group is present that is **NOT** semantically related, labeled as Extras, or randomly sorted.

Coding Rubric for Sorting Patterns

Code	Description
Random (**R**)	Sorting was done at random, with no apparent order. ***Example:*** • Cards laid out without any sorting.
Visual (**V**)	Sorting was based on visual aspects of the cards. ***Examples of visual sorts:*** • Color: Blue, grey, black, etc. • Shape: Circles, long skinny things, flat, etc. • Size: Little pieces, pieces that would be easy to lose, etc. • Other visually apparent features: All things with holes
Functional (**F**)	Cards sorted based on how the Lego pieces could work together. ***Examples of functional groups:*** • Things that make a wheel and axle • Things that could be used with axles • Parts of a gear train
Semantic (**S**)	Cards grouped based on outside information of the Lego pieces. ***Examples of semantic groups:*** • All gears, beams, etc.
Extras (**E**)	Extra pieces that did not fit into another group.

Lego Pieces:

				
Plate	**Cross Block**	**Bevel gear**	**Bushing**	**Hub**
				
Angular Beam	**Crown Gear**	**Studded Beam**	**Worm Gear**	**Tire**
				
Connector peg	**Crank**	**Spur gear**	**Beam**	**Axle**

Sample Sorts:

Visual

- Pieces with holes: studded beam, connector peg, beam, angular beam, plate
- All round: crown gear, spur gear, tire, bevel gear, hub
- Straight: beam, axle, angular beam, studded beam
- Little: worm gear, cross-block, crank, bushing, connector peg
- Skinny: plate
- Black: tire, connector peg, worm gear
- Blue: angular beam, plate, studded beam
- Gray: crown gear, bevel gear, bushing, hub, crank, spur gear, axle

Functional

- Can be used in a gear train: crown gear, bevel gear, spur gear, crank
- Make a wheel together: hub, tire
- Used to make the wheel go: axle, hub, tire, bushing

Semantic

- Gears: worm, bevel, crown, spur
- Beams: beam, angular beam, studded beam
- Connecting pieces: connector peg, bushing, cross block

Appendix K

Lego Build Coding Protocol

Each of the utterances made by the child in the intervals between each building step will be coded to reflect the extent to which the child references procedures and/or strategies while narrating what they are doing while they are building.

Coding rubric

1) Procedures – Reference to the procedures of building. These statements can have relatively limited contextual information ("I put this piece here") or can be highly elaborated. These procedural statements can be coded when the child is describing connecting Lego pieces, finding a specific piece, or that they are connecting a certain piece because it will lead to a particular outcome. These statements do not reflect specific strategies that the child is using to determine how to build.

Codes:

Procedure	***Code***	***Examples***
Reference to Pieces	**PP**	• "I am putting the pieces on" • "I am putting on the wheel and the window" • "I am setting the pieces on the table" • "This one goes here." • "I'm building."
Reference to Quantity	**PQ**	• "I have gotten two black pieces." • "I am putting the orange pieces on."
Reference to the Instructions	**PI**	• "It tells me to put this one right here" • "This says to put these here, but they won't fit"
Procedures with Explanations	**PE**	• "I am building the wheels so that it can roll." • "Putting on the roof so that it can have shade."

2) Strategies – Reference to specific strategies or techniques that the child is using to build with the Legos. These statements can refer to following or referencing the directions, using a specific strategy (i.e., counting, matching size and/or shape) to determine the correct pieces, guessing and checking, and planning out what steps to do next. In addition, examples of strategy talk are often seen when a child indicates that they knew to do something because of additional information ("I knew to fix it because I noticed that if you put 2 plates together it makes 4 groups of 4 bumps.").

Codes:

Strategy	***Code***	***Examples***
Planning	**SP**	• "Have a plan of what you are doing before you begin" • "Think if it will work"
Following Directions	**SD**	• "Looking at the directions" • "It tells you how to figure it out in the directions" • "I realized that the piece did not fit, so I looked

		back at the directions to see if I had the right ones."
Guess and Check	**SG**	• "I am trying the pieces on until I find the right one." • "I tried to put it on a few ways until it fit"
Visual Comparison	**SV**	• "Saw if it was the same size as the pictures." • "Looked for pieces that were the same as in the pictures"
Reference to Length, Shape, or Size	**SS**	• "I knew that they both had to be flat" • "I knew which one to pick because they are the same size and shape" • "I looked for how long they were"
Counting	**SC**	• "I counted the dots on the Legos in the picture." • "Counted the pieces"
References to Prior Knowledge	**SK**	• "I am thinking of the way that I did it before" • "I know that there will be leftover pieces, so I only need to find the ones that I need." • "I know about Lego, so I know how they work together."

3) Relevant talk – There are several types of utterances that are relevant to Lego Building, but not specific to the strategies or procedures that the children are using while building. They could also include questions that the child asks of the experimenter related to the task

Codes:

Relevant Talk	***Code***	***Examples***
References to the Number of Pieces or Pictures	**RP**	• "There are too many pieces." • "These pictures are at a funny angle" • "Collecting the picture."
References to Legos	**RL**	• "I have built lots with Legos before." • "I remember doing this before" • "Are these the same Legos we had last time?" • "These look like pieces that we have in the other sets" • "Are these connector pegs?" • "Because I just know."
Questions of the Experimenter	**RQ**	• "Will there be pieces left over?" • "Does this piece go here?"

Appendix L

Parent Background Questionnaire

Thank you very much for your willingness to provide us with background information that will contribute to our understanding of your child's memory skills. Please note that your answers will be held in confidence and that you should feel free to skip any questions to which you do not wish to respond.

Child's Information

1. Child's Full Name ____

a. Child's Date of Birth: (MM/DD/YYYY) _____/_____/_____

b. Today's Date: (MM/DD/YYYY) _____/_____/_____

c. Child's Race/Ethnicity ____

2. Please list all forms of childcare and/or preschool experiences your child has had since age 3:

a. Type ___________________________________
(e.g. small group home, relative, day care, preschool, etc.)

b. Location ________________________________

c. Dates attended (mm/yr) __________ to __________

d. Hours per week ______

----

a. Type ___________________________________

b. Location ________________________________

c. Dates attended (mm/yr) __________ to __________

d. Hours per week ______

----

a. Type ___________________________________

b. Location ________________________________

c. Dates attended (mm/yr) __________ to __________

d. Hours per week _____

Caregivers' Information *(Although space has been provided for two primary caregivers, please fill out what best fits your family.)*

3. First Primary Caregiver

a. Full Name ____________________________________

b. Relationship to child: ( ) Mother ( ) Father ( ) Other __________

c. Please indicate the **highest** grade completed K-12: ______
High School Degree/GED: ( ) No ( ) Yes

d. Please check the **highest** post-high school education level (to date):

( ) None
( ) Some technical training
( ) Some college completed, no degree
( ) Vocational or Associate's degree
( ) Bachelor's degree
( ) Master's degree
( ) PhD, JD, MD, etc.

e. Are you currently employed?

( ) No ( ) Yes, part-time ________ hrs/week ( ) Yes, full-time ________ hrs/week

f. What is your occupation? Please be as **specific** as possible. ______________

____

g. If you are not currently employed, what was your last job? _______________

____

h. How often do you read by yourself?

( ) Daily ( ) Several times a week ( ) Weekly or less

4. Second Primary Caregiver (*if applicable*)

a. Full Name ____

b. Relationship to child: ( ) Mother ( ) Father ( ) Other __________

c. Please indicate the **highest** grade completed K-12: _____

High School Degree/GED: ( ) No ( ) Yes

d. Please check the **highest** post-high school education level (to date):

( ) None
( ) Some technical training
( ) Some college completed, no degree
( ) Vocational or Associate's degree
( ) Bachelor's degree
( ) Master's degree
( ) PhD, JD, MD, etc.

e. Are you currently employed?

( ) No ( ) Yes, part-time ________ hrs/week ( ) Yes, full-time ________ hrs/week

f. What is your occupation? Please be as **specific** as possible. ______________

____

g. If you are not currently employed, what was your last job? _______________

____

h. How often do you read by yourself?

( ) Daily ( ) Several times a week ( ) Weekly or less

Household Information

5. Are there any other adults living in your home?

( ) No ( ) Yes (*How many?*) ________

(P*lease specify.*)

____

6. Who has the child lived with for most of the past year? (check all that apply)

□ Mother □ Father □ Both □ Grandmother □ Grandfather

□ Guardian □ Other (specify) _____________

7. Does your child have any siblings? ( ) No ( )Yes *(Please provide additional information.*)

	Age	Gender	Does he or she live at home with your child?
a.	____	_______	( ) No ( ) Yes
b.	____	_______	( ) No ( ) Yes
c.	____	_______	( ) No ( ) Yes
d.	____	_______	( ) No ( ) Yes

8. Are any languages other than English spoken in your home?

( ) English only

( ) Other languages spoken

a. What languages are spoken in your home? _______________________

b. Does your child speak a language other than English in your home?

( ) No, my child speaks English only

( ) Yes, but not fluently (*specify language*) __________________

( ) Yes, fluently (*specify language*) ________________________

c. What is the primary language spoken in your home? ________________

d. Please describe when and in what settings your child was first exposed to English (daycare, elementary school, etc.)

____

____

9. How often do you, or other members of the family, read to your child in a typical week?

At bedtime

( ) Never ( ) Once ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 times
More, please estimate _____

Other times

( ) Never ( ) Once ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7

More, please estimate _____

10. During a typical week, how often does your child ask to be read to? ( ) Very often ( ) Often ( ) Sometimes ( ) Seldom ( ) Never

11. Who reads to your child at home?

____

____

12. Does your child read or look at books himself/herself? ( ) Yes ( ) No

13. Does your child have a place to keep his or her books? ( ) Yes ( ) No

14. Approximately how many books does your child own? ( ) 0 ( ) 1 - 20 ( ) 21 - 40 ( ) 41 – 60 ( ) 61 – 80 ( ) 80 or more

15. Does anyone in your home own a library card? ( ) Yes ( ) No

If "Yes," how often is it used? ( ) Once a month or less ( ) More than once a month

15. Does your family subscribe to newspapers and/or magazines? ( ) Yes ( ) No

If "Yes," please circle number of each you have:

Newspaper subscriptions?	0	1	2	3+
Adult magazine subscriptions?	0	1	2	3+
Child magazine subscriptions?	0	1	2	3+

17. Does your child have regular access online or in print to:

a dictionary ( ) Yes ( ) No

encyclopedias ( ) Yes ( ) No

18. Does your child have any math workbooks? ( ) Yes ( ) No

19. Does your child have any reading or letter workbooks? ( ) Yes ( ) No

20. When you and your family are in the car, do you play counting or alphabet games (e.g., counting cows by the side of the road, the color of cars that pass, finding objects that begin with a particular letter, etc.?) ( ) Yes ( ) No

21. In the past few months, how often did you and your child engage in the following activities?

Please circle the number that corresponds with activities you have participated in with your child.

Circle NA if the activity is not applicable to your child.

	Did not occur	A few times a month	Once a week	A few times a week	Almost daily	NA
a. Using number or arithmetic flashcards	0	1	2	3	4	NA
b. Identifying names of written numbers	0	1	2	3	4	NA
c. Playing with number fridge magnets	0	1	2	3	4	NA
d. Counting objects	0	1	2	3	4	NA
e. Sorting things by size, color, or shape	0	1	2	3	4	NA
f. Counting down (10, 9, 8, 7 . . .)	0	1	2	3	4	NA
g. Learning simple sums (i.e., 2+2=4)	0	1	2	3	4	NA
h. Printing numbers	0	1	2	3	4	NA
i. Talking about money when shopping (e.g., "Which costs more?")	0	1	2	3	4	NA
j. Measuring ingredients while cooking	0	1	2	3	4	NA
k. Being timed	0	1	2	3	4	NA
l. Playing with calculators	0	1	2	3	4	NA
m. Collecting things	0	1	2	3	4	NA
n. Working on "Connect-the-dot" activities	0	1	2	3	4	NA
o. Using calendars and dates	0	1	2	3	4	NA
p. Having your child wear a watch	0	1	2	3	4	NA
q. Using number activity books	0	1	2	3	4	NA
r. Reading number story books	0	1	2	3	4	NA
s. Playing board games with a die or spinner	0	1	2	3	4	NA
t. Playing cards games	0	1	2	3	4	NA

22. How many televisions does your family own? __________

23. On average, how many hours per day does your child watch television or movies?

Day of the Week	***Average Number of Hours of TV Watched***
Monday - Friday	/per day
Saturday	/per day
Sunday	/per day

a. Of the total hours listed above, how many of the hours does your child spend watching "educational" television or movies? ____________hours

b. Of the total hours listed above, how many of the hours does your child spend watching "popular" television or movies? ____________hours

24. Does your family own a computer? ( ) Yes ( ) No (skip to question 31)

If "Yes," does your child use the computer? ( ) Yes ( ) No (skip to question 31)

a. If "Yes" how many computer games does your child own that are educational? ________

b. How many computer games does your child own that are for entertainment? ________

c. How many hours on average per day does your child use educational software on a computer?

Monday-Friday ______ Saturday ______ Sunday ______

d. How does your child use the computer? (*Check all that apply*)

( ) Playing educational games
( ) Playing games for entertainment
( ) Homework
( ) Other

____

25. Does your family own a video game system? ( ) Yes ( ) No

If "Yes", how many hours on average per day does your child play video or computer games?

Monday-Friday ______ Saturday ______ Sunday ______

26. Next you will see a set of statements that describe children's reactions to a number of situations. Please tell us what your child's reaction is likely to be in those situations. There are of course no "correct" ways of reacting; children differ widely in their reactions, and it is these differences we are trying to learn about. Please read each statement and decide whether it is a "true" or "untrue" description of your child's reaction within the past six months. Use the following scale to indicate how well a statement describes your child:

	My Child…	**Extremely untrue**	**Quite untrue**	**Slightly untrue**	**Neither true, nor false**	**Slightly true**	**Quite true**	**Extremely true**	**Does Not Apply**
a.	When practicing an activity, has a hard time keeping her/his mind on it.	1	2	3	4	5	6	7	NA
b.	Will move from one task to another without completing any of them.	1	2	3	4	5	6	7	NA
c.	Can wait before entering into new activities if s/he is asked to.	1	2	3	4	5	6	7	NA
d.	Prepares for trips and outings by planning things s/he will need.	1	2	3	4	5	6	7	NA
e.	Has trouble sitting still when s/he is told to (at movies, church, etc.).	1	2	3	4	5	6	7	NA
f.	When drawing or coloring in a book, shows strong concentration	1	2	3	4	5	6	7	NA
g.	Is good at following instructions.	1	2	3	4	5	6	7	NA
h.	Is easily distracted when listening to a story.	1	2	3	4	5	6	7	NA
i.	When building or putting something together, becomes very involved in what s/he is doing, and works for long periods.	1	2	3	4	5	6	7	NA
j.	Approaches places s/he has been told are dangerous slowly and cautiously.	1	2	3	4	5	6	7	NA
k.	Can easily stop an activity when s/he is told "no."	1	2	3	4	5	6	7	NA
l.	Is easily distracted when listening to a story.	1	2	3	4	5	6	7	NA
m.	Sometimes becomes absorbed in a picture book and looks at it for a long time.	1	2	3	4	5	6	7	NA

27. Who completed this questionnaire?

☐ Mother ☐ Father ☐ Grandmother ☐ Grandfather
☐ Guardian ☐ Other (specify) ____________________

Thank you for providing this important information.

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