EXPLORING THE MECHANISMS OF GUIDED PLAY IN PRESCHOOLERS' DEVELOPING GEOMETRIC SHAPE CONCEPTS

A Dissertation
Submitted to
The Temple University Graduate Board

In Partial Fulfillment
of the Requirements for the Degree
DOCTOR OF PHILOSOPHY

---

by
Kelly R. Fisher
Temple University
January, 2011

Examining Committee Members:

Kathryn Hirsh-Pasek, Advisory Chair, Department of Psychology
Kim Curby, Department of Psychology
Nora Newcombe, Department of Psychology
Marsha Weinraub, Department of Psychology
Julie Booth, Department of Education
Roberta Golinkoff, External Member, University of Delaware

ABSTRACT

This dissertation offers the first set of empirical studies to examine the differential impact of didactic instruction and playful learning practices on geometric shape knowledge. Previous research demonstrated that successful child-centered, guided play pedagogies are often characterized by two components: (a) dialogic inquiry, or exploratory talk with the teacher, and (b) physical engagement with the educational materials. Building on this conclusion, three studies examined how guided play promotes criterial learning of shapes. Experiment 1 examined whether guided play or didactic instruction techniques promote criterial learning of four geometric shapes compared to a control condition. Results suggested that children in both didactic and guided play conditions learn the criterial features; however, this equivalence was most evident for relatively easy, familiar shapes (e.g., circles). A trend suggested that guided play promoted superior criterial understanding when learning more complex, novel shapes (i.e., pentagons). Experiment 2 expands on the previous study by examining how exposure to enriched geometric curricular content (e.g., teaching with typical shape exemplars only vs. typical *and* atypical exemplars) augments shape learning in guided play. As hypothesized, children taught with a mix of typical and atypical exemplars showed superior criterial learning compared to those in taught with only typical exemplars. Experiment 3 further explores the factors that facilitate shape learning by comparing the effectiveness of guided play, enriched free-play, and didactic instruction on children's criterial learning of two familiar shapes (triangles, rectangles) and two unfamiliar, complex shapes (pentagons, hexagons). As hypothesized, those who learned via guided play outperformed those who learned in didactic instruction who, in turn, outperformed those in enriched free play. In both didactic instruction and guided play, children's shape concepts persisted over one week. The findings from these studies suggest (1) guided play promotes equal or better criterial learning than didactic instruction, (2) curricular content (shape experience) augments criterial learning in guided play and (3) dialogic inquiry may be a key mechanism underlying guided play. The current research not only has implications for enhancing the acquisition of abstract spatial concepts but also for understanding the mechanisms that foster playful learning.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The landscape of early education has changed dramatically in the last three decades with the growing national concern with kindergarten readiness (Hirsh-Pasek et. al, 2008; NAEYC, 2009; Sigel, 1987). As early childhood programs face mounting pressure to implement early educational standards, a fervent debate has ensued concerning *how* to best facilitate learning to meet new curricular goals (Kochuk & Ratnayak, 2007; Miller & Almon, 2009; Pellegrini, 2009; Sunderman et al., 2004).

In response to recent education reform (NCLB, 2001), didactic practices have gained in popularity (e.g., Association for Didactic Instruction, ADI, 2009; Miller & Almon, 2009; National Institute for Didactic Instruction, NIFDI, 2010; Sunderman et al., 2004). Didactic pedagogies are founded on essentialist and behaviorist philosophies, which hold that there are core sets of basic skills that children must master before more advanced learning can occur (Glickman, 1984). These skills are acquired in discrete, accumulating units through explicit teaching, properly calibrated materials, and practice (Engelmann & Carnine, 1982). In effect, "all details of instruction are controlled to minimize the chance of students' misinterpreting the information being taught and to maximize the reinforcing effect of instruction" (NIFDI, 2010, p.1). Characterized as a "telling" rather than "implying" pedagogy (ADI, 2010), didactic pedagogies take the teacher to be the primary agent of learning while the child is seen as having a more passive role in the learning process.

Conversely, a wide array of scholars and professionals advocate a child-centered approach, as documented in guidelines developed by the National Association for the

Education of Young Children (NAEYC, 2009), and Association for Childhood Education International (ACEI, 2000). Arising from constructivism philosophies, the child-centered approach views children as active constructors of knowledge who learn by exploring and interacting with objects and other people (Bransford, Brown, & Cooking, 2000; Bruner, 1966; Hirsh-Pasek, Golinkoff, Berk, & Singer, 2008; Resnick, 1999; Piaget, 1972; Vygotsky, 1978). In this view, teachers are seen as collaborative partners who enrich and support the child's playful learning experiences (Vygotsky, 1978).

Fundamental differences in educational philosophies have led to years of debate over early education reform, yet very little experimental research has directly compared didactic and child-centered approaches (Glickman, 1984; Golbeck, 2001; Hirsh-Pasek et al., in press). This dissertation offers the first set of empirical studies to examine the differential impact of didactic instruction and playful learning practices (guided play, free play) in the context of a core science, technology, engineering, and mathematics (STEM) foundational area: geometric shape knowledge. Additionally, we take the initial step of exploring the potential mechanisms underlying one child-centered approach, guided play, which has been advocated as the "middle ground" between the two prevalent educational approaches.

Didactic Instruction, Playful Learning, and Education

Didactic Instruction Pedagogy

Early research on preschool and kindergarten program effectiveness suggests that didactic pedagogies significantly improve academic skills over traditional or "business-as-usual" methods (Adams & Engelmann, 1996; Carleson & Francis, 2002; Engelmann & Brunner, 1995; Gersten, Darch, & Gleason, 1988; Kamps et al., 2008; Stockard &

Engelmann, 2008; Swanson & Hoskyn, 1998; Waldron-Soler et al., 2002). This raises the question of what are considered the 'traditional methods'? It is often assumed that "classroom comparisons… show how didactic instruction can be implemented for the best results, consistently surpassing child-centred methods" (Society for Quality Education, 2010, p. 1). However, the business-as-usual comparison programs encompass a variety of educational practices, which do not necessarily reflect a well-planned, child-centered or playful learning program.

Project Follow Through, for example, was a large-scale national study that compared nine experimental preschool models to matched, traditional programs in an effort to improve school readiness in disadvantaged children (Egbert, 1981). The models were grouped into three categories based on what particular sets of skills they were designed to promote in disadvantaged children: basic academic skills (Behavior Reinforcement, DISTAR, Language Development), higher-order cognitive skills (e.g., Cognitively-Oriented Curriculum, Parent Education, Self-Directed Literature/ Tucson Early Education Model), and affective skills (e.g., Learning Center, Open Education, and Self-Esteem).

Of all participating programs, children in the Didactic Instruction System for Reading and Remediation (DISTAR) model emphasizing basic skills outperformed children in the control and experimental groups in reading, math, and language, moving from the 20th percentile to near the 50th percentile (e.g., Education Commission of the States, 1999; Ellis & Fauts, 1993). Additionally, DISTAR children showed the highest gains in self-esteem and higher-order thinking skills (Adams & Engelmann, 1996; Bereiter & Kurland, 1992). Independent follow-up studies show DISTAR children's math and reading scores remained higher than children in matched controls through high school, although these gains generally diminished over time (Becker & Gersten, 1982; Gersten & Keating, 1987; Texas Center for Educational Research, 1997; Meyer, 1984). Others report similar findings for didactic instruction approaches in reviews and meta-analytic studies (Kennedy, 1978; Scheiffer, 2002; Przychodzin, Marchand-Martella, Martella, & Azim, 2004; White, 1988), and a small number of experimental studies (e.g., Gersten, 1985; Stockard, 2009; Rawl & O'Tuel, 1982; Swanson & Hoskyn, 1998).

Limitations. Several substantial caveats, however, are warranted in interpreting the data. Much of the published early childhood research is based on the original Project Follow Through data, which had a variety of methodological limitations built into the original design (e.g., self-selected program implementation, narrow measures, limited causal inferences due to design, choice in statistical analyses, attrition; for a review, see House, Glass, McLean, & Walter, 1978). In particular, inspection of the comparison models reveals several key methodological and philosophical concerns. First, some of the models represented well-developed and experimentally-validated educational materials and methods of instruction (e.g., DISTAR) while others were in a very early stage of development and had not been extensively piloted or field-tested (Elmore, 1977; Watkins, 1997). Reports suggest that program administrators had difficulty interpreting and implementing the models without readily available resources, which would undoubtedly impact the effectiveness of the comparison programs (Elmore, 1977; Vinovskis, 1999). Second, programs varied widely in terms of educational curriculum and pedagogical structure. They ranged from highly structured programs that had scripted pedagogy and well-defined curricula (e.g. DISTAR) to less structured programs that left the curriculum, learning materials, and teaching strategies up to the teacher. In some cases, the less structured programs placed learning entirely in the hands of children with little planning or guidance from teachers (Maccoby & Zellner, 1970). Perhaps this is why there was more within-model variation than between models (Bock, Stebbins, & & Proper, 1977; Gersten, 1984; Kennedy, 1978).

A key question thus remains as to whether the success of didactic programs is due to pedagogical practices ("how you teach") or organized, educational curricula ("what you teach"). When curriculum is controlled in both didactic and comparison programs, some experimental evidence suggests that there is little difference between didactic and traditional approaches (e.g., Cole & Dale, 1986; Cole, Dale, & Mills, 1991; Kuder, 2001). Indeed, when the What Works Clearinghouse (WWC, 2008) evaluated the effectiveness of the didactic instruction programs according to rigorous research standards, they determined that the extent of evidence is small or inconclusive.

Playful Learning Pedagogies

In contrast to didactic instruction, playful learning is emerging as a pedagogical approach that is child-centered and that uses both free- and guided play activities to promote rich curricular goals in young children (Hirsh-Pasek et al, 2009; Resnick, 1994; Singer, Hirsh-Pasek, & Golinkoff, 2006).

Free Play. Free play includes a broad array of activities, such as object play, socio-dramatic play, and imaginary play. Theorists generally agree that free play activities are voluntary, fun, flexible, have no extrinsic goals, may contain an element of make believe, and involves active engagement of the child (Johnson, Christie, & Yawkey, 1999; Pellegrini, 2009; Sutton-Smith, 2001).

Observational studies have demonstrated children's free play often incorporates mathematic and scientific content naturally (Björklund, 2008). Ginsburg, Pappas, and Seo (2001), for example, examined the frequency of mathematic-related activities in four- and five- year-old children's free play period in daycare. Regardless of gender and ethnicity, over half of children's playtime was spent in some form of mathematic or science-related activity: 25% was spent examining pattern and shape, 13% on magnitude comparisons, 12% focused on enumeration, 6% explored dynamic change, 5% compared spatial relations (e.g., height, width, location), and 2% of the time was spent classifying objects; however, the frequency of two-to-five year olds' mathematical activities vary widely, ranging from a daily basis (Saxe, Guberman, & Gearhart, 1987), to a few times per week (Blevins-Knabe & Musun-Miller, 1996; Tudge & Doucet, 2004).

The frequency of this math-related play has also been linked to increases in mathematical knowledge and achievement (e.g. Ginsburg, Lee, & Boyd, 2008; Caldera, McDonald Culp, Truglio, Alvarez, & Huston, 1999; Hirsch, 1996). For example, Wolfgang, Stannard, and Jones (2003) found that preschool children's complexity of block play had positive relationships with seventh-grade mathematical test scores, high school measures of math grades, number of math courses, and number of honors courses. Ramani and Siegler (2008) found the pre-K children's board game play activities correlated with stronger performance on number identification, counting, number line estimation, and magnitude comparison. In addition, they showed that when a numerical board game was played four times (15 minute sessions) over a period of two weeks, children showed significant gains across the four mathematic measures compared to a control group.

Taken together, when children engage in free play activities related to math, they prime the foundation for early mathematical thinking (see Baroody, Lai, & Mix; 2006; Geary, 1994; Ginsburg, Cannon, Eisenband, & Pappas, 2005; Seo & Ginsburg, 2004). Theorists believe children form rudimentary concepts about the properties of objects and relationships in the world through exploration and hands-on experiences; however, much of the research is correlational and requires additional experimental exploration (Clements & Sarama, 2007; Ginsburg, Cannon, Eisenband, & Pappas, 2006). A key question arises from the free play findings: is there a *pedagogy* that embraces the child-centered philosophy that facilitates planned, curricular goals?

Guided Play. Recently, academic scholars have begun to draw distinctions between free- and guided-play activities within playful learning contexts (e.g. Hirsh-Pasek et al., 2009; Fisher et al., in press). Guided play represents an emerging research area that is considered the midpoint between didactic instruction and free play experiences (Hirsh Pasek et al., 2009). In these contexts, educators structure an environment around a general curricular goal that is obtained by encouraging children's natural curiosity, exploration, and play with well-planned curricular materials and activities.

Support for guided play comes from several experimental studies that compare child-centered, playful learning approaches to traditional programs, including the Abecedarian Project (Campbell, Ramey, Sparling, & Miller-Johnson, 2002), Tools of the Mind (Bodrova & Leong, 1996), and Montessori programs (Lillard & Else-Quest, 2005; 2006). The Tools of the Mind program, for example, is designed to promote executive function and academic skills via guided play activities (e.g., teachers help children make ‘play plans’ for dramatic play) and has been evaluated by a number of researchers (Barnett et al., 2008; Bodrova & Leong, 2002; Diamond et al., 2007; What Works Clearing House, 2008). In one such study, Barnett et al. (2008) randomly assigned low-income preschool classrooms to either Tools or control classrooms. The Tools children showed superior gains in executive function, social behavior, and marginally superior language development compared to their counterparts. Similarly, Lillard and Else-Quest (2006) compare play-based, Montessori and traditional, state-funded preschools and found that 5-year-old children who had attended Montessori schools[1] for two years scored significantly higher in reading and math achievement in children in state-directed programs. Montessori preschool attendance also predicts math and science scores on later standardized assessments (e.g., ACT scores, Dohrmann, 2003).

Limitations. These findings suggest playful learning programs have short- and long-term impacts on academic achievement; however, similar to the didactic instruction literature, the definition of traditional pedagogy is not well developed nor consistent. Second, a wide variety of approaches may be used (e.g., modeling, co-playing, environmental enrichment, etc), yet they are rarely empirically studied. Additional experimental evidence is necessary to understand the causal mechanisms underlying the findings.

---

[1] Montessori schools are characteristically known for creating classrooms in which children choose from a number of playful, hands-on activities that have been prearranged by adults. In particular, they employ a special set of educational materials, individual and scaffolded exploration and discovery of materials, and personal and small group instruction for learning.

Playful Learning and Didactic Instruction Comparison Studies

The literature reveals both didactic and playful learning pedagogies are typically compared to 'traditional instruction' methods. To our knowledge, only six sets of studies have *directly* compared didactic and playful learning programs using field and quasi-experimental research methodologies.

Program Comparisons. The first three studies compare the differential impact of specific educational programs on academic achievement. Miller and Bizzell (1983a, b) examined four Head Start preschool models: DISTAR, DARCEE, Montessori, and a traditional program. The first two programs emphasized basic skills through direct teacher instruction while the latter two were child-centered and play-based. DISTAR and DARCEE initially produced greater gains in academic and cognitive areas while the child-centered programs led to higher gains in inventiveness, curiosity, and social participation. By second grade, boys in the Montessori program fared better academically than they did in the other groups. Interestingly, girls did best in DARCEE. Upon closer inspection of these two programs, Miller and Dyer (1975) suggest some striking similarities between Montessori and DARCEE. Both emphasized sensory stimulation, manipulation of materials, and informal conversations between teachers and children. Miller and colleagues suggest that these characteristics were especially beneficial to children, perhaps because they help children hone in relevant learning goals and stay engaged in a pleasurable, meaningful way. This observation sheds light on how earlier conceptualizations of programs may not necessarily fit with the terminology used today. DARCEE was likely categorized as "academic and teacher-centered" because it had a curriculum and instructional plan.

A second study conducted by Karnes and colleagues (1983) examined five programs that varied in terms of structure, including two traditional programs (little structure; child-centered), a Montessori program (moderate structure; child-centered), and two didactic programs (high structure: teacher-centered). At the end of first grade, children in the didactic programs outperformed the others in reading and math; however, this trend faded by third grade. A follow-up study found that two child-centered programs (Montessori and a Traditional model) contained the highest percentage of high school graduates (75% and 70%) and greatest academic achievement.

Lastly, Schweinhart and colleagues (2004; Schweinhart, Weikart, & Larner, 1986) examined the short- and long-term impact of DISTAR and two guided play programs (High/Scope Program and another child-centered nursery school) in a randomized, controlled design. Contrary to previous studies, no significant differences were found between groups in intellectual and academic performance across their educational careers (K – 12).

Teaching philosophies. In a parallel line of research, several studies have examined the impact of educators' personal teaching philosophies and practices on children's academic achievement. In such studies, researchers typically identify classrooms as child-centered, didactic, or mixed-method based on an evaluation of the teachers' prevailing beliefs and practices (Stipek & Byler, 2004). For example, Stipek and colleagues (1995) created a classroom observation measure that was designed to evaluate the nature of teacher-organized activities and teacher characteristics (e.g., warmth, positive control, academic emphasis, child initiative). They found preschool children in didactic programs had higher scores on letters/reading but not on numbers achievement tests. They also displayed negative outcomes on most motivation measures, had higher stress, and had lower expectations of academic success compared to those in child-centered classrooms. In a second study, Stipek et al. (1998) showed different results for preschoolers and kindergartners. Preschool children fared better in the child-centered approach on cognitive and socio-emotional measures. Kindergartners showed higher gains in academic skills in the didactic approach while those in the child-centered class showed higher motivation and problem solving-skills.

Similarly, Marcon (1993; 1999; 2002) identified program models by surveying teachers about their beliefs and practices. After classifying classrooms based on prevailing educational approach (Didactic, Child-Centered, or Mixed), she used a stratified random sampling across the school district to examine the effect of academically-directed, child-centered, and mixed-method practices. Low-income children who were exposed to playful learning preschool environments at age four showed enhanced academic performance in mathematics, reading, language, spelling, handwriting, and science compared to children who experienced more traditional, didactic instruction or mixed method practices. By the end of their sixth year, children in traditional programs earned significantly lower grades compared to children in the playful learning and mixed method programs.

Limitations. These limited studies suggest that both guided play and didactic approaches offer some benefits to young children. While didactic approaches may initially fare better, these results fade over time; conversely, child-centered approaches appear to promote sustained positive academic achievement. Several questions are also raised in light of these findings. Child-centered or playful learning approaches appear to promote a broad array of academic, cognitive, and socio-emotional skills compared to didactic practices (e.g., Hirsh-Pasek et al., 2009). Yet many of the evaluations of learning are narrowly construed to standardized assessments/grades. Additionally, to our knowledge, virtually no studies have examined the short- and long-term retention of knowledge in guided play and didactic pedagogies. Lastly, little is known about *how* pedagogy influences generalization of knowledge. Additional research is necessary to examine these areas.

What is Playful Learning? Conceptual Issues

Although evidence shows playful learning promotes academic achievement, two key issues plague the literature. First, the playful learning definition is relatively ambiguous, encompassing a variety of methodologies that may be differentially promoted across studies. In particular, there may be substantial variations in how instructors interpret and implement the philosophical tenets of these programs. Some may predominantly promote free play with curricular materials while others may mix play and didactic instructional practices (Marcon, 1999; Stipek, 1991).

Relatedly, little is known about the specific roles educators use to facilitate learning in play (Moyles et al., 2002). Teachers' commitment to playful learning may translate into child-centered permissiveness, with adults adopting a predominantly non- -facilitative role. For instance, a teacher may enrich children's play areas with curricular materials and oversee children's play activities without engaging or interacting with the children (e.g., "enriched free play"). Conversely, other educators may take a proactive stance in which they enrich the environment with curricular materials and co-play with the child in a way that fosters discovery and learning (e.g., asking questions to promote discovery/exploration, etc; Docket & Fleer, 1999; Meckley, 2002, in Wood, 2009). Research often fails to report these attributes that are necessary for replication and causal exploration, limiting the construct validity and replicability of playful learning approaches (e.g., Marcon, 1999; Schweinhart, Weikart, & Larner, 1986).

A second issue is the lack of experimental studies that examine the mechanisms underlying playful learning (Hirsh-Pasek et al., 2008). These programs have a fundamentally different structure from didactic and other traditional practices. It is still unclear which components of the learning experience are associated with particular outcomes (e.g., interest/motivation, physical engagement, types of materials, teacher-student interaction, etc), which may also vary according to preschool population (e.g., middle- vs. low-income).

Exploring the Characteristics of Playful Learning Activities

Given the limitations that exist in the extant literature, it is necessary to examine the commonalities across successful playful learning practices to operationalize the constructs and test the mechanisms that potentially drive learning. Although a variety of attributes are implicated in the literature (Docket & Fleer, 1999; Goldbeck, 2001; Meckley, 2002; Wood, 2009; Stipek, 2004), we focus on two prominent characteristics for the purpose of this dissertation: physical engagement and guidance.

Physical Engagement

Across successful playful learning programs, children were actively engaged in the learning process as they physically explored and manipulated educational materials[2]

[2] Educational materials often include the use of manipulatives (e.g,. blocks, tiles, figurines, candies, puzzles), illustrative pictures, art materials (drawing, painting, crafts), or other materials that may be physically touched by the child and used symbolically (e.g., McNeal & Uttal, 2009).

(e.g., Karnes, Schwedel, & Williams, 1983; Lillard & Else-Quest, 2005; Marcon, 2002; Miller & Bizzell, 1983b). During this process, it is generally believed that children extrapolate information about the physical nature of the objects and begin forming rudimentary concepts (Bonawitz, 2009; Ginsburg, Cannon, Eisenband, & Pappas, 2006; Tamis-LeMonda, Uzgiris, & Bornstein, 2002; Vygotsky, 1978). For example, as children plays with shape sorters, they learn to distinguish a triangle from a square based on its predominate physical characteristics. Although experimental evidence suggests physical engagement during play naturally promotes learning (Bonawitz, 2009; Bonawitz, Fischer, & Schulz, 2008; Shulz & Bonawitz, 2007), others have found that the nature of the play activity (e.g., Sarama & Clements, 2009) or the types of materials can assist or impede the process (e.g., Kaminski, Sloutski, & Heckler, 2009).

Guidance

Guidance is also a central feature of playful learning experiences (Docket & Fleer, 1999; Golbeck, 2002; Hirsh-Pasek et al., 2009). In guided play, teachers use a variety of strategies to draw children's attention to critical features of learning that may be otherwise overlooked. These include, but are not limited to, enriching curricular materials and using dialogic inquiry to prompt exploration and discovery (e.g., Bruner, 1996; Montessori, 1917, 1995; Meckley, 2002; Wells, 1999; Wood, 2009).

Enriched curricular materials. Educators' choice of materials influence what features children attend to and learn (Clements & Sarama, 2007; McNeil & Uttal, 2009; Kaminski, Sloutski, & Heckler, 2009).[3] Evidence suggests children's knowledge is

[3] We discuss the importance of curricular material enrichment in playful learning activities; however, we also note that this applies to a wide range of informal (e.g., free play) and formal learning experiences (e.g., guided play, didactic instruction, mixed method practices).

derived from comparisons they make across a variety of experiences with objects (DeLoache & Smith, 1999; Gentner, Loewenstein, & Hung, 2007; Griffin & Case, 1996; Mandler, 1992 & 1993; Smith & Heise, 1992). When children are exposed to a small number of exemplars in a category, they will develop a rigid, 'concrete' concept of the category (e.g., Clements & Sarama, 2007; Gentner & Kurtz, 2006). Conversely, those exposed to a variety of exemplars that range in typicality will likely develop a more conceptual understanding of the category (Gentner, 2005; Smith & Heise, 1992). Based on this literature one might hypothesize that children exposed to prototypical triangle exemplars (e.g., equilaterals) will form a 'concrete' concept of triangles (e.g., triangles have a point on top and wide, horizontal bottoms). Children exposed to a *variety* of triangle exemplars (e.g., equilateral, isosceles, obtuse) will develop a criterial understanding of triangle (e.g., triangles have three sides and three corners). Thus, choice of curricular materials subsequently influences children's thinking and learning during free and guided play activities (Rittle-Johnson, & Siegler, 1998); however, some contend that even the best curricular materials/objects are ineffective if teachers do not guide the learning process (Brown et al., 2009; Uttal et al., 2009).

Dialogic Inquiry. Successful play-based programs often included informal discussions between teachers and children, in which "teachers solicit children's questions, ideas, solutions, and interpretations" to guide learning (Stipek, 2004, p. 555). Dialogic inquiry is one particular strategy for scaffolding children's discoveries beyond their self-initiated explorations of curricular materials (Wells, 1999). In such experiences, the adult or child presents a particular question or dilemma that requires the attention of both individuals to guide them to a solution (Ash & Wells, 2006; Benjamin, Haden, &

Wilkerson, 2010; Duncan, 1995; Renshaw, 2004). A child exploring a novel object alone, for example, is more likely to recall the color, texture, and moveable parts of the object (Fender & Crowley, 2007). When a teacher is present, he or she may ask leading questions to help the child discover abstract aspects of the object beyond its salient features, such as its causal processes (e.g., What makes it move?), utility (e.g., What could you use this for?), and meaningfulness (e.g., Does this remind you of the toy you played with at Grandma's?). Evidence suggests dialogic inquiry prompts learning in a variety of academic domains, including biology (Ash, 2003; Ash, in press; Callanan & Braswell, 2006), language skills (Whitehurst, 1997) causal understanding (Callanan & Oakes, 1992), and symbolic representation of the world (Callanan, Jipson, & Soenichsen, 2002).

Developing Shape Concepts: An Area for Exploration

This dissertation investigates these three features of playful learning practices (enrichment of curricular materials, physical engagement, and dialogic inquiry) in an area well defined in the literature: geometric shape learning. Shape understanding is considered a foundational area for later geometric thinking (Clements & Sarama, 2007) and is listed as a key early standard by the National Council of Teachers for Mathematics (2008) and the newly released Core Curriculum (National Governors Association Center for Best Practices, 2010).

Preschool children start out categorizing shapes by visual similarity and orientation irrespective of definitional properties (Burger & Shaughnessy, 1986; Clements & Sarama, 2007). These concepts are global and holistic in nature, in which the most salient shape properties bind together to form an overall feature or a 'gestalt view' of each shape (Ganel & Goodale, 2003; Keil, 1996; Smith, 1989; Tada & Stiles, 1996). For instance, the angle on top of a typical triangle is the most distinguishing feature and thus defines the overall concept for the child (e.g., triangles have a point on top and wide, horizontal 'bottoms'). Only later do they shift to rule-based/definitional classification systems that rely on the *number* of sides or angles for shape identification (Clements, Swaminathan, Hannibal, & Sarama, 1999; Keil, 1996).

According to Clements and colleagues (1999), preschool children's verbal explanations for shape sorting behavior reveal a reliance on visual similarity as well as a burgeoning awareness of definitional properties of shapes. Four- to six-year olds are often able to identify the geometric properties of a typical shape exemplar, yet fail to apply this knowledge to atypical exemplars. It appears children are in the process of abstracting definitional properties, but this abstraction is inherently tied to their prototypical shape features.

How do children move from concrete-to-abstract concepts of geometric shapes? The observed ontogeny may be due, in part, to children's limited exposure to simple, typical shape forms as well as to current educational pedagogies (Clements & Sarama, 2007; Newcombe, in press; Smith & Heise, 1992). Anecdotal observations of toys (e.g., shape sorters), educational videos (e.g. Caudle & Caudle, 2003; Stott, 2002), and teaching guides (Learning Resources, 2007) reveal a prevalence of typical shape forms. Additionally, early research on U.S. teaching practices shows educators often verify prior shape knowledge rather than promoting new understanding (Lehrer, Jenkins, & Osana, 1998; Thomas, 1982 as reported in Clements & Sarama, 2007). For example, teachers are more likely to ask children to label shapes they already know rather than explore their geometric properties (e.g., Teacher: “What is this shape? <child answers> “Good.” <repeat question for each shape>; Thomas, 1982). Taken together, research suggests children have the capacity to identify geometric properties, but their early shape experiences may continue to promote concrete understandings based on salient perceptual shape features.

The Present Studies

Previous research suggests didactic and playful learning practices are successful in promoting core academic knowledge in the preschool years; however, few experimental studies have compared these approaches directly. This dissertation offers the first set of empirical studies to examine the differential impact of these methods in one-on-one instruction in a laboratory task. Specifically, we compare didactic instruction and two common playful learning practices (guided play and enriched free play) on children’s shape learning. In so doing, we also take the initial step in exploring the potential mechanisms that distinguish guided play from other playful learning experiences (e.g., enriched free play).

For all studies, we operationalized *guided play* as an active, child-centered learning pedagogy that includes both dialogic inquiry and physical engagement with curricular materials. Conversely, *didactic instruction* is characterized as a passive learning pedagogy, in which the experimenter communicates shape information directly to the child (absence of dialogic inquiry and physical engagement with the curricular materials). Lastly, *enriched free play* represents an active pedagogy that prompts physical engagement with enriched curricular materials but without dialogic inquiry or instruction on criterial elements of shapes from the teacher (see Table 1).

Table 1

Comparison of the experimental conditions across dissertation studies

	Type of Guidance			Physical Engagement
	Enriched Materials	Explicit Instruction	Dialogic Inquiry	
Enriched Free Play	✓			✓
Guided Play	✓		✓	✓
Didactic Instruction	✓	✓		

NOTE: For the purposes of comparing the pedagogical styles and provide the optimal opportunity to learn, enriched shape learning materials were used across experiments except experiment 2 (a control condition for materials)

We note that this study is a first step in examining how these approaches may be used in educational settings. In hopes of understanding how specific pedagogical and curricular elements promote learning in a controlled experimental design, we focused on one specific content area (shape learning) and we have operationalized the pedagogies in a narrow manner (i.e., we recognize other elements may characterize guided play).

- In Study 1, we examine whether guided play or didactic instruction techniques promote criterial learning of four geometric shapes (circles, triangles, rectangles, pentagons) compared to the control condition. We use enriched curricular materials in all conditions in an effort to provide optimal learning experience for all children as well as isolate the impact of pedagogical elements (physical engagement, dialogic inquiry).

- Study 2 is an expansion on Study 1 designed to better understand one mechanism that might facilitate children's criterial learning of shapes: curricular materials. In this condition, children were exposed to only *typical* exemplars during guided play rather than being presented with enriched shape materials (both typical and atypical exemplars). Their learning outcomes were compared to children in guided play and the control conditions from Study 1.
- In Study 3, we directly explore the effectiveness of guided play, enriched free play, and didactic instruction on children's criterial learning of two familiar shapes (triangles, rectangles) and two unfamiliar, complex shapes (pentagons, hexagons). We examined the immediate and longer-term retention of learning over a one-week period.

CHAPTER 2

EXPERIMENTS 1 & 2

The first set of experiments in this dissertation explores the impact of instructional technique (guided play, didactic instruction) on children's criterial learning of shapes and to what degree curricular materials influence this relationship (Experiments 1 and 2, respectively). Research documents a concrete-to-abstract shift in children's shape understanding during the primary years. Preschool children start out categorizing shapes by visual similarity and later shift to criterial understanding of shapes that rely on the number of sides or angles for shape identification (Burger & Shaughnessy, 1986; Clements & Sarama, 2007). There is evidence that this shift may be due to teaching practices and children's early experiences with shapes (e.g. Clements & Sarama, 2007; Leher, Jenkins, & Osana, 1998; Smith & Heise, 1992).

Building on the reviewed literature, we test the following predictions in this chapter. The first prediction focuses on *pedagogical* elements that guide attention to relevant criterial features of shapes. The extant literature shows that guided play and didactic instruction promote mathematic knowledge using two distinct methodologies (i.e., active vs. passive learning); however, few experimental studies have compared the two approaches directly, particularly in the context of early geometric shape understanding. Existing evidence supports playful learning approaches in early mathematics education literature (Clements, 2004; Clements, Swaminathan, Hannibal, & Sarama, 1999). In particular, educational techniques that promote hands-on experiences with shapes, such as the Montessori approach (Ongoren & Turcan, 2009), and the use of dialogic inquiry to prompt criterial knowledge (e.g., “why is this a triangle?” Clements, Swaminathan, Hannibal, & Sarama, 1999) appear to foster stronger shape learning over traditional programs. Thus, we predict that guided play, a playful learning approach that combines both of these techniques, will promote stronger criterial learning of shapes than a didactic, more passive learning technique (e.g., Hohmann & Weikart, 1995; Marcon, 1999). This prediction is tested in Experiment 1.

The second prediction explores how curricular materials may guide children’s learning of criterial definitions of shapes. Previous research suggests educational materials used during math lessons should highlight the key *relational* structure (e.g. Kaminski, Sloutsky, & Heckler, 2009). A geometric shape concept such as triangle, for example, represents a variety of forms that share a common set of criterial properties (e.g., all triangles = 3 sides, 3 corners). Children exposed to a greater diversity of exemplars of a shape may be more likely to make comparisons across the exemplars, align their common features, and abstract the relational structure that defines the shape category (Clements & Sarama, 2000; Clements, Swaminathan, Hannibal, & Sarama, 1999; Gentner & Calhoun, in press; Gentner, Loewenstein, & Hung, 2007; Sarama, 2004). Conversely, children exposed to a narrow range of exemplars in a shape category, (e.g., prototypical exemplars that are similar in size, orientation, and angles) will display a concrete understanding of shapes grounded by perceptual similarity (e.g., triangles = point on top, flat bottom). We predict children who are exposed to diverse exemplars during training will show superior criterial learning compared to those exposed to prototypical exemplars during training and those who did not receive training at all. This prediction is tested in Experiment 2.

Experiment 1

Experiment 1 was designed to examine which pedagogical method, didactic instruction or guided play, best promotes criterial learning of shapes in comparison to a control group. In this experiment, children were exposed to a rich palate of exemplars that ranged in typicality during shape training in an effort to promote optimal visual guidance toward relevant criterial features. Children's shape knowledge was tested with two dependent variables— a shape sorting and an embedded shapes task.

We examined three hypotheses. First, we predicted children in guided play would show superior criterial learning than those who receive didactic instruction. Second, we hypothesized children taught in the didactic format will show superior criterial knowledge compared to those in the control group. Third, we also predicted children who are exposed to enriched shape experience via shape training will show criterial learning of shapes while those in the control group will display a more concrete understanding of shapes.

Operational Definitions of Key Constructs

We operationalized *guided play* as an active, child-centered learning pedagogy that included both dialogic inquiry and physical engagement with curricular materials. Conversely, *didactic instruction* was characterized as a passive learning pedagogy, in which the experimenter communicates shape information directly to the child (absence of dialogic inquiry and physical engagement).

The key constructs and their defining criteria were derived from the extant literature in an effort to maintain validity across intervention and experimental research. *Dialogic inquiry* represented a learning experience that is initiated and scaffolded by the experimenter (Stipek, 2004; Wells, 1999). Each child was presented with a dilemma during the shape lesson ('what makes all of the shape cards a particular shape?') and asked questions that prompted the child to compare across shape stimuli and discover of the criterial properties of the shape category. *Physical engagement* refers to the child's ability to physically touch/explore/manipulate the learning materials/stimuli during the shape lesson (Golbeck, 2001; Lillard & Else-Quest, 2005; Marcon, 2002; Miller & Bizzell, 1983b). During shape training, each child was encouraged to count the distinguishing feature of each shape exemplar (e.g., the sides and angles) and draw two novel instances of the shape to facilitate identification and representation of new shape concepts (Clements, Wilson, & Sarama, 2004).

Lastly, one can argue that once children learn the criterial or defining characteristics of shapes (e.g., triangles = 3 sides, 3 corners), they are operating on a more conceptual, rather than perceptual, level of understanding (Keil, 1989; Gentner, 2005). Thus, *criterial learning* refers to the identification of shapes by their definitional properties ("abstract concepts") in two shape tasks as opposed to identifying shapes by their featural similarities (i.e., "concrete" concepts).

Method

Participants

Fifty-one, four- and five-year-old children were recruited from suburban environments in the northeast United States using commercially available mailing lists. The literature shows children of this age range have a relatively concrete concept of shape, relying heavily on visual similarity during categorization tasks yet still have the cognitive capacity to recognize and count shape features (e.g., the number of sides and angles on a triangle; Clements & colleagues, 1999).

The final sample consisted of 42 typically developing children with the following distribution across three conditions: 14 in guided play (M_{age} = 52.36 months, *SD* = 4.60), 14 in didactic instruction (M_{age} = 51.07, *SD* = 4.65), and 14 in control (M_{age} = 56.88, *SD* = 7.45). Conditions were matched on gender and age. Data from an additional nine children (18%) across these conditions were excluded from analyses due to inattentiveness (n = 3), fussiness (n = 2), or failure to complete the study (n = 4[4]). Children were predominantly Caucasian and from middle- and upper-middle class homes. All children completed the training and shape sorting tasks; two children did not complete the embedded shapes task.

Materials

Drawing materials. One sheet of paper and five crayons of varying color were available for the practice drawings.

Shape training stimuli. Four geometric shapes were chosen for training: circles, triangles, rectangles, and pentagons. These shapes were chosen for two reasons: (1) previous research established a concrete-to-abstract ontogeny for each of these shapes (Satlow & Newcombe, 1998) and (2) the rule-based properties are visually identifiable and within preschoolers' counting range.

For each shape category, two typical and two atypical exemplars were created using Serif DrawPlus 4.0 software (4 exemplars per shape, 16 total exemplars; See

---

[4] The experimenter identified children as fussy who appeared physically distraught during the study and failed to maintain attention for more than 10 seconds. Similarly, children'Children were unable to maintain focus on the experiment for more than 10 seconds.

Appendix B). Each exemplar was displayed individually on a 5" x 5" yellow laminated card. Typical exemplars represented those that are commonly seen and recognizable. They shared perceptually similar, canonical shape properties, were displayed in upright orientations, and were medium to medium/large in size (e.g., each filled at least half of the display space). Atypical shapes were equally valid shape forms but not commonly seen (e.g., Satlow & Newcombe, 1998). For example, an equilateral, upright triangle is 'typical' while an obtuse triangle is atypical. These shapes had noticeably skewed orientations (e.g., approx. 15° - 180° rotation), contained exaggerated angles (e.g., acute, obtuse) or lines (e.g., thick), or were an exaggerated size (e.g., each filled very little or almost all of the display space).

Pedagogical Conditions

The experiment consisted of three conditions: guided play, didactic instruction, or a control (dialogic reading activity). The experimental conditions exposed children to the same shape stimuli and criterial shape knowledge but varied on two properties: (1) the use of dialogic inquiry and (2) physical engagement of the shapes via physical touch of the exemplars and practice shape drawing.

Guided play. Participants were taught criterial definitional properties for each shape in a playful, exploratory manner. The experimenter first introduced the child to the experiment by saying "We are going to learn about shapes today. Let's figure out what makes a shape a REAL shape. We are going to start with real circles." For each shape category, an experimenter laid out four exemplar cards (2 typical, 2 atypical) on the table directly in front of the child, pointed to the exemplars, and said

> Look at each of these. There are many REAL<shape name> -- they can be tiny or big, thin or fat, and they can even be turned on their side or upside down! But they are all REAL <shape name>. Although they look different, they are all REAL <shape name>. Can you help me find out what makes all of these REAL <shape name>?"

After a few moments of initial exploration (approximately 10 seconds), the experimenter helped the child 'discover' each shape's distinguishing features through questions and prompts (e.g., What makes all of these look alike? Let's look really closely. Hmmm… I think this shape has some sides/corners. Does it? How many sides does it have? Oh… I see.. what about this one?). Additionally, the experimenter encouraged children to touch/trace shapes as they examined each of the exemplar cards. This 'discovery process' was repeated across each of the four shape exemplars. After discovering the properties across each exemplar, children were asked to help the experimenter recall the shape's distinguishing properties (e.g., "I think I got it… so all of these REAL <*shape name*> have…. What was it again?"). Afterwards, each child was asked to draw two novel instances of the recently learned shape with a crayon on the provided sheet of paper. This training procedure was repeated for each shape category.

Didactic instruction. Participants were taught criterial definitional properties for each shape in a passive learning style. The experiment was set up in the same manner as the guided play condition with the exception of the stimuli being moved approximately five inches away from the child. Pilot data revealed close proximity to the stimuli encouraged touching/interaction behaviors even with explicit instructions not to do so. This distance minimized physical contact with the shapes while maintaining distinguishable features.

The experimenter introduced the child to the experiment using similar wording as the guided play condition but without prompting the child's engagement in the process:

> We are going to learn about shapes today. I am going to show you what makes a shape a REAL shape. We are going to start with real circles. Look at each of these <the experimenter points to the exemplar cards>. There are many REAL<shape name> -- they can be tiny or big, thin or fat, and they can even be turned on their side or upside down! But they are all REAL <shape name>. Although they look different, they are all REAL <shape name>. Ready? I am going to show you what makes these REAL <shape name>.

For each shape category, the experimenter explained the shape's attributes by saying "Each of these are REAL *<shape name>* because…" (circles: all have one solid line all the way around with no missing pieces and no corners; triangles: all have three corners and three sides: rectangles: all have four corners and four sides; pentagons: all have five corners and five sides). Next, the experimenter physically identified and counted these features across each shape exemplar (while the child watched) and then reiterated the definitional features observed across all of the shapes. Lastly, the children *watched the experimenter* draw two novel examples of the newly learned shapes.

Control. Children participated in a dialogic reading activity for the same amount of time as the other conditions. The experimenter read a neutral book to the child that did not prompt shape knowledge. During the activity, the experimenter asked the children questions to maintain interest in the story and encourage dialogic interaction with the experimenter (e.g., "Do you keep your room clean like Van Go Lion? Which is your favorite color?).

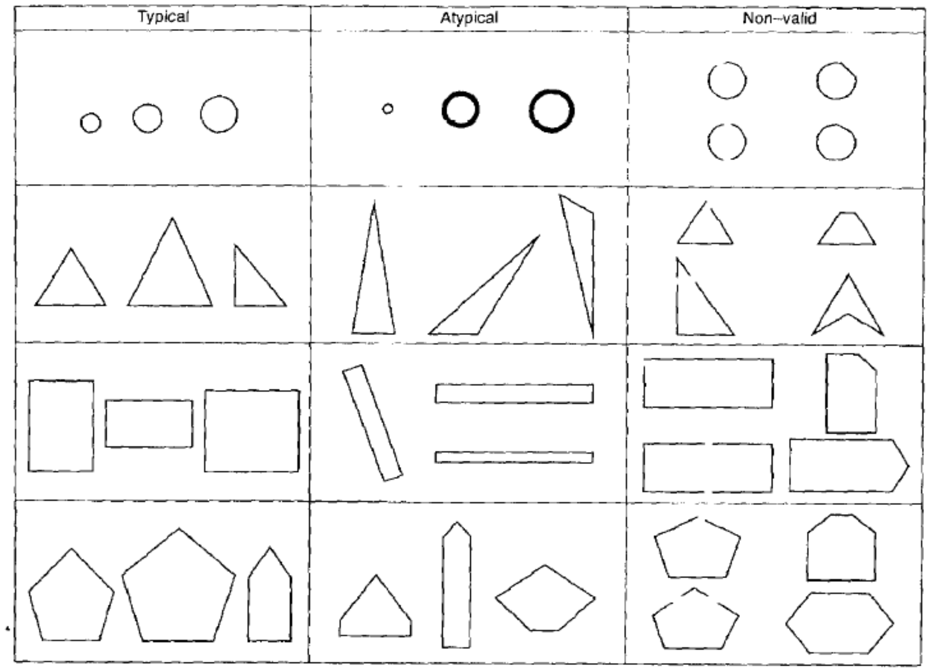


Figure 1. Shape exemplars used by Satlow & Newcombe (1998) in the shape-sorting task.

Measures

Shape-sorting task. To assess shape knowledge, children were asked to complete a shape-sorting task (Satlow & Newcombe, 1998). In this task, children were presented with *novel* exemplars of circles, triangles, rectangles, and pentagons (see Figure 1), with each shape presented individually on 5” x 5” laminated cards. Children saw three typical, three atypical, and four non-valid exemplars of each shape (10 exemplars of each shape type). Typical and atypical forms follow the same guidelines described previously. Non-valid shapes represented forms that did not adhere to a specific geometric definition, with two demonstrating a lack of closure and two with an incorrect number of sides (circles had either one or two straight “flattened” sections).

Each participant worked individually with the experimenter and a handheld puppet to complete the sorting task. The child was introduced to Leelu the Ladybug, "a very picky bug who loves shapes, but only REAL of shapes." The experimenter told the child a story to facilitate shape sorting during the task:

> "As Leelu was flying around the other day, she found cards with shapes on them, some are real shapes and some are not. She needs help sorting them. Would you like to help? We need to put all the *real* shapes in her ladybug box (experimenter points to a red box) and throw away fake shapes in trashcan (experimenter points to a trashcan). Remember, she is really picky and only likes *real* shapes."

For each shape, the child was first shown one model and told, for example, "This is an example of a *real* circle to help you. Remember, there are many real circles that are big and small, different colors, and even turned around! This is just one example of a real circle."[5] The model was then attached to the ladybug box with velcro and remained on display. Each model was a typical instance of the shape but not identical to any of the original training or test items.

Next, the experimenter placed one test card in front of the child and stated, for example, "Look at this carefully. Is this a real circle or a fake circle?"<*pause for response*> "Why do you think so?" Each card was displayed for approximately 10 seconds. Children's comments confirmed that they understood the procedure and attended to the perceptual details of each figure (e.g., "this is fake because it is broken here… so it goes in the trashcan"). The sorting task proceeded through circles, triangles, rectangles, and pentagons using the same instructions. The test cards were presented in a

[5] The original shape-sorting task by Satlow and Newcombe (1998) used two model cards during the sorting task. Pilot testing showed similar results between one and two cards. The former was chosen as a stronger test of criterial knowledge.

randomized order within each shape type and each child sorted all of the shape stimuli. The experimenter could not see the test item as it was displayed to the child.

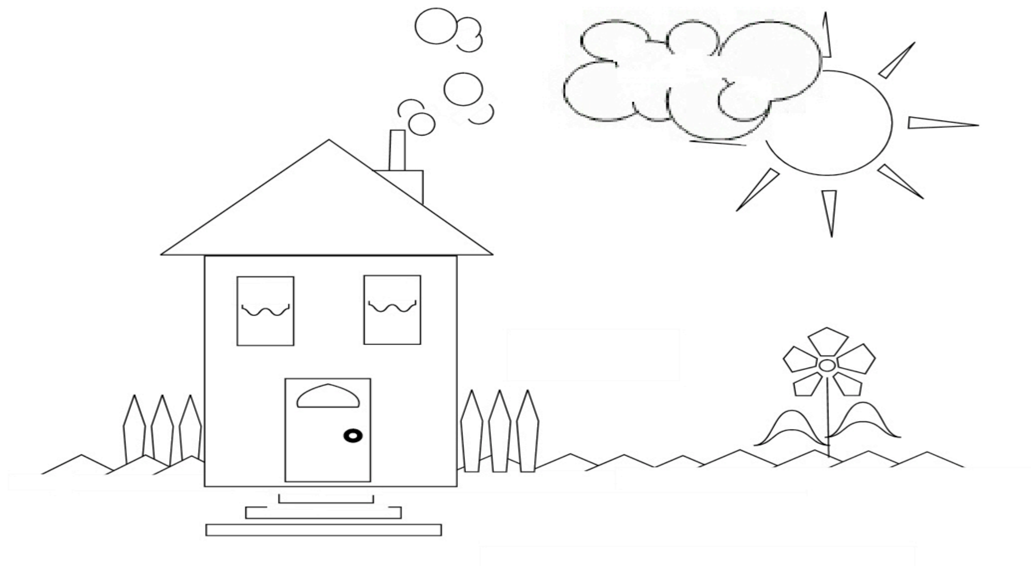


Figure 2: Embedded Shapes Task

Embedded shapes task. This task was designed to assess geometric shape knowledge transfer to a complex shape identification task. As seen in Figure 2, typical, atypical, and non-valid shapes were embedded in a familiar figure. To ensure children adequately examined the picture and all of its components, the experimenter first asked the child to describe the drawing (e.g., “What is this a picture of?” Most common response: “A house”). Next, the experimenter pointed to individual images in the picture and asked the child to label them (the door, windows, roof, chimney, chimney smoke, front steps, sun, clouds, flower, grass, fence).

Children were then instructed to find the 'real' shapes for Leelu the Picky Ladybug. For each shape, the child was presented with a new copy of the picture and instructed to point to the real shapes. This required children to look beyond the 'gestalt' view of the image, break down the picture into components, and extract the valid shape instances that adhere to their definitional properties. This test of shape knowledge is similar to embedded shape tasks used previously in the literature (e.g., Clements, Swaminathan, Hannbal, & Sarama, 1999; Razel & Eylon, 1991).

Procedure

Upon coming to the lab, parents and children were fully informed about the study prior to participation, and those who were interested completed consent forms. Caregivers also filled out demographic information and a background survey of their child's shape knowledge and drawing skill while the child participated in the study. The study was run in a private room while the caregiver waited in an adjacent room.[6]

Children were randomly assigned to one of the three conditions. All sessions were videotaped. The experimenter sat directly across from the child during training and testing. During shape training conditions, the experimenter first inquired about the child's favorite crayon color to use for drawing. For each shape category, four exemplar cards were affixed with velcro to an 11 x 11 inch board covered in green felt and laid on the table in front of the child. The experimenter proceeded with instruction based on the assigned pedagogical style.

[6] A few caregivers stayed during the experiment. They were asked not to speak during the session and children were positioned with their backs to the caregiver.

After shape lessons or the dialogic reading activity, children completed the shape sorting and embedded shapes tasks. The experiment took approximately 30 minutes to complete (shape lessons/reading = 15 minutes; Sorting task = 10 minutes; Embedded shapes task = 5 minutes).

Special efforts were made to ensure children were exposed to the same experiences and criterial knowledge in the experimental conditions. Children in both conditions were exposed to the same exemplars, the same shape property information, and similar drawing experiences. During didactic instruction, the experimenter slowed verbalizations during shape descriptions, feature counting, and drawing time to approximate guided play duration. Even with such controls, guided play took approximately one minute longer (1.10 sec) than the other conditions due to individual differences in children's verbalizations of shape properties and physical drawing ability, with the latter accounting for the majority of the time difference (e.g., time taken to pick up the crayon, steady the hand, and draw, etc).

Results

Data Reduction

Shape Sorting Task. We examined children's criterial learning of shape concepts by looking for specific acceptance patterns across typical, atypical, and non-valid shape forms in the sorting task. Children who relied on perceptual similarity to classify shapes would identify typical shapes as 'real' but reject atypical and non-valid shapes. Conversely, those who developed more abstract, geometric concepts of shape would rely on definitional properties during the shape tasks. They would identify typical *and* atypical shapes as 'real' while reject non-valid shapes. Thus, the key difference between conditions was children's rejection of atypical shapes.

To determine the extent children's category decisions were guided by visual similarities versus criterial concepts in the shape-sorting task, we collapsed across shape type and calculated general acceptance percentages across typical, atypical, and non-valid exemplars (See Table 2) to test hypotheses. We also calculated acceptance rates for typical, atypical, and non-valid shapes within each shape category to explore training effects on shape concepts that vary in complexity (e.g., familiar, simple shapes = circles; complex shapes = pentagons).

Embedded Shapes Task. For the embedded shape task, we followed similar data reduction methods. We collapsed across shape type to calculate general identification percentages for typical and atypical shapes to test our predictions. Few children identified non-valid shapes in the figure and thus these shapes were excluded from analyses. We also employed the same calculations within shape categories for exploratory purposes. See Table 2 for means.

Preliminary Analyses

All analyses were conducted using PASW 18.0 statistical software. Prior to analysis, five dependent variables (sorting task acceptance rates for typical, atypical, and non-valid shapes; embedded shapes identification rates for typical and atypical shapes) were examined for fit between their distributions and the assumptions of multivariate analyses. Z-scores were used to identify suspected univariate outliers ($> |3.29|$) and Mahalanobis distances with $p < .001$ were used to identify multivariate outliers for each variable within group. No outliers were found. As a result, the data set remained unchanged.[7]

Table 2

Experiment 1: Mean acceptance rates for shape knowledge tasks

	Shape Sorting Task			Embedded Shapes Task	
	Typical	Atypical	Non-valid	Typical	Atypical
Guided Play	.86 (.24)	.72 (.35)	.21 (.18)	.50 (.17)	.56 (.23)
Didactic instruction	.80 (.27)	.58 (.36)	.07 (.13)	.56 (.17)	.53 (.20)
Control	.55 (.33)	.27 (.27)	.03 (.05)	.63 (.29)	.43 (.32)

Notes. The values represent mean percentages of instances accepted as 'real shapes' in the sorting task and mean percentages of instances identified as 'real shapes' in the embedded shapes task. Values in parentheses are standard deviations.

A 3 (pedagogy: guided play, didactic instruction, & control) X 2 (gender: male, female) X 2 (age: 4 years or 48 – 59 months; 5 years or 60 – 71 months) multivariate analysis of variance (MANOVA) was performed as a preliminary analysis to assess potential gender and age effects on shape learning and interactions between factors. A total of five between-subject factors were analyzed from the sorting (typical, atypical, and non-valid acceptance rates) and the embedded shapes tasks (typical and atypical identification rates).

Main effects for pedagogy (*Wilks' Lambda*, $F(10, 50) = 2.40$, $p = .02$) and age were significant (*Wilks' Lambda*, $F(5, 25) = 3.45$, $p = .02$). A main effect for gender was

[7] Some variables showed signs of kurtosis and skewness (2.00+), nonparametric statistics yielded the same outcomes as parametric statistics. Thus, we reported parametric analyses for ease of interpretation.

marginally significant (*Wilks' Lambda*, $F(5, 25) = 2.33$, $p = .07$), but no interactions between these factors were found. Follow-up univariate ANOVAs revealed age and gender differentially influenced outcomes on each shape task. Children's age did not influence children's acceptance rates in the sorting task (all *p*'s > .37) yet had a significant effect on identification rates for typical and atypical shapes in the embedded shapes task, *F's* (1, 29) = 15.84 and 9.86, *p*'s < .01, respectively. As seen in Appendix C, pairwise comparisons revealed five-year-olds identified more typical (*M* = .73, *SD* = .20) and atypical shapes (*M* = .61, *SD* = .25) in the picture than four-year-olds (typical: *M* = .47, *SD* = .17; atypical: *M* = .45, *SD* = .24, *p*'s < .01).

Similarly, gender did not impact sorting task outcomes (all *p*'s > .11) yet had a significant effect on children's identification rates of atypical shapes in the embedded shapes task, $F(1, 29) = 5.52$, $p < .05$. Males identified more atypical shapes (*M* = .58, *SD* = .20) than females (*M* = .45, *SD* = .29, p < .05) while no gender differences were found for typical shape identification. As a result of these findings, sorting and embedded shape task variables were analyzed separately to test hypotheses.

What Pedagogy Promotes Criterial Shape Knowledge?

Sorting task. A one-way MANOVA with pedagogy as the between-subjects factor (guided play, didactic instruction, & control) was conducted on acceptance rates for typical, atypical, and non-valid shapes for the sorting task. Pedagogy had a significant main effect on shape acceptance, *Wilks' Lambda*, $F(6, 74) = 3.109$, $p = .01$, $\eta_p^2 = .20$. Follow-up univariate analyses indicated pedagogy significantly influenced children's acceptance of typical, atypical, and non-valid shapes, *F'*s(2, 39) = 4.55 ($\eta_p^2 = .19$), 7.16 ($\eta_p^2 = .27$), and 5.17 ($\eta_p^2 = .21$), respectively, *p*'s < .02.

Table 3

Experiment 1: Univariate ANOVAs for individual shapes trends by exemplar type and condition

Shape Category	Exemplar Type	ANOVA	Significant Pairwise Comparisons[a,b]
Circles	Typical	$F(2, 39) = 5.57, p < .01$	GP > C
			DD > C
	Atypical	$F(2, 39) = 2.74, p = .08$	GP > C
	Non-valid	$F(2, 39) = .674$, *n.s.*	--
Triangles	Typical	$F(2, 39) = 4.56, p < .05$	GP > C
			DD > C
	Atypical	$F(2, 39) = 3.59, p < .05$	GP > C
	Non-valid	$F(2, 39) = 5.15, p < .01$	GP > C
Rectangles	Typical	$F(2, 39) = .952$, *n.s.*	--
	Atypical	$F(2, 39) = 3.54, p < .05$	GP > C
	Non-valid	$F(2, 39) = 3.25$, *n.s.*	--
Pentagons	Typical	$F(2, 39) = 5.59, p < .01$	GP > C
	Atypical	$F(2, 39) = 11.63, p < .001$	GP > C
			DD > C
	Non-valid	$F(2, 39) = 5.12, p < .05$	GP > C

[a] GP = Guided Play, DD = Didactic Instruction, C = Control

[b] Significant at p < .05 with Bonferroni corrections

Pairwise comparisons with Bonferroni corrections revealed children who received shape training showed superior criterial geometric knowledge than those in the control condition. In particular, children in both guided play (p = .02) and didactic instruction (p = .08) identified more typical shapes as 'real' compared to those in the control group. Similarly, both training conditions accepted more atypical shapes than those in the control (p's < .05). Children in guided play showed more false positives than the other two groups; specifically, they accepted more non-valid instances compared to didactic instruction (p = .05) and the control (p = .02). Lastly, children in both guided play and didactic instruction did not significantly differ in their acceptance of typical and atypical shapes (p's > .30).

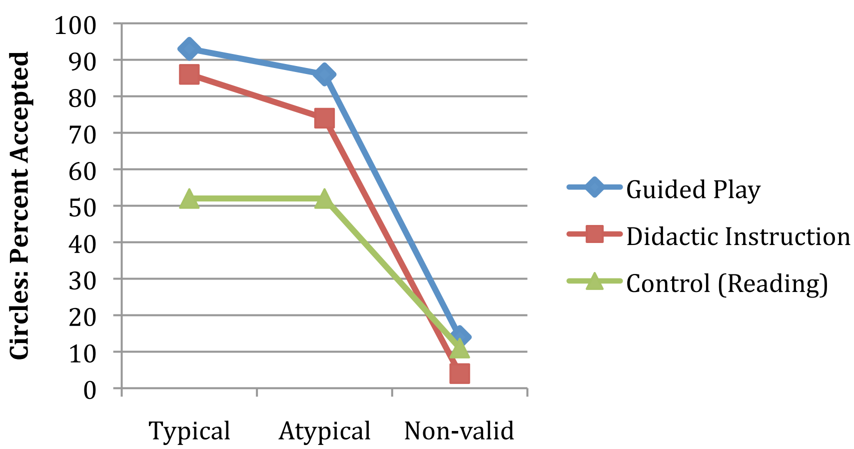


Figure 3. Experiment 1: Mean percentages of circle exemplars accepted in the sorting task by condition

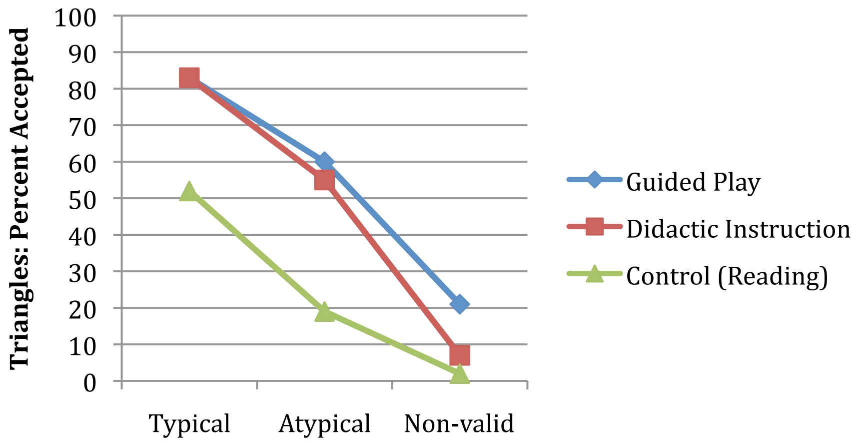


Figure 4. Experiment 1: Mean percentages of triangle exemplars accepted in the sorting task by condition

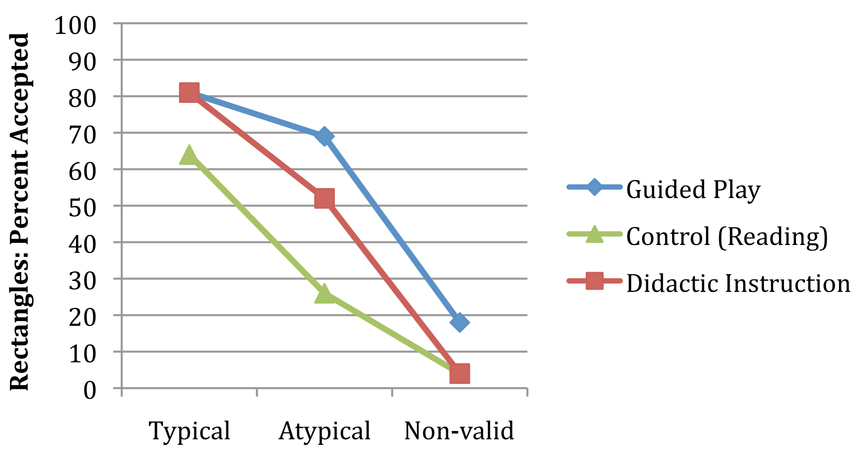


Figure 5. Experiment 1: Mean percentages of rectangle exemplars accepted in the sorting task by condition.

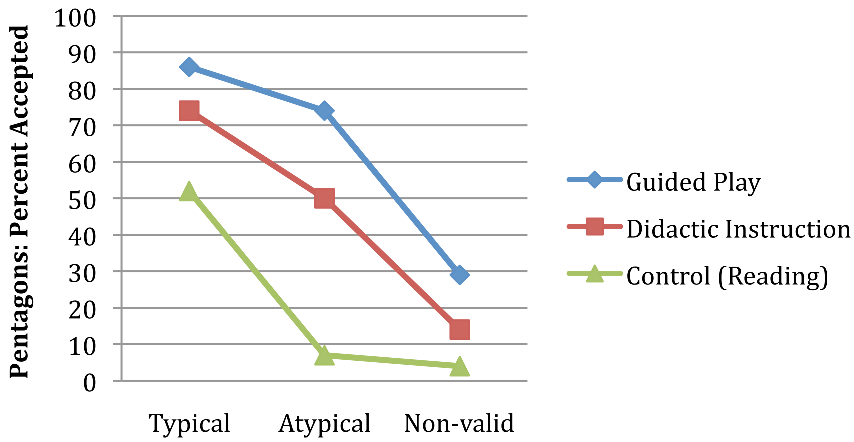


Figure 6. Experiment 1: Mean percentages of pentagon exemplars accepted in the sorting task by condition

Exploratory analyses: Individual shape trends. To understand how differences between training conditions manifest in specific shape concepts, we also explored acceptance patterns *within* each shape category for typical, atypical, and non-valid shapes from the sorting task. A one-way MANOVA with pedagogy as the between-subjects factor (guided play, didactic instruction, & control) was conducted on acceptance rates for 12 dependent variables (typical, atypical, and non-valid variables per shape category).

Pedagogy influenced shape acceptance, *Wilks' Lambda*, $F(24, 56) = 1.62$, $p = .07$, $\eta_p^2 = .41$. As seen in Table 3, follow-up univariate analyses of variance (ANOVAs) indicated guided play significantly influenced children's acceptance of typical, atypical, and non-valid shapes in each shape category while didactic instruction had a significant effect on acceptance of typical circles and triangles and atypical pentagons.

As seen in Figures 3 through 6, both guided play and didactic instruction showed similar acceptance patterns for simple, typical familiar shapes (e.g., circles, triangles);

however, children in the guided play condition showed superior geometric knowledge for two complex shapes (rectangles, pentagons). When looking at means, children accepted 20% more atypical complex shapes than didactic instruction, although this failed to reach significance. Interestingly, children who received shape training through didactic instruction seemed uncertain about atypical complex shape classification, signified by at-chance acceptance rates (~50%) while those in the control condition relied heavily on perceptual similarity.

Embedded shapes task. A multivariate analysis of covariance (MANCOVA) with pedagogy as the between-subjects factor (guided play, didactic instruction, & control) and age and gender as covariates, was conducted on general identification rates for typical and atypical shapes for the embedded shapes task. A main effect for pedagogy was found, *Wilks' Lambda*, $F(4, 70) = 2.69$, $p = .04$; however, when accounting for age and gender, pedagogy did not significantly influence children's identification of typical or atypical shapes, F's$(2, 36) = .42$ and 4.59, respectively, *n.s*.

Discussion

The preliminary study examined the differential impact of two pedagogical styles (guided play, didactic instruction) on children's criterial learning of shapes compared to a control condition (reading activity). In particular, we were interested in seeing whether (a) guided play is a superior pedagogy to didactic instruction in teaching geometric shape concepts, (b) whether didactic instruction was superior to the control condition, and (c) whether shape training experience influenced children's shape knowledge beyond the concrete understanding of shapes common in preschoolers' understanding.

Is Guided Play A Superior Pedagogy?

Correlational and experimental research has shown guided play is often considered a superior pedagogical method compared to other approaches (e.g., Callanan & Braswell, 2006; Marcon, 1993, 1999); however, few have explored the mechanisms that underlie guided play. Using dialogic inquiry and physical engagement as defining pedagogy characteristics, we examined the differential impact of guided play and didactic instruction on preschoolers' developing shape concepts.

We hypothesized children in guided play would show significantly advanced criterial learning than those in didactic instruction. Contrary to our prediction, no significant differences in shape knowledge were found between guided play and didactic instruction on typical and atypical shape acceptance in the sorting task or in the embedded shapes task. Children in guided play, however, accepted more non-valid instances compared to didactic instruction, although this increased acceptance of non-valid forms is below the rate reported in previous research (Satlow & Newcombe, 1998)

Why might children in guided play display an over-generalized acceptance to non-valid forms? Children appear to be transitioning between a reliance on concrete characteristics of shapes to definitional understandings, as shown by an increased acceptance of valid (typical and atypical) *and* non-valid instances. Non-valid instances are particularly telling of the children's dual reliance on both definitional and concrete properties. The non-valid instances share canonical shape elements without meeting the definitional characteristics (e.g., upright triangle with a broken side), suggesting the guided play children have an expanding concept of shape that is still weighted, to some degree, on concrete characteristics.

Three additional possibilities may account for children's increased acceptance of non-valid forms during guided play. First, guided play may prompt children to form multiple cognitive prototypes of shapes rather than learning the definitional properties. Children would be able to match shapes on a wider range of physical attributes, resulting in increased acceptance of typical, atypical, and non-valid instances. Second, some children may extract a shape concept that results in a different acceptance pattern. For example, two children identified shapes with broken sides as 'fake' and all other shapes as 'real.' Additional research should investigate how training influences these cognitive processes in greater detail. Third, children may not really be learning.

Initial interpretation suggests guided play and didactic instruction appear equal in learning outcomes; however, an underlying trend in acceptance patterns suggests guided play may provide a stronger foundation for certain geometric shapes concepts. Guided play promoted higher frequencies of acceptance within each shape category. Furthermore, children in guided play displayed slightly superior shape knowledge for complex shapes (those with more numbers of sides/angles: rectangles, pentagons), although this difference failed to reach significance.

Criterial vs. Concrete Knowledge of Shapes

As hypothesized, children in both guided play and didactic instruction demonstrated criterial learning of geometric shapes compared to children who did not receive shape lessons. They overcame non-canonical appearances and accepted typical *and* atypical instances that possessed criterial shape properties. Although they did not show *complete* criterial understanding of shapes (i.e., 100% acceptance of typical and atypical shapes, 100% rejection of non-valid shapes) the acceptance patterns in the sorting task mimicked the concrete-to-abstract shift in geometric shape understanding demonstrated by early elementary children in prior research (Keil, 1989; Satlow & Newcombe, 1998).

In contrast, those in the control condition displayed concrete knowledge of shapes, with a high rate of rejection across atypical and non-valid shapes. Interestingly, those in the control condition accepted approximately 50% of typical shapes, which is lower than the rate reported in the literature (approximately 80%, Satlow & Newcombe, 1998; see Appendix A). Children's verbalizations and patterns of acceptance across sorting test items suggest that they relied heavily on size and orientation when classifying shapes. Several children rejected all typical shapes that did not *exactly* match the exemplar displayed during the task, reducing the mean to approximately 50%. When these children were removed from the data set, the acceptance rates paralleled those reported by Satlow and Newcombe. This finding highlights individual differences in the concrete nature of children's conceptual understanding of shapes, with some adhering to direct matching while others accepted slight variations in concepts.

We also examined children's ability to generalize their knowledge to a complex embedded shapes task. Contrary to the aforementioned trends, neither guided play nor didactic instruction improved children's identification of typical or atypical shapes in the figure compared to the control. Several reasons may account for the discrepancies between the sorting and embedded shapes tasks. First, children may be more likely to apply new knowledge in a simple, controlled activity compared to a 'real world' context. During the sorting task, children made one-to-one comparisons between the test item (the card to be sorted) and the exemplar. Conversely, the embedded shapes task required children to identify the correct shape among many other instances of valid and non-valid forms as well as other shape types. This may increase the cognitive demand on the child, in which they 'revert back' to their original shape conceptions, as suggested by the similar acceptance rates between the training and the control groups. Second, the longevity of the study may have had an adverse impact on children's identification performance. Anecdotal reports suggest children were sometimes tired or rushed through the embedded shapes task. Lastly, it may be the case that the task is too difficult for preschoolers.

Previous research shows didactic instruction initially fosters stronger academic outcomes compared to playful learning programs (e.g. Karnes etl al., 1983; Miller & Bizzell, 1983a,b; Miller & Dyer, 1975). In contrast, the current study demonstrates that guided play is as equally effective as didactic instruction in promoting criterial shape knowledge. A key question that remains is whether the use of enriched, diverse curricular materials (both typical and atypical shapes) was the operative mechanism underlying learning outcomes for the interventions. This question is explored in Experiment 2.

EXPERIMENT 2

In Experiment 1, children in guided play and didactic instruction show evidence of criterial learning; however, exposure to enriched shape materials may be responsible for guiding children's attention to relevant definitional features of the shapes (Uttal et al., 2009). Evidence suggests children require multiple exemplars, typical and atypical, to move beyond salient perceptual features to more abstract or relational understandings (Clements & colleagues, 1999; Gentner, 2005; Gentner & Medina, 1999; Kuehne, Gentner, & Forbus, 2000; Marcus, Vijayan, Rao, & Vishton, 1999). Thus, the learning outcomes found in Experiment 1 may be due to children's exposure to a greater diversity of shapes exemplars.

The present study expands on Experiment 1 by exploring how diversity of curricular materials (exposure to typical and atypical shapes) influences children's criterial learning of geometric shapes during guided play. In a new guided play condition, children were exposed only to typical exemplars rather than being presented with typical *and* atypical exemplars during the lesson.[8] We compared the learning outcomes of children trained with typical exemplars to children in enriched guided play (trained with enriched, diverse exemplars) and the control condition from Experiment 1. We hypothesized that children trained with only typical exemplars would show significantly less criterial shape knowledge than those trained with enriched, varied curricular materials (guided play condition from Experiment 1). We also predicted that children trained with typical exemplars would display concrete understanding of shapes comparable to those who did not receive shape training (control condition from Experiment 1).

Method

Participants

Eighteen, four- and five-year-old children were recruited from suburban environments in the northeast United States using commercially available mailing lists. The final sample consisted of 14 typically developing children (Mean age = 54.92 months, *SD* = 3.77) with equal numbers of girls and boys. This sample was matched on

[8] The guided play pedagogy was chosen because children (a) performed equally well in the training conditions in the previous study; (b) appeared to enjoy the guided play pedagogy; and, ultimately, (c) time constraints limited our ability to assess didactic instruction with typical exemplars.

gender and age to the guided play and control conditions from the preliminary study. Data from 4, four-year-old children were excluded from analyses due to fussiness (n =1), experimenter error (n = 1), and inattentiveness (n =2). Children were predominantly Caucasian and from middle- and upper-middle class homes.

Materials

Drawing materials. One sheet of paper and the choice of one of five crayons of varying color was available during practice drawings.

Shape training stimuli. Four geometric shapes were chosen for training: circles, triangles, rectangles, and pentagons. Four exemplar training cards were created for each shape category: two typical exemplars (replicas from Study 1) and two new typical exemplars (created using Serif DrawPlus 4.0 software). See Appendix D for the training stimuli (4 exemplars per shape, 16 total exemplars). Typical exemplars represented those that are commonly seen and recognizable. They shared perceptually similar, canonical shape properties (similar angles, orientations) and showed slight variations in size (width, height).

Training: Guided Play Using Typical Exemplars Only

Children were prompted to explore and discover the definitional properties by comparing each exemplar card as described in Experiment 1.

Measures

Children’s shape learning was assessed using the shape sorting and embedded shapes tasks used in Experiment 1.

Procedure

We followed the same instructions and procedure outlined in Experiment 1. We compared children from the typical-only training condition to the enriched guided play and control conditions from Experiment 1.

Results

Data Reduction

Shape Sorting Task. Data reduction methods were the same as those in Experiment 1. We examined children's shape concepts by looking for specific acceptance patterns across typical, atypical, and non-valid shape forms in the sorting task. To determine the extent children's category decisions were guided by visual similarities versus abstract, definitional concepts in the shape-sorting task, we collapsed across shape type and calculated general acceptance rates across typical, atypical, and non-valid exemplars (See Table 4) to test hypotheses. We also calculated acceptance rates for typical, atypical, and non-valid shapes within each shape category to explore training effects on shape concepts that vary in complexity (e.g., simple, familiar shapes = circles; complex shapes = pentagons).

Embedded Shapes Task. For the embedded shape task, we followed similar data reduction methods. We collapsed across shape type to calculate general identification rates for typical and atypical shapes as well as employ the same calculations within shape categories. See Table 4 for acceptance percentages.

Preliminary Analyses

All statistical analyses were conducted using PASW 18.0 software. In order to examine the effect of content experience in guided play, we combined data from the preliminary study with the current data set resulting in three groups: typical exemplar training (new condition), typical and atypical exemplar training or "enriched experience" (preliminary study), and the control (preliminary study).

Table 4

Experiment 2: Mean acceptance rates for shape knowledge tasks

	Shape Sorting Task			Embedded Shapes Task	
	Typical	Atypical	Non-valid	Typical	Atypical
Typical Exemplars[a] (Guided Play)	.76 (.23)	.39 (.33)	.09 (.14)	.47 (.24)	.41 (.27)
Enriched Exemplars[b] (Guided Play)	.86 (.24)	.72 (.35)	.21 (.18)	.50 (.17)	.56 (.23)
Control[b]	.55 (.33)	.27 (.27)	.03 (.05)	.63 (.29)	.43 (.32)

Notes. The table includes data from Experiment 2[a] and Experiment 1[b]. The values represent mean percentages of instances accepted as 'real shapes' in the sorting task and mean percentages of instances identified as 'real shapes' in the embedded shapes task. Values in parentheses are standard deviations.

Prior to analysis, five dependent variables (sorting task acceptance rates for typical, atypical, and non-valid shapes; embedded shapes identification rates for typical and atypical shapes) were examined for fit between their distributions and the assumptions of multivariate analyses. Z-scores were used to identify suspected univariate outliers (> |3.29|) and Mahalanobis distances with $p < .001$ were used to identify multivariate outliers for each variable within group. No outliers were found. As a result, the data set remained unchanged.[9]

A 3 (content experience: typical exemplars, enriched exemplars, and control) X 2 (gender: male, female) X 2 (age: 4 years, 48 – 59 months; 5 years, 60 – 71 months)

[9] Some variables showed signs of kurtosis and skewness (2.00+), nonparametric statistics yielded the same outcomes as parametric statistics. Thus, we reported parametric analyses for ease of interpretation.

multivariate analysis of variance (MANOVA) was performed as a preliminary analysis to assess potential gender and age effects on shape learning across conditions. A total of five between-subject factors were analyzed from the sorting (typical, atypical, and non-valid acceptance rates) and the embedded shapes tasks (typical and atypical identification rates). A main effect for curricular materials was found (*Wilks' Lambda*, $F(10, 52) = 2.70$, $p = .01$) while no effects were found for age or gender (all p's > .38) and no interactions between these factors were found (all p's > .24). Given these findings, we collapsed across gender and age. Sorting and embedded shape task variables were analyzed separately to test hypotheses.

Does Enriched Curricular Materials Influence Criterial Learning?

A one-way MANOVA with curricular materials as a between-subjects factor (typical exemplars, enriched exemplars, and control) was conducted on acceptance rates for typical, atypical, and non-valid shapes for the sorting task. Curricular materials had a significant main effect on shape learning, *Wilks' Lambda*, $F(6, 74) = 3.28$, $p < .01$, $\eta_p^2 = .21$. Follow-up univariate analyses indicated type of exemplar experience significantly influenced children's acceptance of typical, atypical, and non-valid shapes in the sorting task, F's(2, 39) = 4.51 ($\eta_p^2 = .19$), 7.77 ($\eta_p^2 = .29$), and 4.59 ($\eta_p^2 = .19$), respectively, p's < .02.

Pairwise comparisons with Bonferroni corrections revealed children learning with typical exemplars demonstrated less criterial learning compared to those who were exposed to enriched materials (trained with both typical and atypical exemplars). They did not significantly differ in their acceptance rates for *typical* shapes in the sorting task as those trained with enriched content; however, they accepted fewer *atypical* ($p = .03$)

and marginally fewer *non-valid* shapes (p = .08) than those trained with enriched content. No significant differences were found between children trained with typical exemplars alone and those in the control condition across typical, atypical, and non-valid shapes (all p's > .16).

Additionally, curricular materials had no main effect on shape identification in the embedded shapes task, *Wilks' Lambda*, $F(6, 74) = 3.21$, *n.s.*

Table 5

Experiment 2: Univariate ANOVAs for individual shape trends by exemplar type and condition

Shape Category	Exemplar Type	ANOVA	Significant Pairwise Comparisons[a,b]
Circles	Typical	$F(2, 39) = 4.96, p < .05$	EGP > C
	Atypical	$F(2, 39) = 4.23, p < .05$	EGP > TGP & C
	Non-valid	$F(2, 39) = .64$, *n.s.*	--
Triangles	Typical	$F(2, 39) = 3.67, p < .05$	EGP > C
	Atypical	$F(2, 39) = 4.61, p < .05$	EGP > TGP & C
	Non-valid	$F(2, 39) = 5.45, p < .01$	EGP > C
Rectangles	Typical	$F(2, 39) = 1.04$, *n.s.*	--
	Atypical	$F(2, 39) = 3.50, p < .05$	EGP > C
	Non-valid	$F(2, 39) = 2.10$, *n.s.*	--
Pentagons	Typical	$F(2, 39) = 6.45, p < .01$	EGP & TGP > C
	Atypical	$F(2, 39) = 11.88, p < .001$	EGP > C
	Non-valid	$F(2, 39) = 4.76, p < .05$	EGP > C

[a] TGP = Typical Exemplar Guided Play, EGP = Enriched Guided Play, C = Control

[b] Significant at p < .05 with Bonferroni corrections

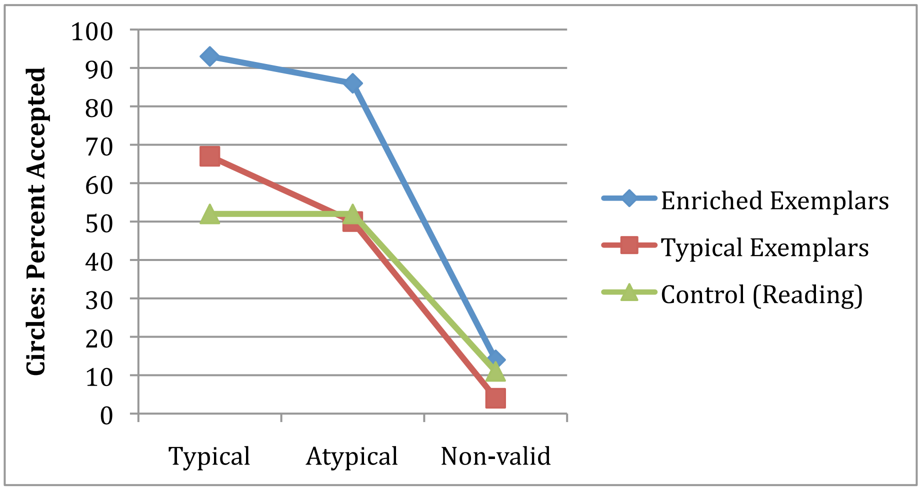


Figure 7. Experiment 2: Mean percentages of circle exemplars accepted in the sorting task by condition

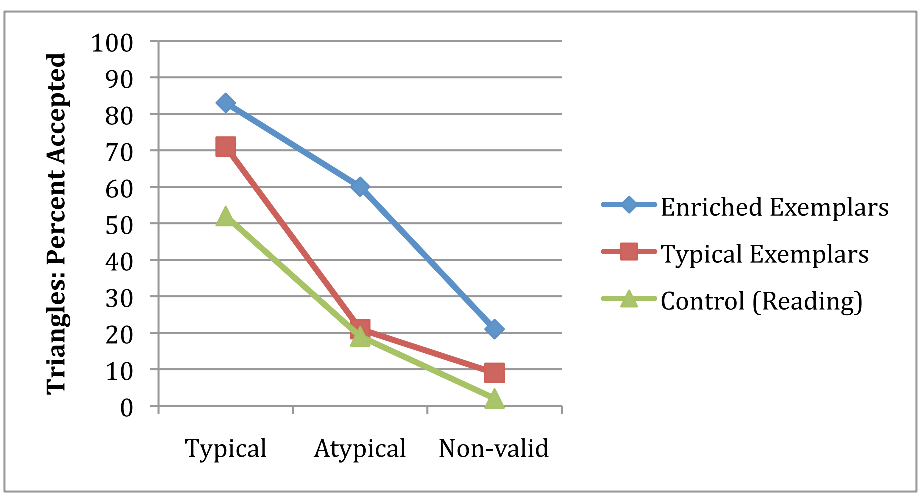


Figure 8. Experiment 2: Mean percentages of triangle exemplars accepted in the sorting task by condition

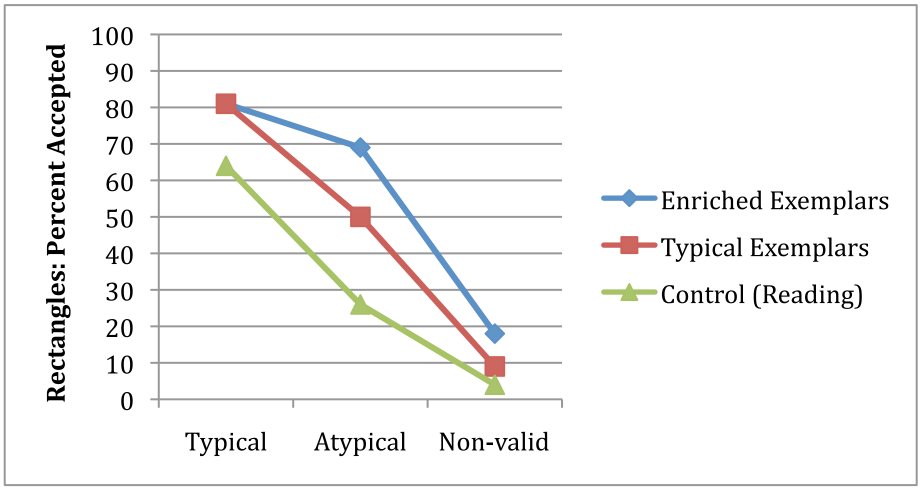


Figure 9. Experiment 2: Mean percentages of rectangle exemplars accepted in the sorting task by condition

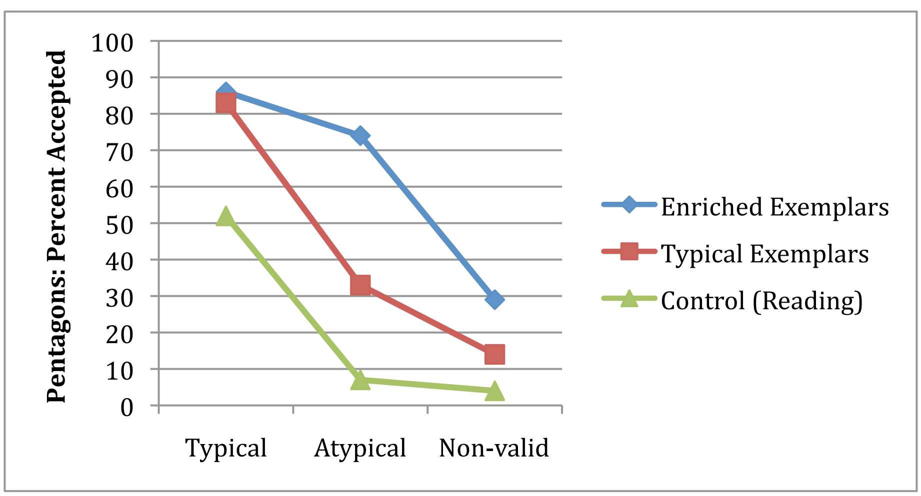


Figure 10. Experiment 2: Mean percentages of pentagon exemplars accepted in the sorting task by condition

Individual Shape Trends

To understand how differences between conditions manifest in specific shape concepts, we also explored acceptance rates for each of the four geometric shapes in the sorting task. A one-way MANOVA with curricular materials as a between-subjects factor was conducted on acceptance rates for 12 dependent variables (typical, atypical, and non-valid variables per shape category). A main effect for curricular materials was found, *Wilks' Lambda*, $F(24, 56) = 2.97$, $p < .001$, $\eta_p^2 = .56$. As seen in Table 5, children in enriched guided play showed significantly higher frequencies of acceptance for *atypical* circles and triangles over those trained with typical exemplars; however, rates of acceptance were similar between the training groups for all other shapes. Additionally, children trained with typical exemplars accepted more typical pentagons than those in the control condition, but did not significantly differ on other shape forms.

As seen in Figures 7 through 10, several interesting trends emerged across familiar shapes (circles, triangles) and novel, complex shapes (rectangles, pentagons). First, children trained with typical exemplars accepted 10-16% more typical, familiar instances (circles and triangles) than those in the control group, although these failed to reach normative levels of statistical significance. Their acceptance rates for atypical and non-valid instances were equivalent. Second, the typical-only training group's acceptance rates for complex shapes were higher for typical and atypical instances compared to the control. Children accepted significantly more typical pentagons than the control while the rest of the findings were trends.

Discussion

The present study expands on Experiment 1 by exploring how diversity of curricular materials (exposure to typical and atypical shapes) influences children's criterial learning of geometric shapes during guided play. As hypothesized, children trained with typical exemplars showed significantly less criterial shape knowledge than those trained with enriched curricular materials (from Study 1); in particular, they accepted fewer atypical shapes than those in enriched guided play. These findings suggest that enriched curricular experience accounts for a significant proportion of learning in guided play. This likely extends to didactic instruction as well since they were exposed to the same enriched curricular materials and no significant differences were found between training groups.

We also predicted children trained with typical exemplars would display concrete understanding of shapes comparable to those in the control condition. Indeed, children showed similar acceptance patterns as the control condition; they displayed higher average acceptance rates of typical shapes and rejected more atypical and non-valid instances. They also showed slightly higher acceptance of typical shapes than those in the control, most likely because they were exposed to a broader range of typical exemplars during training. We also examined children's ability to generalize new shape knowledge to a complex embedded shapes task. Similar to the findings in Experiment 1, children trained with typical exemplars did not improve identification of typical or atypical shapes in the embedded shapes task compared to the control.

Exploratory analyses of individual shapes revealed a slight divergence in acceptance patterns from the control group for atypical, complex shapes during the shape sorting task. Children trained with typical exemplars accepted more atypical rectangles and pentagons than the control group, yet this also failed to reach significance. It appears that guided play training may have helped children expand shape concepts; however, pedagogy was not enough to help children look past salient perceptual features to learn the criterial knowledge of shapes. These findings suggest that both curricular materials and pedagogy are important for learning geometric shape properties.

General Discussion

The findings from the Experiments 1 and 2 provide an initial look into how pedagogical and curricular materials influence shape learning. Experiment 1 suggests both guided play and didactic instruction promote criterial shape concepts when children are given enriched curricular materials. Although guided play and didactic instruction generally appeared equal in learning outcomes, inspection of individual shape acceptance rates suggest that the answer is more complex. Children in guided play accepted a higher frequency of typical, atypical, and non-valid shapes, similar to the transition between a concrete and abstract understanding of shape described in the literature (e.g., Keil, 1989; Satlow & Newcombe, 1998). While they accepted more non-valid shapes (21%), this was below the rate reported in previous studies (Satlow & Newcombe, 1998). Furthermore, different response patterns emerged between the two training groups for more complex shapes (or those with greater numbers of sides/corners). Children in didactic instruction showed uncertainly in classifying atypical rectangles and pentagons (signified by 50% rejection rates) while those in guided play appeared accepted the majority of those in the category.

We also explored how enriched shape experience influenced the learning process during guided play. When materials were limited to ‘typical’ shape experiences (Experiment 2), children demonstrated a ‘concrete’ concept of shape regardless of instruction, suggesting carefully planned curricular materials plays a key role in facilitating shape knowledge. It must be noted, however, that even when children were trained with typical exemplars, there was some evidence of expanding shape knowledge (but not to the degree of those trained with enriched content experience). Taken together, these findings suggest that both curricular materials and pedagogy are important for learning geometric shape properties.

Although these results are promising, several limitations exist in the studies. First, children in guided play took, on average, one minute longer during the training session than those in didactic instruction, potentially gaining the advantage of longer exposure to training stimuli. We do not feel that this had a substantial impact on the results in that children’s verbalization of shape properties and physical drawing ability accounted for the majority of the time difference (e.g., time taken to pick up the crayon, steady the hand, and draw, etc). Second, children’s fine motor movement was functionally limited, making it difficult for them to draw straight lines and angles. This made it problematic to monitor children’s practice drawings for definitional understanding. Third, although children were randomly assigned in both studies, this process may have resulted in differences between conditions in general shape knowledge and educational experience. Fourth, other motivational factors may account for the findings in the study, including interest or perceived meaningfulness of the experience. Fifth, additional control studies can further examine the unique contribution of enriched curricular materials on shape learning. (e.g., exposure to enriched materials without pedagogical methods, such as enriched free play). Sixth, we examined three familiar shapes and one novel, complex shape (pentagon) in the current studies. Familiarity with the shape categories in the task may have facilitated learning across conditions, resulting in no significant differences between training groups. However, the difference in response patterns for pentagons suggest guided play and didactic instruction may foster different learning outcomes when the task is more complex. The following study seeks to further tease apart the mechanisms of guided play while controlling for some of these limitations.

CHAPTER 3

EXPERIMENT 3

In Experiment 3 we directly explored the effectiveness of didactic instruction and two playful learning pedagogies, guided play and enriched free play, on children's criterial learning. We made four changes in the methodology in light of the observed trends and limitations in the previous studies. First, we replaced circles with an additional *novel,* complex shape, resulting in a more balanced design with two familiar, moderately complex shapes (triangles, rectangles) and two novel, complex shapes (pentagons, hexagons) to control for shape familiarity and complexity. Second, we replaced shape drawing with a shape construction task (i.e., children create shapes from pre-cut wax sticks) to control for variability in children's fine motor control and drawing skill and equalize training time across conditions. Third, children were recruited from two full-time preschools in the same geographic region with similar socio-economic backgrounds. The conditions were matched on age, gender, and preschool attendance to minimize potential demographic effects. Fourth, the introduction to shape training was changed to maximize initial and long-term interest in the study. Lastly, we examined a longer-term impact of learning with a follow-up assessment approximately seven days after the initial training period.

Comparing Guided Play and Didactic Instruction

In light of the reviewed literature and our previous research findings, we explored two predictions. Our first hypothesis concerned the differential impact of guided play and didactic instruction on children's criterial learning of more complex shapes. Our previous research demonstrates that preschoolers learn equally well in guided play and didactic instruction; however, some evidence suggests that guided play promoted stronger criterial knowledge than didactic instruction for novel, complex shapes. We suggest that guided play, an active, child-centered pedagogy, helps direct children's attention, extract conceptual information, and prompts deeper conceptual processing of novel, more complex shapes compared to didactic approaches. Thus, we predicted that children in guided play would demonstrate superior criterial learning of shapes in the new task compared to those in didactic instruction, particularly on the novel shapes.

Examining the Role of Dialogic Inquiry in Playful Learning Approaches

A review of the extant literature shows that the definition of a child-centered, playful learning pedagogy is relatively ambiguous, encompassing a variety of teaching methodologies (Moyles, et al., 2002). In the current study we begin an initial exploration in how interactive adult guidance, in the form of dialogic inquiry, influences the learning process beyond exposure and engagement with curricular materials. In the current study we compared guided play to an enriched free play condition. Guided play included both dialogic inquiry *and* physical engagement with curricular materials while enriched free play represented physical engagement with curricular materials without adult guidance. By directly comparing these two conditions, we *begin* to tease apart the impact of dialogic inquiry on the learning process. Additionally, the enriched free play condition illuminates how a non-interactive and non-directive teacher role, one sometimes found in child-centered learning environments, impacts children's acquisition of criterial shape concepts (Wood, 2009).

Our second prediction focused on the adult's role in facilitating criterial learning when children are engaged with the curricular materials. A variety of intervention studies have shown that when adults enrich children's play areas with toys and materials related to academic knowledge, children naturally incorporate the academic concepts into their activities without adult active guidance (e.g., Arnold, Fisher, Doctoroff, & Dobbs, 2002; Griffin & Case, 1996; Griffin, Case, & Siegler, 1994; Whyte & Bull, 2008). Cook (2000), for example, found when children's pretend play environments were enriched with artifacts emphasizing number symbols, children engaged in more talk and activity related to mathematical concepts. This may promote higher frequencies of academically relevant play behavior, which has also been linked to academic achievement (e.g. Ginsburg, Lee, & Boyd, 2008; Caldera, McDonald Culp, Truglio, Alvarez, & Huston, 1999; Hirsch, 1996). This suggests that the enrichment of play areas with learning-oriented materials may facilitate new learning. To our knowledge, no studies have examined how enriching children's free play experiences directly promote criterial learning of geometric shapes.

A growing body of evidence, however, suggests that children's engagement with enriched and well-planned curricular materials alone does not guarantee learning and transfer of ideas, particularly for early mathematic understanding (e.g., Brown, McNeil, & Glenberg, 2009; Uttal et al., 1997; Uttal et al., 2009; Uttal, Liu, & DeLoache, 1999). Sarama and Clements (2009) contend that when children play with learning materials/objects without guidance from a teacher, it is unlikely to relate to or facilitate the *intended* learning objective (e.g., using blocks to create a design is less likely to result in learning numeration). Others suggest that the very nature of the materials impede learning. According to Kaminski, Sloutski, and Heckler (2009), everyday concepts like "chair" are grounded in perceptual similarity and are learned quickly with exposure; however, mathematical ideas have criterial definitions based on a relational structure that is often overlooked when using materials with additional irrelevant features (e.g., colors, texture, different materials). For example, children may erroneously learn that blocks refer to large, red wooden toys rather than learning that all blocks have six sides. This suggests that children likely need additional adult guidance beyond enriched curricular materials to help children hone in on relevant features for criterial shape learning (e.g., Bruner, 1966). Thus, we hypothesized children in guided play will show better criterial learning compared to those engaged in enriched free play.

Operational Definitions of Key Constructs

Similar to our previous studies, *didactic instruction* was characterized as a passive learning pedagogy, in which the experimenter communicates shape information directly to the child (absence of dialogic inquiry and physical engagement). Conversely, *guided play* was conceptualized as a child-centered learning pedagogy that promotes learning through adult-interactive guidance. The teacher facilitates the child's discovery of the key concept via dialogic inquiry and by encouraging physical engagement with the curricular materials. Lastly, *enriched free play* represented an active pedagogy that prompts physical engagement with curricular materials but without dialogic inquiry or instruction on criterial elements of shapes. The word "enriched" denotes children were exposed to the same enriched curricular materials as the training conditions; that is, they were exposed to typical and atypical exemplars for each shape category.

The key constructs and their defining criteria were derived from the extant literature in an effort to maintain validity across intervention and experimental research. *Dialogic inquiry* represented a learning experience that is initiated and scaffolded by the experimenter (Stipek, 2004; Wells, 1999). Each child was presented with a dilemma during the shape lesson ('what makes all of the shape cards a particular shape?') and asked questions that prompted the child to compare across shape stimuli and discover of the criterial properties of the shape category. *Physical engagement* refers to the child's ability to physically touch/explore/manipulate the learning materials/stimuli during the shape lesson (Golbeck, 2001; Lillard & Else-Quest, 2005; Marcon, 2002; Miller & Bizzell, 1983b). During shape training conditions, each child was encouraged to count the distinguishing feature of each shape exemplar (e.g., the sides and angles) and create two novel instances of the shape to facilitate identification and representation of new shape concepts (Clements, Wilson, & Sarama, 2004).

Lastly, one can argue that once children learn the criterial or defining characteristics of shapes (e.g., triangles = 3 sides, 3 corners), they are operating on a more conceptual, rather than perceptual, level of understanding (Keil, 1989; Gentner, 2005). Thus, *criterial learning* refers to the identification of shapes by their definitional properties ("abstract concepts") in two shape tasks as opposed to identifying shapes by their featural similarities (i.e., "concrete/perceptual" concepts).

Method

Participants

Forty, four- and five-year-old children were recruited from two preschools in suburban environments in the northeast United States. Teachers and administrators distributed recruitment packets to families containing a letter of introduction, time and dates of the experiments at the school, consent forms, background questionnaires, instructions, and a return envelope (See Appendix E). Additionally, the experimenter recruited families in person during one recruitment day per school to answer parents' questions and maximize participation. The completed recruitment packets were returned in an envelope via a private drop box in the administrator's office and collected by the experimenter.

The final sample consisted of 38 typically developing children with the following distribution across three conditions: 12 in guided play (M_{age} = 56.70 months, *SD* = 6.26; 6 males), 14 in didactic instruction (M_{age} = 57.55, *SD* = 7.39; 7 males), and 12 in exploratory play (M_{age} = 55.46, *SD* = 6.60; 6 males). Date from two four-year-old children were excluded from analyses due to inattentiveness (2 females from didactic instruction). Children were predominantly Caucasian and from middle- and upper-middle class homes.[10] Three children, distributed equally across conditions, did not complete the second phase of the study due to extended illness or absence.

Materials

Shape construction sticks. Store-purchased wax-covered strings (Bendaroos) were used to construct shapes during training because they had the ability to stick together to create angles/corners of shapes and were easily maneuverable (e.g., picked up, transported across a table, etc). Strings were straightened into 'sticks' and cut into three sizes: small (2.5"), medium (4"), and large (6"). All wax sticks were the same color. A diagram identifying eight novel shape construction activities (two per shape) was created to ensure the experimenter provided the same practice experiences across conditions. The diagram was only visible to the experimenter.

[10] We chose not to collect additional demographic data (e.g., income, age, parents' education levels) since such questions may limit participation, particularly if they would have to report information via phone or by drop box.

Shape Training Stimuli. Four geometric shapes were chosen for training: triangles, rectangles, pentagons, and hexagons. The shape training stimuli were replicated from Study 1 with the exception of the new hexagon category. Hexagons were chosen as a novel, complex shape primarily because the rule-based properties are visually identifiable and within preschoolers' counting range. The hexagons were created in the same manner as the original stimuli. Two typical and two atypical exemplars were created using Serif DrawPlus 4.0 software (4 exemplars per shape, 16 total exemplars; See Appendix F). Each exemplar was printed on a 5" x 5" yellow laminated card with a piece of velco attached to the back. Typical exemplars represented those that are commonly seen and recognizable. They shared perceptually similar, canonical shape properties, were displayed in upright orientations, and were medium to medium/large in size (e.g., each filled at least of half of the display space). Atypical hexagons were equally valid shape forms but not commonly seen. For example, an equilateral, upright hexagon is 'typical' while an irregular hexagon is atypical. These shapes had noticeably skewed orientations, contained exaggerated side lengths (e.g., some sides were three times as long as others), or were an exaggerated size (e.g., each filled very little or almost all of the display space).

Enriched Free Play Shape Stimuli. A second set of exemplar cards was created using the same methodology as described previously. To maximize their perceived playfulness and enhance children's interaction with the stimuli, we created shape cards by cutting each shape along its outer edges (the black line of the shape remained clearly visible). Velcro was attached to the back of each card so that it could be affixed to an 11 x 11 inch felt-covered board.

Hexagon Stimuli (for Sorting Task). In order to establish a working set of hexagon figures to be used with children in the sorting task, we followed the same procedure Satlow and Newcombe (1998) used to create their stimuli. A larger pool of instances of typical, atypical, and non-valid instances of hexagons were created using Serif Drawing software. Eleven instances demonstrated a range of typicality similar to the characteristics found in the other sorting task items (i.e., variations in size and orientation). Four non-valid instances of hexagons were included, two demonstrating a lack of closure and two with an incorrect number of sides.

The instances were presented to 18 adults on a computer using Microsoft Powerpoint software. Adults examined each shape individually for approximately five seconds and were asked to classify them on an answer sheet (e.g., "Please identify each shape as a valid or non-valid hexagon"). Adults rated 97% of the figures accurately, indicating that the stimuli satisfactorily represented each shape and that violations of shape definition were easily discernable. Adults were then asked to make additional judgments regarding the typicality of each of the 11 valid hexagons using a 7-point Lickert scale (1 = less typical, 7 = more typical). Ratings of three highly typical and three least typical instances of each shape differed significantly and were used as test times (*t*-tests, *p*'s < .02). The final hexagon test items consisted of 10 total instances: 3 typical, 3 atypical, and 4 non-valid.

Pedagogical Conditions

The experimental conditions exposed children to the same stimuli and curricular materials knowledge but varied on two properties: (1) the use of dialogic inquiry, and (2) physical engagement of the shapes via physical touch of the training exemplars and shape construction practice. A general description of the three pedagogical conditions follows below

Guided play. Children were taught criterial properties of shapes by scaffolded exploration and discovery. The experimenter introduced the child to the experiment by saying that they were going to discover the secret of the shapes. The experimenter and the child put on make-believe detective hats after which she laid out four exemplar training cards on a green felt board (typical exemplars first) and said,

> Did you know all shapes have secrets? Today I need your help in discovering the secret of the shapes. There are many different types of <shape name>, some are different sizes, some lay on their sides, and some look funny. Although these four <shape name> look different, they are all REAL <shape name>. What's their secret?"

If a child was quiet or unable to identify the properties on his/her own after initial exploration (approximately 10 seconds), the experimenter scaffolded the child's discovery through leading questions (e.g., "Hmmm… I think this has some sides. How many sides are there?"). During this time, the child was prompted to count and touch the properties of each shape exemplar. After discovering the properties across each exemplar, children were asked to help the experimenter recall the shape's distinguishing properties (e.g., "I think I got it… so all of these REAL <shape name> have…. What was it again?").

Finally, children were encouraged to create two novel instances of the recently learned shape using the construction sticks. The experimenter laid sticks in the general shape figure (e.g., in a triangle form but with approximately 1 inch gaps between the sticks). Previous pilot testing showed children had difficulty creating shapes if the sticks were given to them in a pile or row. If children were unable to create the shape, experimenters provided scaffolded assistance (e.g., how many corners do you need?). The experimenter asked children to describe how the newly created shapes were similar to those on the card (e.g., “Great job! So what makes these real triangles like the others?”) This process was repeated for each shape category.

Didactic instruction. Children passively discovered the geometric shape attributes by watching and listening to the experimenter. The experiment was introduced and set up in the same manner as the guided play condition with the exception of the stimuli being moved approximately five inches away from the child. Pilot data revealed close proximity to the stimuli encouraged touching/interaction behaviors even with explicit instructions not to do so. This distance minimized physical contact with the shapes while maintaining distinguishable features.

The experimenter introduced the child to the experiment by saying that she was going to discover the secret of the shapes for the participant. The experimenter put on make-believe detective hat after which she laid out four exemplar training cards on a green felt board (typical exemplars first) and said,

> Did you know all shapes have secrets? Today I am going to discover the secret of the shapes for you. There are many different types of <shape name>, some are different sizes, some lay on their sides, and some look funny. Although these four <shape name> look different, they are all REAL <shape name>. Watch me very carefully, ok?”

If the child attempted to help, the experimenter asked the child to ‘be the teacher’ and watch quietly to make sure she did not do anything incorrectly. Children were comfortable with this role and rarely talked or interacted as the experimenter went through the training. The child listened to the experimenter identified the definitional properties on each exemplar card. After shape training, the experimenter repeated the shape properties (e.g., "See, I got it! Triangles are made of three corners and three sides!") and proceeded to create two novel examples of the shape using construction sticks. Lastly, the experimenter reiterated how the newly created shapes and shape exemplars were similar (e.g., "Yep, these are REAL triangles, they have 3 sides and 3 corners just like the others on the cards!").

Enriched free play. Children were exposed to the same shapes as the other conditions through a free, exploratory play activity. Prior to the start of the study, the experimenter placed a green felt board on the table and organized the cards in one large group. The cards were organized by their respective shape categories within this larger group (e.g., triangle cards grouped together) to enhance children's natural, within-category comparison when looking over the cards.

Upon entering the room, the experimenter introduced the child to the activity by saying:

> I have some shape cards to play with. They are REAL triangles, rectangles, pentagons, and hexagons. This is a really neat game. You can create a design on the board with the shapes, tell a story with the shapes, or play with them in any way you like! You can play with the cards while I finish writing over here, okay?

If they did not start interacting with the cards or asked for help, the experimenter suggested that they create a design (e.g., a face). Children were given seven minutes to play with the shapes.

After shape play, the experimenter removed the shape cards from sight and laid out 12 construction sticks, four of each size. The experimenter prompted construction play by saying, for example, "I have a new activity for you. Here are some sticks. You can use them in many ways— you can connect them together and make designs or do whatever you want with them! Would you like to play with them?" Children were given six minutes to play with the construction sticks in any way that they wished.

This condition effectively promoted naturalistic, physical engagement with the shape cards and construction sticks without guidance toward learning definitional properties. Only one child did not use the allotted time for each task (shape play = ~5.50 minutes, construction play – 7 minutes).

Measures

Shape-sorting task. To assess shape knowledge, children were asked to complete a shape-sorting task (adapted from Satlow & Newcombe, 1998). In this task, children were presented with *novel* exemplars of triangles, rectangles, pentagons, and hexagons (see Appendix G), with each shape presented individually on white 5" x 5" laminated cards. The first three shapes were replicated from Study 1 with the addition of the hexagons (see previous section under materials for hexagon construction and validation). Children saw three typical, three atypical, and four non-valid exemplars of each shape (10 exemplars of each shape type). Typical and atypical forms follow the same guidelines described previously. Non-valid shapes represented forms that did not adhere to a specific geometric definition, with two demonstrating a lack of closure and two with an incorrect number of sides (circles had either one or two straight "flattened" sections).

Each participant worked individually with the experimenter and a handheld puppet to complete the sorting task. The child was introduced to Leelu the Ladybug, "a very picky bug who loves shapes, but only REAL of shapes." The experimenter told the child a story to facilitate shape sorting during the task:

> As Leelu was flying around the other day, she found cards with shapes on them, some are real shapes and some are not. She needs help sorting them. Would you like to help? We need to put all the *real* shapes in her ladybug box (experimenter points to a red and black box) and throw away and fake shapes go in trashcan (experimenter points to a trashcan). Remember, she is really picky and only likes *real* shapes.

For each shape, the child was first shown one model and told, for example, "This is an example of a *real* triangle to help you. Remember, there are many real triangles that are big and small, different colors, and even turned around! This is just *one* example of a *real* triangle." [11] The model was then attached to the ladybug box with velcro and remained on display. Each model was a typical instance of the shape but not identical to any of the original training or test items.

Next, the experimenter placed one test card in front of the child and stated, for example, "Look at this carefully. Is this a real triangle or a fake triangle?"<*pause for response*> "Why do you think so?" Each card was displayed for approximately 10 seconds. Children's comments confirmed that they understood the procedure and attended to the perceptual details of each figure (e.g., "this is fake because it is broken here… so it goes in the trashcan"). The sorting task proceeded through triangles, rectangles, pentagons, and hexagons using the same instructions. The test cards were presented in pre-determined randomized order within each shape type and each child sorted all of the shape stimuli. The experimenter could not see the test item as it was displayed to the child.

Embedded shapes task. This task was designed to assess geometric shape knowledge transfer to a complex shape identification task (see Appendix H). Typical and

[11] The original shape-sorting task by Satlow and Newcombe (1998) used two model cards during the sorting task. Pilot testing showed similar results between one and two cards. The former was chosen as a stronger test of conceptual knowledge.

atypical shapes were embedded in a familiar figure. This task was adapted from the previous studies in two ways. First, two butterflies and an additional flower was added in the picture to represent typical and atypical hexagons. Second, invalid or incomplete shapes were removed from the original picture since children rarely identified these shapes and we also wanted to maintain similar amounts of white space around the shape images. This limits our ability to make direct comparisons between the embedded shape task findings across the dissertation studies.

To ensure children adequately examined the picture and all of its components, the experimenter first asked the child to describe the drawing (e.g., “What is this a picture of?” Most common response: “A house”). Next, the experimenter pointed to individual images in the picture and asked the child to label them (the door, windows, roof, chimney, chimney smoke, front steps, sun, clouds, flowers, grass, fence, butterflies).

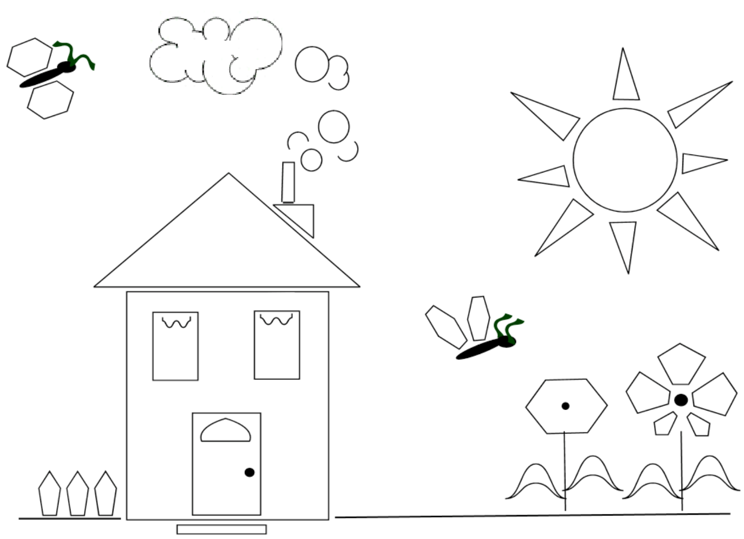


Figure 11: Experiments 3: Embedded Shapes Task

Children were then instructed to find the 'real' shapes for Leelu the Picky Ladybug. For each shape, the child was presented with a new copy of the picture and instructed to point to the real shapes. This required children to look beyond the 'gestalt' view of the image, break down the picture into components, and extract the valid shape instances that adhere to their definitional properties. This test of shape knowledge is similar to embedded shape tasks used previously in the literature (e.g., Clements, Swaminathan, Hannbal, & Sarama, 1999; Razel & Eylon, 1991).

Procedure

The study was conducted in a private room at the preschool. Children were randomly assigned to one of three conditions: guided play, didactic instruction, or enriched free play. The experimenter sat directly across from the child during training and testing. Shape training proceeded in the following order: triangles, rectangles, pentagons, and hexagons. Four exemplar cards were affixed with velcro to an 11 x 11 inch board covered in green felt which was displayed on a table in front of the child. Each exemplar was displayed in a set order and according to a pre-specified orientation (i.e., a small mark on the back of each card indicated the 'top' of the shape card for consistency in presentation). The experiment proceeded according to the assigned pedagogical methodology. After shape training or enriched free play, children completed the shape sorting and embedded shapes tasks. The experiment took approximately 28 minutes to complete (shape lessons/play = 13 minutes; Sorting task = 10 minutes; Embedded shapes task = 5 minutes).

Special efforts were made to ensure children were exposed to the same experiences and content knowledge in the conditions. In the two training conditions, children were exposed to the same exemplars, the same shape property information, and the construction sticks were laid out in the same orientation. During didactic instruction, the experimenter slowed verbalizations during shape descriptions (while maintaining a naturalistic tone), feature counting, and shape construction time to approximate guided play duration. In the enriched free play condition, children were exposed to the same shape exemplars and heard the same shape names as the other conditions. Furthermore, the play condition children were exposed to the shape cards and construction sticks for approximately the same aggregate time frame as the other experimental conditions. We were unable to video record the experiment in the preschools, so a timer was used to monitor training time across conditions. Even with these controls, the guided play condition took approximately one minute longer than other conditions during shape construction practice, primarily because of their desire to get the sticks to adhere together or difficulty getting the sticks to line up perfectly.

Children were asked to return one week after initial training and assessment, with the average latency between time 1(T1) and time 2 (T2) being 7.22 days (*SD* = .68). During T2, all children were first prompted to recall the activities from the first session (e.g., "Do you remember what activities we did last time?") prior to the start of the study. Next, to maximize interest and participation during T2, children were introduced to the study in the following manner:

> Do you remember Leelu the Ladybug? She was so excited about the shape cards and pictures you colored for her! She played with them over

> the weekend but she was so excited that she dropped them and mixed them up! Can you help her sort them again?

Next, children were asked to complete the embedded shapes task. T2 took approximately 15 minutes to complete.

Results

Data Reduction

Shape Sorting Task. Data reduction methods were the same as those in the previous studies. We examined children's shape knowledge by looking for specific acceptance patterns across typical, atypical, and non-valid shape forms in the sorting task. To determine the extent children's category decisions were guided by visual similarities versus abstract, definitional concepts in the shape-sorting task, we collapsed across shape type and calculated general acceptance rates across typical, atypical, and non-valid exemplars (See Table 6) to test hypotheses. We also calculated acceptance rates for typical, atypical, and non-valid shapes within each shape category to explore training effects on shape concepts that vary in complexity (e.g., familiar, moderately complex shapes = triangles, rectangles; novel, complex shapes = pentagons, hexagons).

Embedded Shapes Task. For the embedded shape task, we followed similar data reduction methods. We collapsed across shape type to calculate general identification rates for typical and atypical shapes as well as employ the same calculations within shape categories. See Table 6 for acceptance percentages for both tasks.

Table 6

Experiment 3: Mean percent of shapes (SD) accepted across exemplar type for shape knowledge tasks during Time 1 and Time 2

	Shape Sorting Task			Embedded Shapes Task	
	Typical	Atypical	Non-valid	Typical	Atypical
Time 1					
Guided Play	.96 (.10)	.79 (.25)	.14 (.19)	.58 (.20)	.65 (.26)
Didactic Instruction	.71 (.25)	.34 (.30)	.09 (.10)	.53 (.23)	.43 (.23)
Enriched Free Play	.53 (.19)	.14 (.20)	.07 (.14)	.52 (.25)	.30 (.19)
Time 2					
Guided Play	.92 (.20)	.80 (.31)	.08 (.15)	.76 (.16)	.67 (.27)
Didactic Instruction	.72 (.22)	.42 (.30)	.18 (.16)	.54 (.23)	.50 (.25)
Enriched Free Play	.50 (.28)	.11 (.19)	.09 (.16)	.56 (.21)	.32 (.22)

Preliminary Analyses

All statistical analyses were conducted using PASW 18.0 software. Prior to analysis, 10 dependent variables (sorting task acceptance rates for typical, atypical, and non-valid shapes during T1 and T2; embedded shapes identification rates for typical and atypical shapes during T1 and T2) were examined for fit between their distributions and the assumptions of multivariate analyses. Z-scores were used to identify suspected univariate outliers (> |3.29|) and Mahalanobis distances with $p < .001$ were used to identify multivariate outliers for each variable within group. No outliers were found. As a result, the data set remained unchanged.[12]

A 3 (pedagogy: guided play, didactic instruction, enriched free play) X 2 (gender: male, female) X 2 (age: 4, 5) X 2 (time: T1, T2) mixed-measures MANOVA was performed as a preliminary analysis to assess potential gender and age effects on shape learning and retention. Condition, gender, and age were between subjects; time was within subjects.

A main effect for pedagogy was found (*Wilks' Lambda*, $F(10, 38) = 4.57$, $p = .001$, $\eta_p^2 = .55$) while no effects were found for age or gender (all p's > .42) and no interactions between these factors. Additionally, there was no significant effect of time on children's retention of shape concepts and no interactions between factors were found (all p's > .47). Given these findings, we collapsed across gender and age. Sorting and embedded shape task variables were analyzed separately to test hypotheses.

Which Pedagogy Promotes Superior Criterial Learning of Shapes?

Sorting Task. A 3 (pedagogy: guided play, didactic instruction, & exploratory play) X 2 (time: T1 & T2) mixed-measures MANOVA was conducted on acceptance rates for typical, atypical, and non-valid shapes for the sorting task. Pedagogy was between subjects; time was within subjects.

Pedagogy had a significant main effect on shape acceptance, *Wilks' Lambda*, $F(6, 60) = 7.36$, $p = .001$, $\eta_p^2 = .42$. Follow-up univariate ANOVAs indicated pedagogy significantly influenced children's acceptance of typical and atypical shapes, F's(2, 32) =

---

[12] Some variables showed signs of kurtosis and skewness (2.00+), Kruskal-Wallis nonparametric statistics yielded the same between-subject factor outcomes as parametric statistics. Thus, we reported parametric analyses for ease of interpretation.

Table 7

Experiment 3: Univariate ANOVAs for individual shape trends by exemplar type and condition during T2

Shape Category	Exemplar Type	ANOVA	Significant Pairwise Comparisons [a,b]
Triangles	Typical	$F(2, 32) = 9.74, p < .001$	GP > FP DD > FP[+]
	Atypical	$F(2, 32) = 19.68, p < .001$	GP > DD & FP DD > FP[+]
	Non-valid	$F(2, 32) = .15$, *n.s.*	--
Rectangles	Typical	$F(2, 32) = 2.06$, *n.s.*	--
	Atypical	$F(2, 32) = 6.36, p < .01$	GP > FP GP > DD[+]
	Non-valid	$F(2, 32) = .56$, *n.s.*	--
Pentagons	Typical	$F(2, 32) = 5.63, p <. 01$	GP > FP
	Atypical	$F(2, 32) = 15.57, p < .001$	GP & DD > FP GP > DD[+]
	Non-valid	$F(2, 32) = 1.65$, *n.s.*	--
Hexagons	Typical	$F(2, 32) = 10.34, p < .001$	GP & DD > FP
	Atypical	$F(2, 32) = 11.06, p < .001$	GP > DD & FP DD > FP[+]
	Non-valid	$F(2, 32) = 2.72, p = .08$	GP > DD[+]

[a] GP = Guided Play, DD = didactic instruction, FP = Enriched Free Play
[b] Significant at $p < .05$ with Bonferroni corrections unless otherwise noted
[+] Marginally significant at $p < .10$

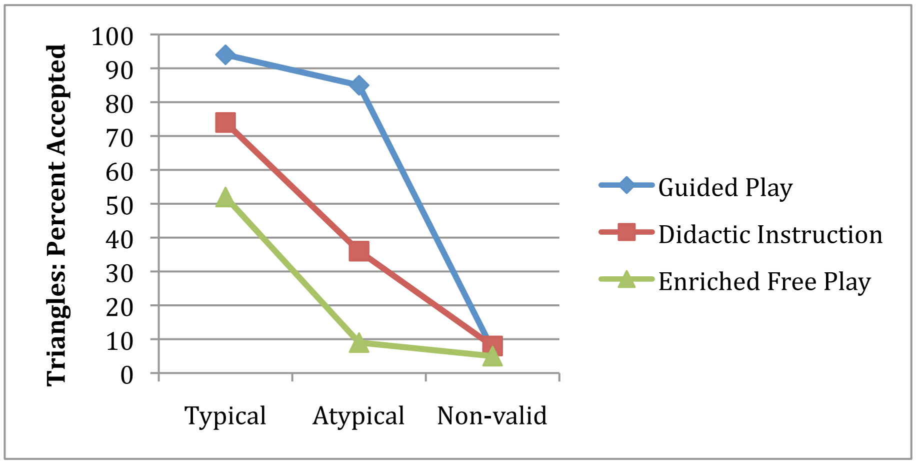


Figure 12. Experiment 3: Mean percentages of triangles accepted in the sorting task by condition.

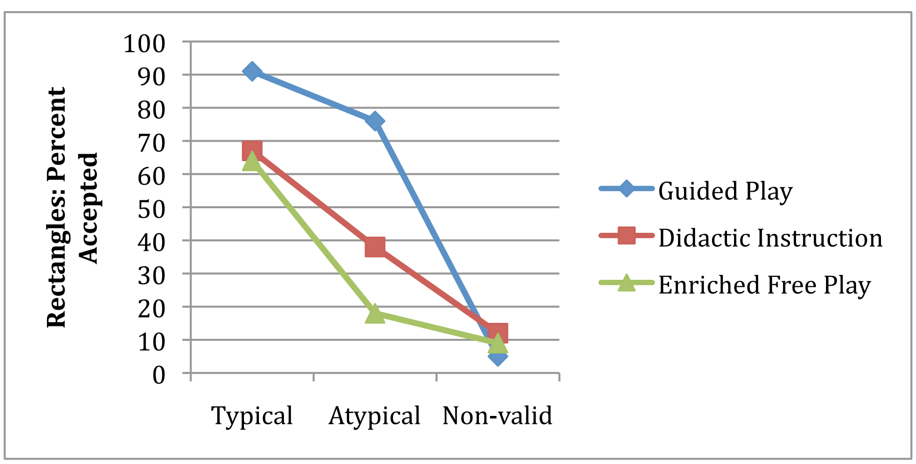


Figure 13. Experiment 3: Mean percentages of rectangles accepted in the sorting task by condition

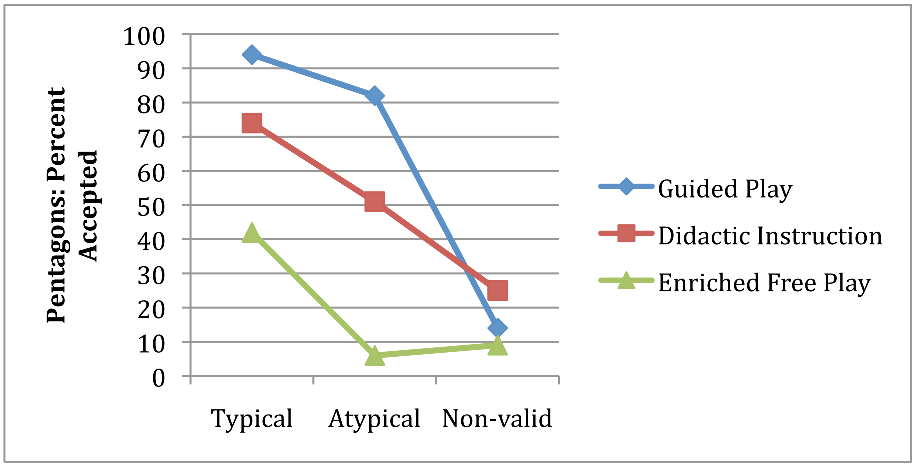


Figure 14. Experiment 3: Mean percentages of pentagons accepted in the sorting task by condition

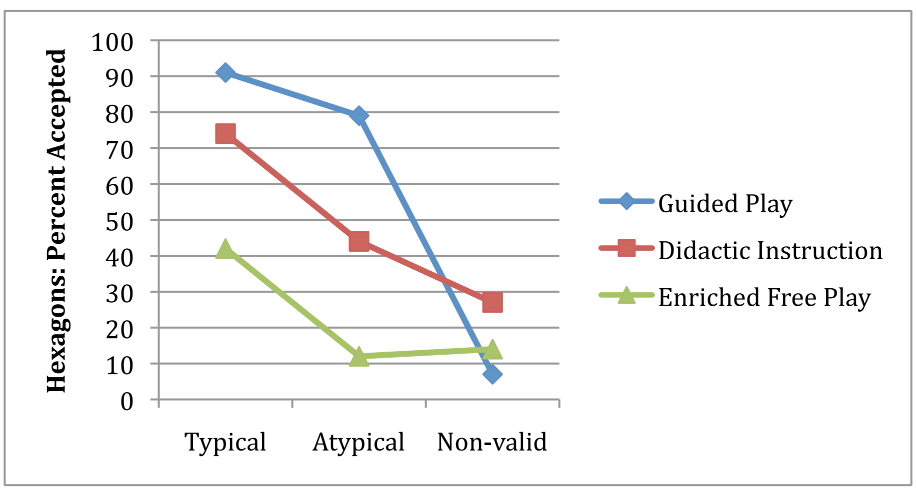


Figure 15. Experiment 3: Mean percentages of hexagons accepted in the sorting task by condition

13.66 ($\eta_p^2 = .46$) and 20.38 ($\eta_p^2 = .56$), respectively, *p*'s < .001, but not non-valid shapes. Pairwise comparisons with Bonferroni corrections revealed children in guided play identified more *typical* and *atypical* shapes as 'real' compared to those in didactic instruction and in exploratory play (*p's* < .02). Similarly, children in didactic instruction accepted more valid shapes (typical and atypical) than those in exploratory play (*p's* < .05).

Across conditions, children did not show a significant change in shape knowledge between T1 and T2 on the sorting task, *Wilks' Lambda*, $F(3, 30) = .531$, *n.s.*

To understand how differences between training conditions manifest in specific shape concepts, we examined acceptance patterns *within* each shape category for typical, atypical, and non-valid shapes during T2. A one-way MANOVA with pedagogy as the between-subjects factor (guided play, didactic instruction, & control) was conducted on acceptance rates for 12 dependent variables (typical, atypical, and non-valid variables per shape category). Pedagogy had a main effect on shape knowledge, *Wilks' Lambda*, $F(24, 42) = 3.11$, $p < .001$, $\eta_p^2 = .64$. See Table 7 for follow-up univariate analyses.

As seen in Figures 12 through 15, two interesting trends emerged. First, guided play children showed criterial learning across *all* shape categories, signified by significantly higher acceptance rates across typical *and* atypical instances compared to the other conditions. Second, children in didactic instruction showed slightly different response patterns. When examining the means, they had equivalent acceptance rates to enriched free play for *typical* rectangles, but not for *typical* triangles and hexagons (pentagons showed a trend, yet failed to reach normative levels of significance). They also showed larger acceptance rates for *atypical* shapes than those in enriched free play, but not to the degree of those in guided play.

Embedded Shapes Task. A 3 (pedagogy: guided play, didactic instruction, & exploratory play) X 2 (time: T1 & T2) mixed-measures MANOVA was conducted on identification rates for typical and atypical shapes. Pedagogy was between subjects; time was within subjects.

Pedagogy had a main effect on shape identification in the figure, *Wilks' Lambda*, $F(4, 62) = 3.75$, $p < .01$, $\eta_p^2 = .20$, with a significant effect on *atypical* shapes, $F(2, 32) = 7.43$, $p < .01$, $\eta_p^2 = .32$, but not typical shapes, $F(2, 32) = 2.20$, *n.s*. Children in guided play identified more atypical shapes than those in free, exploratory play ($p < .01$) and marginally more than didactic instruction ($p < .10$). Children in didactic instruction did not significantly differ from enriched free play in their identification of typical or atypical shapes.

Children's identification rates remained consistent over T1 and T2 on the embedded shapes task, *Wilks' Lambda*, $F(2, 31) = 1.66$, *n.s.*

Discussion

In Study 3, we directly explored the effectiveness of guided play, enriched free play, and didactic instruction on children's criterial learning of two familiar shapes (triangles, rectangles) and two unfamiliar, complex shapes (pentagons, hexagons). We examined the immediate and longer-term retention of learning over a one-week period. As predicted, children in guided play demonstrated improved criterial learning of shapes compared to children in didactic instruction *and* enriched free play. They accepted more valid instances (typical and atypical shapes) of shapes while rejecting the majority of non-valid instances. This trend was consistent across familiar and novel shapes. Although they did not show *complete* criterial learning (i.e., 100% acceptance of typical and atypical shapes, 100% rejection of non-valid shapes) the acceptance patterns in the sorting task mimicked the concrete-to-abstract shift in geometric shape understanding demonstrated by early elementary children in prior research (Keil, 1989; Satlow & Newcombe, 1998).

Unlike the findings from our previous research, this trend extended to a difficult embedded shapes task, in which guided play children identified more atypical shapes than those in the other conditions. Perhaps the ability to construct shapes as well as being able to clearly verify their commonalities with the exemplar cards promoted stronger learning and transfer; however, the change in the embedded image task limits the conclusions we can draw between Experiments 1 and 3.

Is Guided Play Superior to Didactic Instruction on a Complex Shape Task?

Didactic children's geometric concepts were more concrete in nature compared to guided play. They demonstrated higher acceptance rates for typical shapes while rejecting the majority of atypical and non-valid shapes. They did, however, show evidence of an expanding concept of shape, but not to the degree of guided play. This was a departure from the findings of Experiment 1, in which didactic and guided play children displayed similar levels of criterial learning across the simple, familiar shapes. While several possibilities may account for the decreased effectiveness of didactic instruction compared to the previous experiment (e.g., changes in methodology, differences in samples), we believe that limited sample size and variability in individual responsiveness to didactic instruction drove the effect.

What Role Does Dialogic Inquiry Play?

Also as predicted, children in enriched free play displayed concrete concepts of shapes compared to guided play. In fact, they demonstrated highly rigid shape concepts, accepting approximately 50% of typical shapes and less than 15% of atypical shapes. Children's verbalizations and patterns of acceptance across sorting test items suggest that they relied heavily on size and orientation when classifying shapes (i.e., exact matches). In line with previous research, the findings suggest that preschool children need additional guidance to learn shape concepts beyond engagement with enriched curricular materials (Brown, McNeil, & Glenberg, 2009; Bruner, 1966; Uttal et al., 2009; Uttal, Liu, & DeLoache, 1999).

The observed acceptance rate for typical shapes in the enriched free play condition is lower than the rate reported in the literature (approximately 80%, see Appendix G for original Satlow & Newcombe data). This departure from the literature is likely due to methodological differences between the studies. Satlow and Newcombe (1998) displayed two typical, yet unique exemplars, during the shape-sorting task, which would promote a higher rate of matching between test items and thus a higher acceptance rate among typical shapes. We chose to display only one typical exemplar as a more difficult test of criterial learning.

It must be noted that guided play and enriched free play vary on an additional factor: goal-directedness. During the enriched free play session, children were prompted to interact with the shapes without a specific learning goal; that is, instruction encouraged play activity rather than encouraging discovery of the 'secret of the shapes.' We chose this approach for two reasons. First, the extant literature characterizes dialogic inquiry as an educational method that prompts curiosity and leads discovery (Ash & Wells, 2006; Renshaw, 2004; Wells, 1999). If we prompted children to 'discover the secret of the shapes' during enriched free play, we would effectively be using dialogic learning techniques in the non-dialogic inquiry condition. Second, by encouraging free play with the shape materials, we simulated a more permissive, non-facilitative pedagogy that is found in some preschools (Wood, 2009).

Limitations

Several additional limitations are also evident in the current study. First, although we attempted to control for time, children in guided play took approximately one minute longer during the training session than those in didactic instruction, potentially gaining the advantage of longer exposure to training stimuli. We do not feel that this had a substantial impact on the results in that children's construction of shapes accounted for the majority of the time difference (e.g., time taken to pick up the sticks and get the sticks to join together, etc). Second, other additional motivation factors may account for some of the variance, including children's interest in the content, the perceived meaningfulness of the experience, and the child-experimenter relationship (Deci, Vallerand, Pelletier, & Ryan, 1991). Third, the results are drawn from a relatively small sample of children, limiting the generalizability of the findings. Lastly, statistical limitations were also present relating to the sample size as well as multiple comparisons across variables.

Even with these limitations, the current research adds to the literature in several meaningful ways. First, children in guided play show stronger criterial learning than those in didactic instruction, lending support to the child-centered philosophy. Second, children require adult guidance when learning new criterial concepts of shapes. Although children in the enriched free play condition were exposed to both typical and atypical shape exemplars, they displayed rigid, concrete shape concepts. This parallels previous findings in the literature suggesting children may be unable to extract key definitional knowledge when engaging in play behaviors even when enriched materials (with both typical and atypical exemplars) are given to them (e.g. Kaminski, Sloutski, & Heckler, 2009; Sarama & Clements, 2009; Uttal et al., 2009). All of the children chose to create designs or tell stories with the shapes during free play rather than sorting or comparing shapes. In such cases, children primarily focus on arranging the cards in a pattern (e.g., a face) rather than noticing common definitional features because such features are irrelevant to his chosen task. This likely accounts for some of the rigidity of geometric concepts.

It is possible that the nature of children's free play activities may have been effected by the instruction set of the free play condition (i.e., suggestions of how to play with the cards); however, we do not believe that it significantly influenced children's learning outcomes for two reasons. First, other free play activities that *do not* prompt comparison of shape properties would likely yield similar concrete concepts since such comparisons are key to conceptual learning (Gentner, 2005; Gentner & Calhoun, in press). For example, the experimenter may have suggested children use the shapes to make stickers or pretend the shapes were mini-aliens. The goals of such activities do not encourage within-shape category comparison, which is necessary for criterial learning of shape concepts. Second, if children *were* encouraged to sort shapes without additional adult guidance, they will most likely match shapes based on overall shape similarity rather than relational or criterial properties (Gentner, 2002). For example, typical triangle exemplars would be grouped separately from atypical triangles. Such sorting activity would likely result in rigid, concrete shape concepts as well. Future research should explore the impact of such instruction sets on developing criterial concepts.

The current study demonstrates that children's shape knowledge is malleable and heavily influenced by pedagogical experience. After approximately 15 minutes of shape training, children displayed drastically different shape knowledge across playful learning and didactic instruction conditions. Guided play was significantly superior to other educational methods on the complex shape lesson. Learning was relatively robust, showing no decline over a one-week period.

GENERAL DISCUSSION

Research in the last four decades has demonstrated playful learning and didactic instruction approaches facilitate academic achievement; yet very little experimental research has directly compared these pedagogies (Glickman, 1984; Golbeck, 2001; Hirsh-Pasek et al., in press). This dissertation offers the first set of empirical studies to examine the differential impact of didactic instruction and playful learning practices (guided play, enriched free play) on geometric shape learning. We also examined how enriched curricular materials influence the learning process.

Guided Play: A Superior Pedagogy?

Results from Experiments 1 and 3 build on the previous literature that suggests guided play is a viable child-centered pedagogy that promotes significant learning outcomes (e.g., Marcon, 1999, 2002; Stipek & colleagues, 1992). In the first experiment children were taught shape properties of predominantly simple, familiar shapes using guided play and didactic instructional approaches. Children in both conditions displayed similar criterial learning compared to a control condition (Experiment 1). With additional controls implemented in Experiment 3, guided play children showed significantly stronger shape concepts than those in didactic instruction. Learning was relatively robust, showing no decline over a one-week period.

Disentangling the Ambiguity of Guided Play

Guided play has been advocated as the “middle ground” between the two prevalent educational ideologies, one that provides the benefits of curriculum-oriented experiences while promoting learning in a developmentally-appropriate way (Bennett et al., 1997; Fisher et al., 2009; Moyles et al., 2002; Wood, 2005). Teachers play a unique role in guided play experiences. In the current research, the experimenter gently scaffolded learning by enriching children's curricular content with a variety of shape exemplars and prompting exploration and discovery via dialogic inquiry. Our findings suggest that the combination of these elements facilitate stronger criterial learning than enriched free play and explicit, didactic instruction in the context of geometric shape learning.

A key conceptual issue remains: Is guided play really "play?" Although there is no standard definition, contemporary theorists generally agree that playful activities are enjoyable, flexible, and involve active engagement of the child (Johnson, Christie, & Yawkey, 1999; Pellegrini, 2009; Sutton-Smith, 2001). Guided play, as conceptualized in this dissertation, is considered playful because (a) they enjoy the learning process, (b) the learning process is flexible and arises from children's own discoveries (e.g, children can make mistakes, can explore materials in different ways, etc), and (c) they are actively, physically engaged during the activity. We recognize that other dimensions are also common in children's play behaviors that are not prevalent in our definition of guided play (e.g, make-believe, child-initiation, lack of extrinsic goals). We also note that each dimension of play likely represents a continuum on which play activities differentially encompass each of these dimensions (e.g., board games, make-believe, drawing, etc).

In this dissertation, we chose to narrowly construe our definition of guided play to learn what mechanisms drive learning. In so doing, we also begin to unravel the ambiguity underlying 'guided play.' Future research should examine what combinations of the play dimensions are necessary to promote learning and whether children deem the activities that they encompass as playful.

The Role of Dialogic Inquiry and Physical Engagement in Playful Learning

Relatedly, the literature and studies presented in this dissertation illustrate that we are only in the beginning stages with this research. We take the initial step in exploring the mechanisms that underlie guided play pedagogy by manipulating two elements implicated in the playful learning extant literature: physical engagement and dialogic inquiry. Additional research is necessary to adequately explore the gradations of physical engagement (e.g., how much the child is engaged; who initiated engagement; distinctions between cognitive and physical engagement), dialogic inquiry (e.g., frequency of prompting; when prompting occurred), and the combination of these variables. For example, another condition might explore the impact of dialogic inquiry without the presence of physical engagement. We also note that other factors were implicated in the current research and require additional experimental exploration (e.g., interest, motivation, personal meaningfulness, etc; Deci, 1992; Renninger, 2001). Lastly we recognize that we have narrowly defined guided play for the purpose of this research. Other guidance techniques that facilitate learning are implicated in the literature (e.g., modeling, organized social games, etc). Thus, guided play is a relatively new research area that is ripe for future exploration.

While dialogic inquiry and physical engagement are key characteristics of guided play, they are not unique to this literature. These attributes are found in a variety of domains that evoke interest and engage children, such as art activities, sports, and music. Future research should also examine whether these criteria influence learning in these other less academic domains.

Content versus Pedagogy?

The current research shows curricular materials *and* pedagogical practices uniquely influence children's geometric shape knowledge. As seen in Experiments 1 and 2, children's exposure to enriched curricular materials had a profound impact on their criterial learning of shapes. Children trained with typical shapes during guided play showed poorer criterial learning compared to those who were trained with enriched materials (typical and atypical shapes). It is interesting to note that children trained with typical exemplars also showed evidence of expanding shape knowledge, but not to the degree of those who received a more varied learning experience.

These findings also align with the conceptual learning literature (e.g., Gentner & Calhoun, in press), suggesting children need a variety of exemplars to move beyond perceptual understandings to abstract, relational concepts. Schema abstraction is a key mechanism for facilitating the concrete-to-abstract shift (e.g., Gentner, 2005; Gentner & Medina, 1999; Kuehne, Gentner, & Forbus, 2000; Marcus, Vijayan, Rao, & Vishton, 1999). In these contexts, children are exposed to a series of exemplars that range from highly similarity to dissimilar instances of a concept (while still sharing the same relational structure). As children make exploratory comparisons across exemplars, they align their common features and extract the relational structure, resulting in a new, more abstract conceptualization (or re-representation of the concept). By exposing children to typical and atypical instances of each shape category, children were able to move beyond their canonical shape concepts to definitional or abstract concepts.

Additionally, the findings from Experiment 3 expand and build upon the previous research suggesting that children's engagement with enriched materials alone does not guarantee learning of mathematical concepts (e.g., Brown, McNeil, & Glenberg, 2009; Uttal et al., 1997; Uttal et al., 2009; Uttal, Liu, & DeLoache, 1999). Children who participated in enriched free play showed no evidence of criterial learning, suggesting even well-planned curricular materials are not enough to spark children's attention to the key definitional features of shapes without some guidance. The literature reveals physical engagement facilitates learning, but it is not necessary or sufficient for criterial learning of shape properties (Uttal et al., 2009).

Taken together, the research suggests curricular content and pedagogy are integral components of the learning process, and that one should not be emphasized over the other. While other international early childhood programs promote both curriculum goals and child-centered playful learning practices (for a review, see Wood, 2009), the current trend in U.S. public policy, appears fundamentally flawed at its base. Educational reform predominantly focuses on curricular content standards to the exclusion of discussions about pedagogy (NCLB, 2001; National Council of Teachers for Mathematics; 2008). In fact, the new core curriculum strongly evades such discussions (National Governors Association Center for Best Practices, 2010). As a result, educators forgo child-centered play practices in an effort to promote curricular content, often with the misguided belief that play and academics are polar extremes that are fundamentally incompatible (Kochuk & Ratnaya, 2007; Viadero, 2007). The evidence suggests that can children learn core academic mathematic knowledge via playful experiences.

Playful Learning in the Classroom: When and Why?

As highlighted in this paper, a prominent barrier in examining and implementing playful learning pedagogies is the conceptual ambiguity associated with the construct.

Even when play is valued in the classrooms, educators do not always know how to plan, structure, enrich, or facilitate playful learning (Bennett et al., 1997; Moyles et al., 2002). Experimental research may help elaborate what types of experiences facilitate learning.

The current study offers a definition of guided play and suggests that guided play facilitates geometric shape learning while enriched free play alone likely impedes children's ability to focus on relevant features to form relational understandings. We are careful to note that the nature of the learning goal likely constrains the learning process (Livingstone, 2001). For example, criterial or relational learning of mathematical concepts may require additional guidance while the development of pre-literacy skills may not. Furthermore, the timing of play may be influential. While our findings show that free play with enriched curricular materials is not enough to promote learning, several studies indicate that practice-play *after* a learning activity is beneficial (e.g., McInnes, Howard, Miles, & Crowley, 2009; Radcliff, 2007; Thomas, Howard, & Miles, 2006).

The current research should not be construed as suggesting free play has little benefit. A wealth of research shows that free play is important for many reasons and that it also has academic (e.g., Cloran, 2005; Ginsburg, Lee, & Boyd, 2008; Hans et al.; Hirsch, 1996; Roskos & Christie, 2001; Pellegrini & Galda, 1993; Tykkyläinen & Laakso, 2009; Wolfgang, Stannard, & Jones, 2001) and social benefits, such as enhanced executive functioning, and emotion regulation (Berk, Mann, & Ogan, 2006; Fantuzzo, Sekino, & Cohen, 2004; Lemche, Lennertz, Orthmann, Ari, Grote, Hafker, et al., 2003).

Playful learning, including both guided- and free- play, is beneficial across a variety of domains, and it is evident that clearer distinctions between free- and guided-play in the literature are warranted in order to explore the mechanisms underlying these learning processes. Particular attention must also be paid to a variety of variables within the learning context, as they likely impact the learning process (e.g., including the nature of learning, the content domain, the timing, the role of the teacher).

Limitations and Future Directions

We recognize that these findings are limited by the nature and scope of the current investigation. This work is but a first step in an uncharted area. Additional experimental investigations are necessary to explore how demographic variables may influence the effectiveness of the pedagogical approaches (e.g., socio-economic backgrounds, age, learning abilities). It may be the case that guided play, as conceptualized and tested in this dissertation, may not be viable for all individuals. Children from disadvantaged backgrounds may respond differently to the interventions, given that they often display marked deficiencies in foundational knowledge (e.g., counting, shape recognition; NCES, 2000) and other cognitive skills that underlie learning (e.g., executive functioning, spatial understanding; Blaire, 2003; Hackman & Farah, 2009; Levine et al., 2005). For instance, children who are unable to count would have difficulty in discovering the criterial features of shapes. Additionally, evidence suggests that specific educational approaches, such as didactic instruction, may be better for those with learning disabilities (e.g., Cole & Dale, 1986; Przchodzin, Marchand-Martella, Martella, & Azim, 2004; Waldron-Soler, 2002) whereas neither guided play nor didactic instruction is appropriate for three-year-olds (based on pilot testing).

A wide variety of individual differences were also evident in the study. Some children learned a different criterial concept than what was taught during guided play (e.g., a triangle is *anything* that has interconnected sides), others demonstrated an expanding concept of shape but not complete criterial understanding, and a few children displayed 100% accuracy. Future research should explore what factors account for the individual differences in learning outcomes.

Another point of interest is whether a particular pedagogy can foster learning and transfer of knowledge. According to Sutton-Smith (1997), play may facilitate transfer of knowledge and skills between different contexts and domains; however, this has seldom been explored in the literature. Our research shows children in guided play transferred their criterial knowledge of shapes to a sorting task as well as more difficult embedded shapes task in Experiment 2. Although their acceptance patterns were not as robust as those found in the sorting task (a near-transfer task), this finding provides initial evidence for its potential cross-transfer effects. Additional lines of research should examine how criterial learning in guided play may generalize to contexts (e.g., recognition of shapes at home), to other tasks (e.g., other shape identification or construction tasks), and academic domains (e.g., criterial learning for animals or science-based principles).

Lastly, additional research should explore what other cognitive and socio-emotional outcomes are simultaneously promoted during guided play. Similar to free play activities, children are cognitively and socially engaged during guided play. It may be the case that this pedagogy may dually facilitate academic knowledge as well as executive functioning (e.g., sustained attention, deductive reasoning) and socio-emotional skills.

Conclusions

The research is poised to have a significant impact in the area of cognitive development and in translational science in several meaningful ways. First, the program of research moves beyond the descriptive accounts found in the extant literature to examining *why* and by *what means* guided play or 'child-initiated' learning works. Importantly, the results give real substance to theories of guided play and playful learning. Second, the current study synthesizes four independent, yet complimentary lines of research: playful learning, dialogic inquiry, physical engagement, and conceptual learning. Lastly, the findings from this study will add to our existing knowledge about how we may enhance the acquisition of abstract geometric concepts in early childhood, one that may help fill a critical educational goal.

REFERENCES

Adams, G. L., & Engelmann, S. (1996). *Research on direct instruction: 25 years beyond DISTAR.* Seattle, WA: Educational Achievement Systems.

Adelson, R. (2004). Instruction versus exploration in science learning. *Monitor on Psychology, 35,* 34-35.

Ash, D. (2002). Negotiations of thematic conversations about biology. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums*. Mahwah, NJ: Lawrence, Erlbaum Associates.

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching, 40*, 138-162.

Ash, D. & Wells, G. (2006). Dialogic inquiry in classroom and museum: Action, tools, and talk. In Z. Bekerman, N. Burbules, & D. Silberman-Keller (Eds.), *Learning in places: The informal education reader.* New York, NY: Peter Lang Publishing, Inc.

Association for Childhood Education International (2010). About ACEI: Guiding principles and beliefs. Retrieved May 4, 2010, from http://acei.org/about/

Association for Direct Instruction. (2009). *General frequently asked questions.* Retrieved April 16, 2010, from http://www.apastyle.org/learn/faqs/web-page-no-author.aspx.

Barnett, W.S., Jung, K., Yarosz, D.J., Thomas, J., Hornbeck, A., Stechuk, R., & Burns, S. (2008). Educational effects of the Tools of the Mind curriculum: A randomized trial. *Early Childhood Research Quarterly, 23,* 299 - 313.

Baroody, A.J., Lai, M., & Mix, K.S. (2006). The development of young children's early number and operation sense and its implications for early childhood education. In B. Spodek & O. Saracho (Eds.), *Handbook of research on the education of young children* (Vol. 2, pp. 187-221). Mahwah, NJ: Erlbaum.

Becker, W.C., & Gersten, R. (1981). A follow up of Follow Through: The later effects of the Direct Instruction model on children in fifth and sixth grades. Boston, MA: Paper presented at Conference on a Society for Research on Child Development.

Benjamin, N., Haden, C., & Wilkerson, E. (2010). Enhancing building, concersation and learning through caregiver-child interactions in a children's museum. *Developmental Psychology, 46*, 502-516

Bereiter, C., & Kurland, M. (1981). A constructive look at Follow Through results. *Interchange, 12,* 1-19.

Berger, K. (2008). *The developing person through childhood and adolescence* (8th Ed). New York, NY: Worth Publishers.

Bjorklund, C. (2008). Toddlers' opportunities to learn math. *International Journal of Early Childhood, 40,* 81-95.

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting*, *5*, 35-45.

Bock, G., Stebbins, L., & Proper, E. (1977). *Education as experimentation: A planned variation model (Volume IV-A & B) Effects of follow through models.* Washington, D.C: Abt Associates.

Bodrova, E., & Leong, D. J. (1996). *Tools of the mind: The Vygotskian approach to early childhood education*. Englewood Cliffs, NJ: Prentice Hall.

Boekerts, M. & Minnert, A. (1999). Self-regulation with respect to informal learning. *International Journal of Educational Research, 31,* 533-544.

Bonawitz, E.B. (2009). *The rational child: Theories and evidence in prediction, exploration, and explanation.* MIT PhD Thesis in Brain and Cognitive Sciences.

Bonawitz, E.B., Fischer, A., Schulz, L.E. (2008). Training a Bayesian: Three-and-a-half-year-olds' reasoning about ambiguous evidence. *Proceedings of the Thirtieth Annual Conference of the Cognitive Science Society.* Washington, DC.

Bransford, J., Brown, A., & Cooking, R. (Eds.). (2000). How children learn. In *How people learn: Brain, mind, experience, and school* (pp. 79-113). Washington, DC: National Academy of Sciences.

Bransford, J.D., Vye, N., Stevens, R., Kuhl, P., Schwartz, D., Bell, P., Meltzoff, A., Barron, B., Pea, R., Reeves, B., Roschelle, J. & Sabelli, N. (2006). Learning theories and education: Toward a decade of synergy. In P. Alexander & P. Winne (Eds.), *Handbook of Educational Psychology.* Second Edition. Mahwah, NJ: Erlbaum, 209-244.

Bronfenbrenner, U. (1970). *Two worlds of childhood: U.S. and U.S.S.R.* New York, NY: Pocket Books.

Bruner, J. (1996). *The culture of education*. Cambridge, MA: Harvard University Press.

Burger, W. F., & Shaughnessy, J. M. (1986). Characterizing the van Hiele levels of development in geometry. *Journal for Research in Mathematics Education, 17,* 31–48.

Burts, D.C., Hart, C.H., Charlesworth, R., & DeWolf, M. (1993). Developmental appropriateness of kindergarten programs and academic outcomes in first grade. *Journal of Research in Childhood Education, 8*, 23-31.

Caldera, Y.M., McDonald Culp, A., Truglio, R.T., Alvarez, M., & Huston, A.C. (1999). Children's play preferences, construction play with blocks, and visual-spatial skills: Are they related? *International Journal of Behavioral Development, 23,* 855-872.

Callanan, M.A. & Braswell, G. (2006). Parent-child conversations about science and literacy: Links between formal and informal learning. In Z. Bekerman, N. Burbules, & D. Silberman-Keller (Eds.), *Learning in places: The informal education reader* (pp. 123 -138). New York, NY: Peter Lang Publishing, Inc.

Callanan, M., Cervantes, C., & Sabbagh, M. (1999). Conversation and conceptual development: Challenges, alternatives, and future directions. *Human Development*, 42, 356-361.

Callanan, M., Jipson, J., & Soennichsen, M. (2002). Maps, globes and videos: Parent-child conversations about representational objects. In S. Paris (Ed.) *Perspectives on Object-Centered Learning in Museums* (pp. 261-283). Mahwah, NJ: Erlbaum.

Callanan, M. & Oakes, L. (1992). Preschoolers' questions and parents' explanations: Causal thinking in everyday activity. *Cognitive Development*, *7*, 213-233.

Campbell, F. A., Ramey, C. T., Pungello, E., Sparling, J., & Miller-Johnson, S. (2002). Early childhood education: Young adult outcomes from the Abecedarian Project. *Applied Developmental Science, 6*, 42 - 57.

Carleson, C. & Francis, D. (2002). Increasing the reading achievement of at-risk children through Direct Instruction: Evaluation of the Rodeo Institute for Teacher Excellence (RITE). *Journal of Education for Students Placed At Risk, 7,* 141 – 166.

Caudle, R. & Caudle, B (Producers). (2003). *Colors, shapes, and counting*. United States: Rock-n-Learn, Inc.

Clements, D.H. (2004). Geometric and spatial thinking in early childhood education. In D.H. Clements & J. Sarama (Eds)., Engaging young children in mathematics (pp. 267 – 298). Mahwah, NY: Lawrence Erlbaum Associates.

Clements, D.H. (2000). 'Concrete' manipulatives, concrete ideas, *Contemporary Issues in Early Childhood, 1,* 45-60.

Clements, D.H. & Sarama, J. (2000). Young children's ideas about geometric shapes. *Teaching Children Mathematics, 6,* 482 – 488.

Clements, D.H. & Sarama, J. (2007). Early childhood mathematics learning. In F.K. Lester, Jr. (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning* (pp. 461-555). New York: Information Age Publishing.

Clements, D.H., S. Swaminathan, M.A. Hannibal, & Sarama, J. (1999). Young children's concepts of shape. *Journal for Research in Mathematics Education, 30,* 192–212.

Cole, K., & Dale, P. (1986). Direct language instruction and interactive language instruction with language delayed preschool children: A comparison study. *Journal of Speech and Hearing Research, 29,* 206 – 217.

Cole, K., Dale, P., & Mills, P. (1991). Individual differences in language delayed children's responses to direct and interactive preschool instruction. *Topics in Early Childhood Education, 11,* 99 – 124.

Copple, C., Sigel, I. E., & Saunders, R. (1979). *Educating the young thinker: Classroom strategies for cognitive growth.* New York: D. Van Nostrand Co.

Deci, E. L. (1992). The relation of interest to the motivation of behavior: A self-determination theory perspective. *The Role of interest in learning and development*. In A. Renniner, S. Hidi, & A Krapp (Eds.), Interest in learning and development (pp. 43-70). Hillsdale, NY: Erlbaum.

DeLoache, J. S., & Smith, C. M. (1999). The early understanding and use of symbolic representations. In I. E. Sigel (Ed.), *Theoretical perspectives in the development of representational (symbolic) thought* (pp. 61-86). Hillsdale, NJ: Erlbaum.

Dewey, J. (1916) *Democracy and education. An introduction to the philosophy of education.* New York, NY: Free Press.

Dewey, J. (1929) *Experience and Nature*. New York, NY: Dover.

Diamond, A., Barnett, W.S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science, 317,* 1387-1388.

Dockett, S. & Fleer, M. (1999). *Play and pedagogy in early childhood: Bending the rules*. Marrickville, New South Wales: Harcourt Brace.

Dohrmann, K.R. Evaluating outcomes of Montessori education: A review of research. (2003). Association Montessori Internationale/ USA, 410 Alexander Street, Rochester, New York. 14607-1028.

Dohrmann, K. R., Nishida, T., Gartner, A., Lipsky, D. & Grimm, K. (2007). High school outcomes for students in a public Montessori program. *Journal of Research in Childhood Education*, 22, 205-217.

Duncan, R.M. (1995). Piaget and Vygotsky revisited: Dialogue or assimilation? *Developmental Review, 15,* 458-472.

Education Commission of the States (1999). *Direct instruction.* Denver, CO: ECS.

Egbert, R.L. (1981). Some thoughts about Follow Through thirteen years later. Lincoln, NB: Nebraska University.

Ellis, A.K., & Fouts, J.T. (1993). *Research on educational innovations.* Princeton Junction, NJ: Eye on Education.

Elmore, R.F. (1977). Follow Through: Decision-making in a large-scale social experiment. Unpublished doctoral dissertation, Harvard Graduate School of Education.

Engelmann, S. & Brunner, E. (1995). *Reading Mastery*. Worthington, OH: McGraw Hill.

Englemann, S. & Carnine, D. (1982). *Theory of instruction: Principles and applications.* New York: Irvington Publishers.

Fein, G., & Rivkin, M. (1986). *The young child at play: Reviews of research*. Washington, D.C.: NPEYC.

Fender, J.G. & Crowley, K. (2007). How parent explanation changes what children learn from everyday scientific thinking. *Journal of Applied Developmental Psychology, 28,* 189-210.

Fisher, K., Hirsh-Pasek, K., Golinkoff, R.M., Berk, L., & Singer, D. (2010, forthcoming). Playing around in school: Implications for learning and educational policy. In A. Pellegrini (Ed), *Handbook of the Development of Play*. Oxford Press.

Fosnot, C. (1996). Constructivism: A Psychological theory of learning. In C. Fosnot (Ed.) *Constructivism: Theory, perspectives, and practice,* (pp.8-33). New York: Teachers College Press.

Ganel, T., & Goodale, M. A. (2003). Visual control of action but not perception requires analytical processing of object shape. *Nature, 426*, 664–667.

Geary, D.C. (1994). *Children's mathematical development: Research and practical applications.* Washington, DC: American Psychological Association.

Geary, D.C. (2006). Development of mathematical understanding. In D. Kuhn, R. Siegler, W. Damon, & R. Lerner (Eds*.)*,*Handbook of child psychology: Vol 2, Cognition, perception, and language* (6th ed., pp. 777-810). Hoboken, NJ: John Wiley & Sons Inc.

Gentner, D. (2005). The development of relational category knowledge. In L. Gershkoff-Stowe & D. H. Rakison, (Eds.), *Building object categories in developmental time* (pp. 245-275). Hillsdale, NJ: Erlbaum.

Gentner, D., & Kurtz, K. (2006). Relations, objects, and the composition of analogies. *Cognitive Science, 30,* 609-642.

Gentner, D., Loewenstein, J., & Hung, B. (2007). Comparison facilitates children's learning of names for parts. *Journal of Cognition and Development*, *8,* 285-307

Gersten, R., & Carnine, D. (1983). *The later effects of Direct Instruction Follow Through: Preliminary findings.* Montreal, PQ: Paper presented at American Educational Research Association

Gersten, R., Darch, C., & Gleason, M. (1988). Effectiveness of a direct-instruction academic kindergarten for low income students. *Elementary School Journal*, *89*, 227-240.

Gersten, R., and Keating, T. (1987). Long-term benefits from direct instruction. *Educational Leadership, 44,* 28 – 31.

Ginsburg, H.P., Cannon, J., Eisenband, J.G., & Pappas, S. (2005). Mathematical thinking and learning. In K. McCartney & D. Phillips (Eds.), *Handbook of early child development*. Oxford, England: Blackwell.

Ginsburg, H., Lee, J.S., Boyd, J. (2008). Mathematics education for young children: What it is and how to promote it. S*RCD Social Policy Report: Giving Child and Youth Development Knowledge Away*, XXII.

Ginsburg, H., Pappas, S., & Seo, K. (2001). Everyday mathematical knowledge: Asking young children what is developmentally appropriate. In S.L. Golbeck (Ed.), *Psychological perspectives on early childhood education: Reframing dilemmas in research and practice* (pp.181-219). Mahwah, NJ: Lawrence Erlbaum Associates.

Glickman, C. D. (1984). Play in public school settings: A philosophical question. In T. D. Yawkey & A. D. Pellegrini (Eds.), *Child's play: Developmental and applied* (pp. 255-271). Hillsdale, NJ: Lawrence Erlbaum Associates.

Golbeck, S.L. (2001). Instructional models for early childhood: In search of a child-regulated/teacher-guided pedagogy. In S.L. Golbeck (Ed.), *Psychological* *perspectives on early childhood education: Reframing dilemmas in research and practice* (pp. 3 - 29). Mahwah, NJ: Lawrence Erlbaum Associates.

Griffin, S.A., & Case, R. (1996). Evaluating the breadth and depth of training effects, when central conceptual structures are taught. In R. Case & Y. Okamoto (Eds.), *The role of central conceptual structures in the development of children's thought. Monographs of the Society for Research in Child Development, 61*, 83-102.

Hill, C. (2007). *Standards in math: Government organizations.* Retrieved on July 28, 2009, from: http://edstandards.org/StSu/Math.html

Hirsch, E. S. (1996). *The block book* (3rd ed.). Washington, DC: National Association for the Education of Young Children

Hirsh-Pasek, K. (1991). Pressure or challenge in preschool? How academic environments affect children. In L. Rescorla, M.C. Hyson, & K. Hirsh-Pasek (Eds.), *New directions in child development. Academic instruction in early childhood: Challenge or pressure?* (No. 53, pp. 39-46). San Francisco: Jossey-Bass.

Hirsh-Pasek, K. & Golinkoff, R. (in press). The great balancing act: Optimizing core curricula through playful pedagogy. E. Zigler, S. Barnett, & W. Gilliam (Eds.) *The preschool education debates.*

Hirsh-Pasek, K., Golinkoff, R., Berk, L., & Singer, D. (2008). *A Manifesto for playful learning in preschool: Presenting the scientific evidence.* New York, NY: Oxford University Press.

Hohmann, M. & Weikart, D. (1995). *Educating young children: Active learning practices for preschool and child care programs* (2nd Ed). Ypsilanti, MI: High/Scope Press.

House, E., Glass, G., McLean, L., & Walker, D. (1978). No simple answer: Critique of the Follow Through evaluation. *Harvard Educational Review,* 48, 128-160.

Hutt, S., Tyler, S., Hutt, C., & Christopherson, H. (1989). *Play, exploration, and learning: A natural history of the pre-school.* London: Routledge.

Johnson, J. E., Christie, J. F., & Yawkey, T. D. (1999). *Play and early childhood development.* New York, NY: Addison Wesley Longman.

Kaminski, J.A., Sloutsky, V.M., & Heckler, A. (2009a). Transfer of mathematical knowledge: The portability of generic instantiations. *Child Development Perspectives, 3,* 151 – 155.

Kaminski, J.A., Sloutsky, V.M., & Heckler, A. (2009b). Concrete instantiations of mathematics: A double-edged sword. *Journal for Research in Mathematics Education, 40,* 90 – 93.

Kamps, D., Abbott, M., Greenwood, C., Wills, H., Veerkamp, M., & Kaufman, J. (2008). Effects of small-group reading instruction and curriculum differences for students most at risk in kindergarten: Two-year results for secondary- and tertiary-level interventions. *Journal of Learning Disabilities, 41,* 101 – 114.

Karnes, M.B., Schwedel., A.M., & Wiliams, M.B. (1983). A comparison of five approaches for educating young children from low-income homes. Consortium for Longitudinal Studies (Ed.), *As the twig is bent: Lasting effects of preschool programs* (pp. 133 – 170). Hillsdale, NJ: Lawrence Erlbaum Associates.

Keil, F. (1996). *Concepts, kinds, and cognitive development.* Cambridge, MA: MIT Press.

Kennedy, M. (1978). Findings from the Follow Through planned variation study. Washington, D.C.: U.S. Office of Education.

Kirschner, Sweller, & Clark (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, & inquiry-based teaching. *Educational Psychologist, 41,* 75-86.

Klahr, D. (2009) "To every thing there is a season, and a time to every purpose under the heavens": What about didactic instruction? In S. Tobias and T. M. Duffy (Eds.) *Constructivist theory applied to instruction: Success or failure?* (pp. 291-310). Taylor and Francis.

Klahr, D. & Nigam, M. (2004). The equivalence of learning paths in early science instruction: effects of didactic instruction and discovery learning. *Psychological Science, 15*, 661-667.

Kochuk, N., & Ratnayaka, M. (2007). *NCLB/ESEA: It's time for a change! Voices from America's classrooms*. National Education Association.

Kotovsky, L., & Gentner, D. (1996). Comparison and categorization in the development of relational similarity. *Child Development*, *67,* 2797-2822.

Kuder, S.J. 2001. Effectiveness of the DISTAR reading program for children with learning disabilities. *Journal of Learning Disabilities. 23,* 69-71.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lehrer, R., Jenkins, M., & Osana, H. (1998). Longitudinal study of children's reasoning about space and geometry. In R. Lehrer & D. Chazan (Eds.), *Designing learning* *environments for developing understanding of geometry and space* (pp. 137–167). Mahwah, NJ: Erlbaum.

Lillard, A., & Else-Quest, N. (2006). Evaluating Montessori education. *Science, 313,* 1893-1894.

Love, J. M., Ryer, P., & Faddeis, B. (1992). *Caring environments: Program quality in California's publicly funded child development programs.* Portsmouth, NH: RMC Research Corporation.

Maccoby, E.E., & Zellner, M. (1970). Experiments in primary education: Aspects of Project Follow-Through. New York: Harcourt Brace Jovanovich, Inc.

Mandler, J.M. (1992). The foundations of conceptual thought in infancy. *Cognitive Development, 7,* 273 – 285.

Mandler, J.M. (1993). On concepts. *Cognitive Development, 8,* 141 – 148.

Marcon, R. (1993). Socioemotional versus academic emphasis: Impact on kindergartners' development and achievement. *Early Child Development and Care, 96,* 81-91.

Marcon, R. (1999). Differential impact of preschool models on development and early learning of inner-city children: A three cohort study. *Developmental Psychology, 35*, 358-375.

Marcon, R. (2002). Moving up the grades: Relationships between preschool model and later school success. *Early Childhood Research and Practice, 4,* 517 – 530.Medin, D.L. & Smith, E.E. (1984). Concepts and concept formation. *Annual Review of Psychology, 35,* 113 – 138.

McNeil, N.M. & Uttal, D.H. (2009). Rethinking the use of concrete materials in learning: Perspectives from development and education. *Child Development Perspectives, 3,* 137 – 139.

Meckley, A. (2002). *Observing children's play: Mindful methods*. Paper presented at the meeting of the International Toy Research Association. London, England.

Medin, D. L. & Smith, E. E. (1984). Concepts and concept formation. In M. R. Rosenzweig & L. W. Porter (Eds.), *Annual Review of Psychology, 35,* 113-118.

Meyer, L.A. (1984). Long-term academic effects of the direct instruction Project Follow Through. *Elementary School Journal, 84,* 380 – 394.

Miller, E. & Almon, J. (2009). *Crisis in the kindergarten: Why children need to play in school.* Alliance for Childhood: College Park, MD.

Miller, L.B. & Bizzell. R. (1983a). The Louisville experiment: A comparison of four programs. In Consortium for Longitudinal Studies (Ed.), *As the twig is bent: Lasting effects of preschool programs* (pp. 171 - 200). Hillsdale, NJ: Lawrence Erlbaum Associates.

Miller. L.B. & Bizzell, R. (1983b). Long term effects of four preschool programs: sixth, seventh, and eighth grades. *Child Development, 54,* 727 – 741.

Miller, L.B. & Dyer, J. (1975). Four preschool programs: Their dimensions and effects. *Monographs of the Society for Research in Child Development, 162,* 5- 6.

Montessori, M. (1917). *The advanced Montessori method: Spontaneous activity in education.* Frederick A. Stokes Company.

Montessori, M. (1995). *The absorbent mind* (1st ed.). New York: Henry Holt.

Moyles, J., Adams, S. & Musgrove, A. (2002). Study of pedagogical effectiveness in early learning (SPEEL). Research report 363, Department for Education and Skills. London: Her Majesty's Stationery Office.

National Association for the Education of Young Children (2009). *Developmentally appropriate practice in early childhood programs serving children from birth through age eight*. Washington, D.C.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA.

National Governors Association Center for Best Practices. (2010). Retrieved on May 25, 2010, from http://www.corestandards.org/

National Institute for Direct Instruction (n.d.). About direct instruction. Retrieved on April 10, 2010, from http://www.nifdi.org/15/about-di.

National Institute for Direct Instruction (n.d.). Basic philosophy of direct instruction. Retrieved on April 10, 2010, from http://www.nifdi.org/15/basic-philosophy-and-assumptions-of-di.

Nelson, K. D., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural developmental theory. *Psychological Review, 111,* 486-511.

Newcombe, N. (in press). Picture this: Increasing math and science learning by improving spatial thinking. *American Educator.*

No Child Left Behind Act. (NCLB, 2001). *Public Law 107 – 110*, USA.

Ongoren, S. & Turcan, A.L. (2009). The effectiveness of Montessori education method in the acquisition of the concept of geometrical shapes. *Procedia-Social and Behavioral Sciences, 1,* 1163 – 1166.

Ornstein, P.A., Haden, C.A., & Hedrick, A.M. (2004). Learning to remember: Social-communicative exchanges and the development of children's memory skills. *Developmental Review, 24,* 374-395.

Owens, K. (1999). The role of visualization in young students' learning. In O. Zaslavsky (Ed.), *Proceedings of the 23 rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 1, pp. 220–234). Haifa, Isreal: Technion.

Pellegrini, A. D. (2009), Research and policy on children's play. *Child Development Perspectives, 3,* 131-136.

Piaget, J. (1964/1999). *The early growth of logic in the child.* London: Routledge and Kegan Paul, Ltd.

Piaget, J. (1972). *To Understand Is To Invent*. New York, NY: The Viking Press, Inc.

Piaget, J. & Inhelder, B. (1969/2000). *The psychology of the child.* New York: Basic Books.

Przychodzin, A., Marchand-Martella, N., Martella, R. & Azim, D. (2004). Direct Instruction mathematics programs: An overview and research summary. *Journal of Direct Instruction*, *4*, 53-84

Ramani, G.B. & Siegler, R.S. (2008). Promoting broad and stable improvements in low-income children's numerical knowledge through playing number board games. *Child Development, 79*, 375-394.

Rawl, Ruth K., & O'Tuel, Frances S. (1982). A comparison of three prereading approaches for kindergarten students. *Reading Improvement, 19*, 205-211

Reese, E., Haden, C. A., & Fivush, R. (1993). Mother-Child Conversations About the Past - Relationships of Style and Memory over Time. *Cognitive Development, 8,* 403-430.

Renshaw, P.D. (2004). Dialogic teaching, learning, and instruction: theoretical roots and analytical frameworks. In J.L. Van der Linden & P.D. Renshaw, *Dialogic Learning (pp. 1 – 16).* New York, NY:Kluwer Academic Publishers.

Resnick, L. B. (1994). Situated rationalism: Biological and social preparation for learning. In H. L. A., & S. A. Gelman (Eds.), *Mapping the mind. Domain-specificity in cognition and culture* (pp. 474–493). Cambridge, MA: Cambridge UniversityPress.

Resnick, L. B. (1999, June 16). Making America smarter. *Education Week*. 3840.

Ryder, R.J., Burton, J.L. & Silberg, A. (2006). Longitudinal study of didactic instruction effects from 1st through 3rd grades. *Journal of Educational Research, 99,* 179-191.

Rittle-Johnson, B., & Siegler, R. S. (1998). The relation between conceptual and procedural knowledge in learning mathematics: A review. In C. Donlan (Ed.), The *development of mathematical skills* (pp. 75-110). East Sussex, UK: Psychology Press

Rogoff, B. (2003). *The cultural nature of human development. New York, NY: Oxford University Press.*

Sarama, J. & Clements, D.H. (2009). "Concrete" computer manipulatives in mathematics education. *Child Development Perspectives, 3,* 145 – 150.

Satlow, E., & Newcombe, N. (1998). When is a triangle not a triangle? Young children's conceptions of geometric shapes. *Cognitive Development, 13,* 547-559.

Saxe, G. B., Guberman, S. R., & Gearhart, M. (1987). Social processes in early number development. *Monographs of the Society for Research in Child Development,52* (2, Serial No. 216).

Schieffer, C., Marchand-Martella, N.E., Martella, R.C., Simonsen, F.L., & Waldron-Soler, K.M. (2002). *Journal of Direct Instruction, 2,* 87 – 119.

Schulz, L., & Bonawitz, E.B. (2007). Serious fun: Preschoolers play more when evidence is confounded. *Developmental Psychology, 43,* 1045-1050.

Schweinhart, L. (2004). The High/Scope Perry preschool study through age 40. Ypsilanti, MI: High/Scope Educational Research Foundation.

Schweinhart, L.J., Weikart, D.,& Larner, M.B. (1986). Consequences of three preschool curriculum models through age 15. *Early Childhood Research Quarterly, 1*, 15-45.

Seo, K.H., & Ginsburg, H.P. (2004). What is developmentally appropriate in early childhood mathematics education? Lessons from new research. In D. H. Clements, J. Sarama & A.-M. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 91-104). Hillsdale, NJ: Erlbaum.

Sigel, I. E. (1987). Does hothousing rob children of their childhood*? Early Childhood Research Quarterly, 2,* 211-225.

Singer, D. G., Golinkoff, R. M., & Hirsh-Pasek, K. (2006). *Play: How play motivates and enhances children's cognitive and social-emotional growth.* New York, NY: Oxford University Press.

Smith, L. B. (1989). A model of perceptual classification in children and adults. *Psychological Review, 96,* 125–144.

Smith, L. B. (2005). Emerging idea about categories. In L. Gershkoff-Stowe & D. H. Rakison (Eds.), *Building Object Categories in Developmental Time* (pp. 159-173). Malwah, NJ: Lawrence Erlbaum Associates

Smith, L. B. & Heise, D. (1992). Perceptual similarity and conceptual structure. In B. Burns (Editor), *Percepts, Concepts and Categories.* Elsevier Science Publishers B. V. pp. 233-272.

Society for Quality Education. (2010). *A better method.* Retrieved on April 29th, 2010, from http://www.societyforqualityeducation.org/parents/bkgrnd2.html#whatis.

Stipek, D. & Byler, P. (2004). The early childhood classroom observation measure. *Early Childhood Research Quarterly, 19,* 375 - 397.

Stipek, D., Daniels, D., Galluzzo, D., & Milburn, S. (1992). Characterizing early childhood education programs for poor and middle-class children. *Early Childhood Research Quarterly, 7,* 1-19.

Stipek, D., Daniels, D., Galluzzo, D., Millburn, S., & Salmon, J. M. (1998). Good beginnings:What difference does the program make in preparing young children for school. *Journal of Applied Developmental Psychology, 19,* 41-66.

Stipek, D., Feiler, R., Daniels, D., & Millburn, S. (1995). Effects of different instructional approaches on young children's achievement and motivation. *Child Development, 66,* 209-223.

Stockard, J. (2009). *Promoting early literacy of preschool children: A study of the effectiveness of Funnix Beginning Reading.* National Institute of Direct Instruction (Technical Report 2009-1).

Stockard, J. & Engelmann, K. (2008). *Academic kindergarten and later academic success: The impact of direct instruction* (Technical Report 2008-7). Eugene, OR: National Institute for Direct Instruction.

Stott, M. (Producer). (2002). *Shapes and colors.* United States: Brainy Baby, Inc.

Sunderman, G. L., Tracey, C. A., Kim, J., & Orfield, G. (2004). Listening to teachers: Classroom realities and No Child Left Behind. *Childhood Education*, *82*, 19-23.

Sutton-Smith, B. (2001). *The ambiguity of play.* Cambridge, Mass.: Harvard University Press.

Swanson, H. L., & Hoskyn, M. (1998). Experimental intervention research on students with learning disabilities: A meta-analysis of treatment outcomes. *Review of Educational Research, 68,* 277-321.

Tada, W. L., & Stiles, J. (1996). Developmental change in children's analysis of spatial patterns. *Developmental Psychology, 32*, 951–970.

Tamis-LeMonda, C. S, Uzgiris, I. C., & Bornstein, M. (2002). Play in parent-child interactions. In M. Bornstein (Ed.), *Handbook of Parenting: Practical Issues in Parenting* (vol. 5, 2nd ed., pp. 221-242). NJ: Lawrence Erlbaum Associates.

Texas Center for Educational Research (1997). *Reading programs for students in the lower elementary grades: What does the research say?* Austin, TX: TCER.

Thomas, B. (1982). *An abstract of kindergarten teachers' elicitation and utilization of children's prior knowledge in the teaching of shape concepts*: Unpublished manuscript, School of Education, Health, Nursing, and Arts Professions, New York University.

Tudge, J. & Doucet, F. (2004). Early mathematics experiences: Observing young black and white children's everyday activities. *Early Childhood Research Quarterly, 19,* 21-39.

Uttal, D. H., Liu, L. L., & DeLoache, J. S. (1999). Taking a hard look at concreteness: Do real objects help children learn? In C. Tamis-LeMonda & L. Balter (Eds.), *Child psychology: A handbook of contemporary issues* (pp. 177-192). Hamden, CT: Garland.

Uttal, D., O'Doherty, K., Newland, R., Hand, L. L., & DeLoache, J. (2009). Dual representation and the linking of concrete and symbolic representations. *Child Development Perspectives, 3,* 156–159.

van Hiele, P. M. (1986). *Structure and insight: A theory of mathematics education*. Orlando, FL: Academic Press.

Vinovskis, M. A. (1999). Do federal compensatory education programs really work? A brief historical analysis of Title I and Head Start. *American Journal of Education, 107,* 187 -

Vygotsky, L.S. (1978). *Mind and society: The development of higher mental processes.* Cambridge, MA: Harvard University Press.

Waldron-Soler, K., Martella, R., Marchand-Martella, N., Tso, M., Warner, D., & Miller, D. (2002). Effect of a 15-week Language for Learning implementation with children in an integrated school. *Journal of Direct Instruction, 2,* 75 – 86.

Watkins, C.L. (1997). Project Follow Through: A case study of contingencies influencing instructional practices of the educational establishment. Cambridge, MA: Cambridge Center for Behavioral Studies.

Watson, T. & Hempenstall, K. (2008). Effects of a computer based beginning reading program on young children. *Australasian Journal of Educational Technology*, *24*(3), 258-274.

Wells, G. (1999). *Dialogic inquiry: Towards a sociocultural practice and theory of education.* New York, NY: Cambridge University Press.

Wells, G. (2002). Dialogue in activity theory. *Mind, Culture, and Activity, 9,* 43 – 66.

What Works Clearing House (2007). *Direct Instruction, DISTAR, and Language for Learning*. Washington, D.C.: US Dept. of Education, Institute of Educational Sciences.

What Works Clearing House (2008). *Tools of the Mind.* Washington, D.C.: US Dept. of Education, Institute of Educational Sciences.

White, W. (1988). A meta-analysis of the effects of direct instruction in special education, *Education and Treatment of Children, 11,* 364 – 374.

Wisler, C., Burns, G.P.,Jr.,& Iwamoto, D. (1978). FT redux: A response to the critique by House, Glass,McLean, & Walker. *Harvard Educational Review, 48,* 171-185.

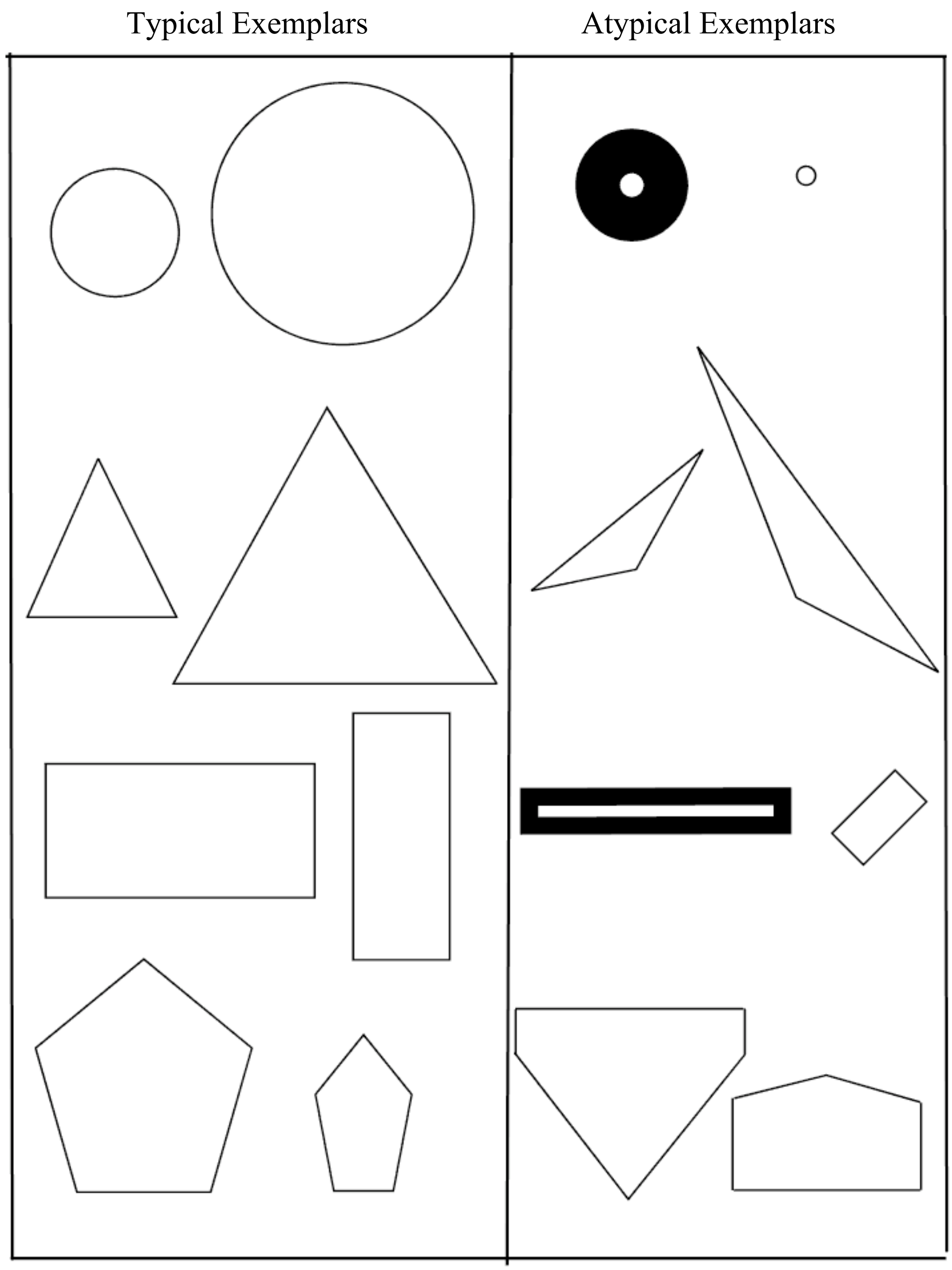
Wolfgang, C.H., Stannard, L.L., & Jones, I. (2003). Advanced construction play with LEGOs among preschoolers as a predictor of later school achievement in mathematics. *Early Child Development and Care, 173,* 467-475.

Wood, E. (2009). Conceptualizing a pedagogy of play: International perspectives from theory, policy, and practice. In D. Kuschner (Ed)., *From children to red hatters;*

Diverse images and issues of play: Vol. 8. Play & Culture Studies. New York, NY: University Press of America.

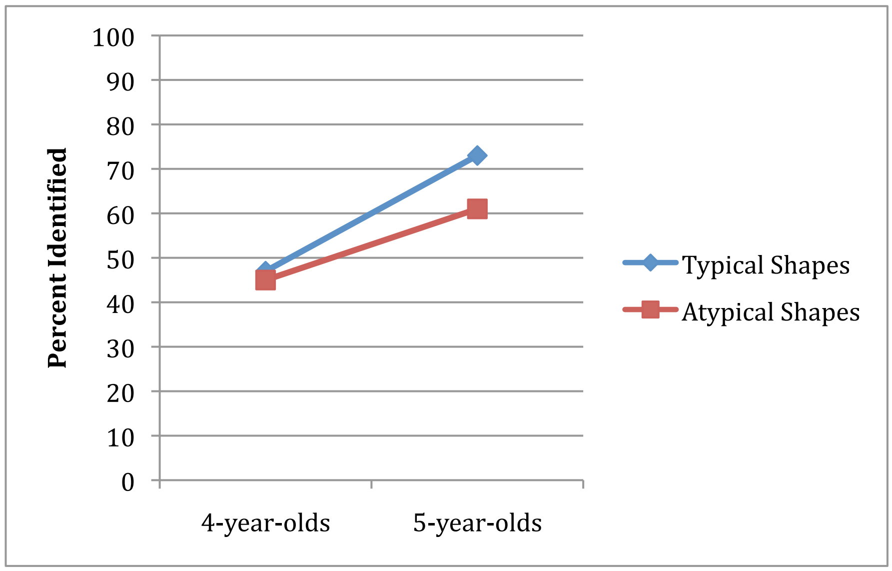
APPENDIX A

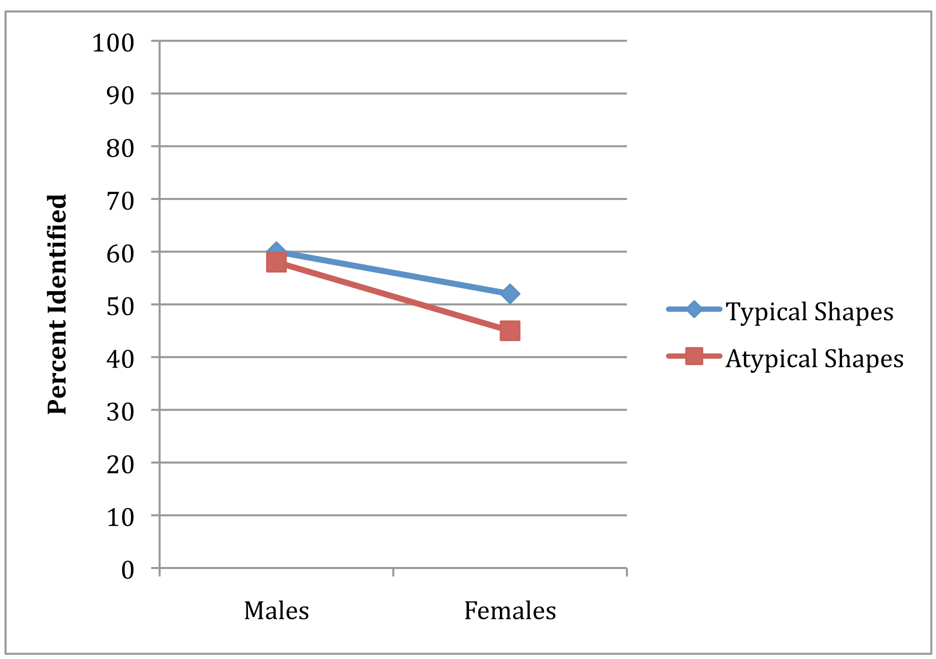
EXPERIMENT 1: SHAPE TRAINING STIMULI



APPENDIX B

EXPERIMENT 1: AGE AND GENDER DIFFERENCES ON THE EMBEDDED SHAPES TASK



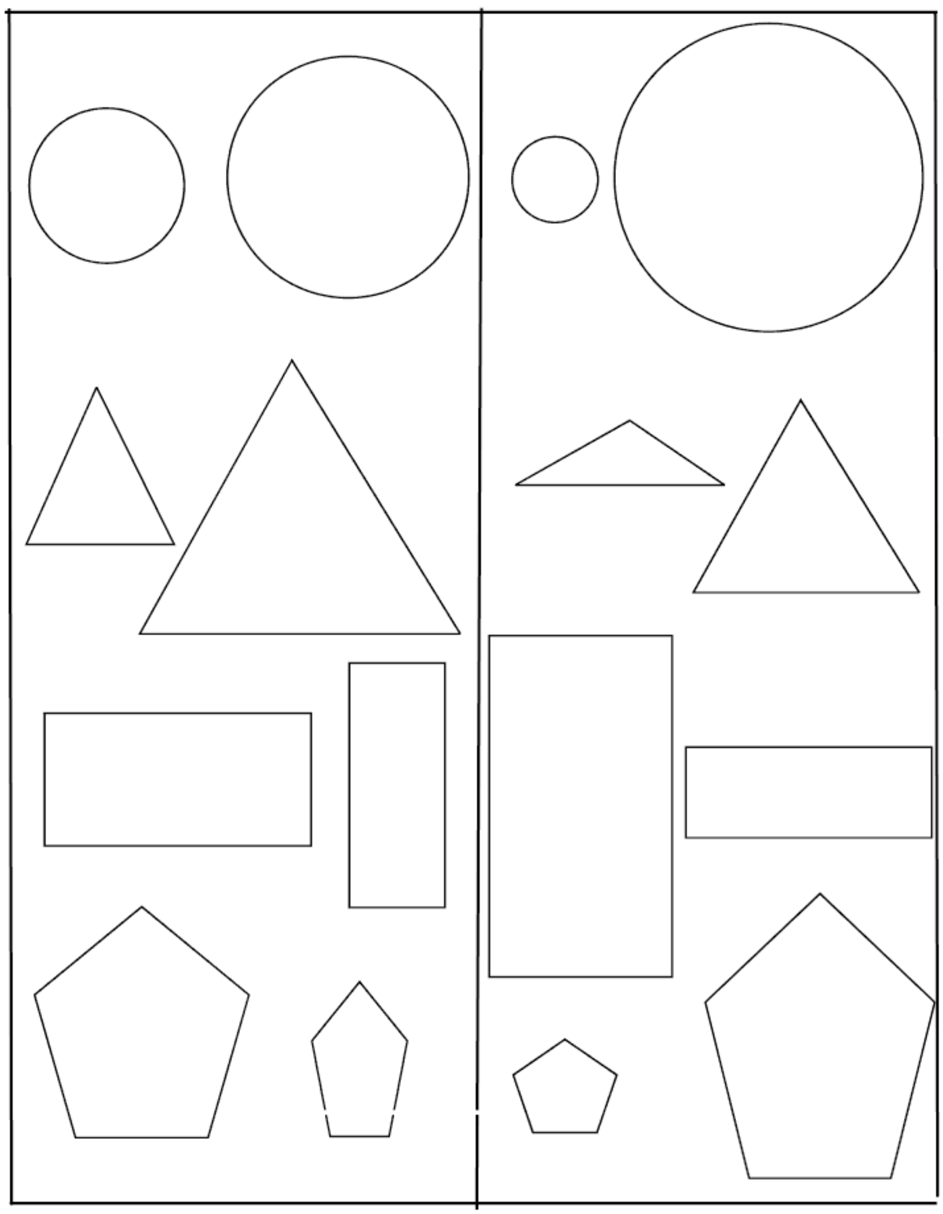


APPENDIX C

EXPERIMENT 2: SHAPE TRAINING STIMLUI

Typical Exemplars *(Original to preliminary study)*

New Typical Exemplars



APPENDIX D

EXPERIMENT 3: RECRUITMENT PACKET & CONSENT FORMS

(EXPERIMENT 1 & 3: SAME CONSENT FORMS)

Dear Parent or Guardian,
We invite you and your child to participate in an exciting new research opportunity happening at your child's school!

Who are we? We are a developmental research center directed by nationally recognized authorities and professors on child development, Drs. Kathy Hirsh-Pasek and Nora Newcombe. Our research has been featured on TV shows like *The Today Show*, *The View*, *20/20, Channel 10 NBC News,* and published in magazines like *Parents*, *Child*, and *Working Mother*. We have published several books for parents and teachers to share what we have learned through our research.

What are we studying? Our research is aimed at understanding *how* children learn. We ask questions such as, "What contexts influence children's quality of learning?" and "What types of learning materials work best?" By participating in this research, you will help us understand how to best teach academic readiness skills.

What will my child and I do? Your child will be taught a lesson by a researcher during the school day. After the lesson, your child will be asked to recall what s/he has learned in several fun, game-like tasks. The entire process will take approximately 20 minutes per child. Additionally, we will return to your child's school one week later to see how much each information your child remembers. Your child's name and responses are kept completely confidential. We do not look at how a particular child scores on each task. Instead, we look at how children score on average, and how they improve over time.

I am interested, what should I do now? We will be conducting research on how different teaching approaches influence children's learning at your center from ______________________ *to* _________________________. We are particularly interested in recruiting *4 & 5 year-old children* for the current study. Please read and sign the attached consent forms and the parent questionnaires. Return the consent forms & questionnaire in the enclosed envelope to your child's preschool teacher by ________________________________ If you have any questions, please call us between 9am and 5pm at (267) 468-8610 or email Kelly Fisher, at kelly.fisher@temple.edu.

Thank you for taking the time to read about our project. We hope that you will be interested in assisting us with our research!

Sincerely,

Kelly Fisher, Ph.D. Candidate, Temple University
Kathy Hirsh-Pasek, Ph.D., Temple University
Nora Newcombe, Ph.D., Temple University

CONSENT FORM: PARTICIPATION (Child)

Project Title (#12745): Exploring the Mechanisms of Guided Play

Investigator: Kathy Hirsh-Pasek, Ph.D., Temple University Dept. of Psychology, 267-468-8610

Nora Newcombe, Ph.D., Temple University Dept. of Psychology, 267-468-8610

Please take a moment to fill out this consent form so that you can participate in our research. This study examines how different teaching methods help children learn. During the experiment, your child will be taught a simple lesson on how to identify and make geometric forms. We will also return to your child's school one week later to examine the long term retention of learning. All results will be tallied at the group level rather than by individual response. Participant data will be maintained indefinitely and possibly deposited in data sharing banks. If you or your child would like to stop the experiment, let us know. You are free to quit the experiment at any point. There are no known risks associated with this study beyond the risks of everyday life. This research will be used to inform child development experts about the relation between teaching practices and early learning, as well as give your child the chance to have a positive and educational experience.

Let me take this moment to thank you for joining us in the exciting process of scientific discovery. If you have any questions about language development or about this experiment in particular, please give me a call: 267-468-8610. If you would like further information regarding the rights of a research subject, you may contact Richard Throm at (215) 707-8757.

I, ________________________________(name), agree to let my child, ______________________, participate in this study of reading behavior with Drs. Kathy Hirsh-Pasek and Nora Newcombe. As part of the research, I agree to let my child be videotaped and understand that the videotape will be used for research and educational purposes only. Our names will be kept confidential at all times.

____

Signature of Parent/Guardian | Date | Child's Date of Birth

Thank you,

_________________________________ ____________________

Principal Investigator Signature | Date

_________________________________ ____________________

Authorized Representative Signature | Date

Demographic Information

Child's Information

Child's name: ______________________________

Child's birth date: ______________ Child's gender: Female ____ Male ____

Does your child have any medical complications, developmental, or learning disabilities? If so, please explain. ____
____
____
____

Family's Information:

1. Parent's education (highest level completed):

Mother:	*Father:*
_____ some high school	_____ some high school
_____ high school graduate	_____ high school graduate
_____ trade/vocational school	_____ trade/vocational school
_____ some college	_____ some college
_____ college graduate	_____ college graduate
_____ graduate school graduate	_____ graduate school graduate
_____ currently in school	_____ currently in school
_____ other	_____ other

2. Parent's Age: *Mother*_______ *Father*________

3. Parent's Employment:
   Mother: __________ hours per week *Father*: __________ hours per week

4. Ethnic Group:

Mother:	*Father:*
_____ African-American	_____ African-American
_____ Asian/Pacific Islander	_____ Asian/Pacific Islander
_____ Caucasian/White	_____ Caucasian/White
_____ Hispanic/Latino	_____ Hispanic/Latino
_____ Other	_____ Other
_____ Unknown	_____ Unknown

Thank you for participating in our research!

Shape Knowledge and Drawing Questionnaire

Questions Pertaining to Your Child

1. Does your child draw? (circle one) (a) Yes (b) No

2. If yes, how often? (circle one)
   (a) Several times a day (b) once a day (c) once every other day (3-4 times per week)
   (d) twice a week, (e) once a week (f) 2-3 times per month (rarely draws)

3. If s/he draws, what medium does your child use? (check all that apply)
   ___crayons ___ colored or graphite pencils ___ markers ___chalk ___pens
   ___ computer programs or toys used for drawing/sketching
   ___ Other:____

4. What figures are commonly seen in your child's drawings? (check all that apply)
   ___scribbles ___lines ___circles ___squares ___dots ___triangles
   ___ other geometric shapes: ____

5. Can your child recognize shapes? If so, which ones? ______________________________
   ____

6. Does your child have any toys or books that teach shapes? (a) Yes (b) No

7. If so, what kinds of toys or books does your child have that teaches shapes? ___________
   ____
   ____

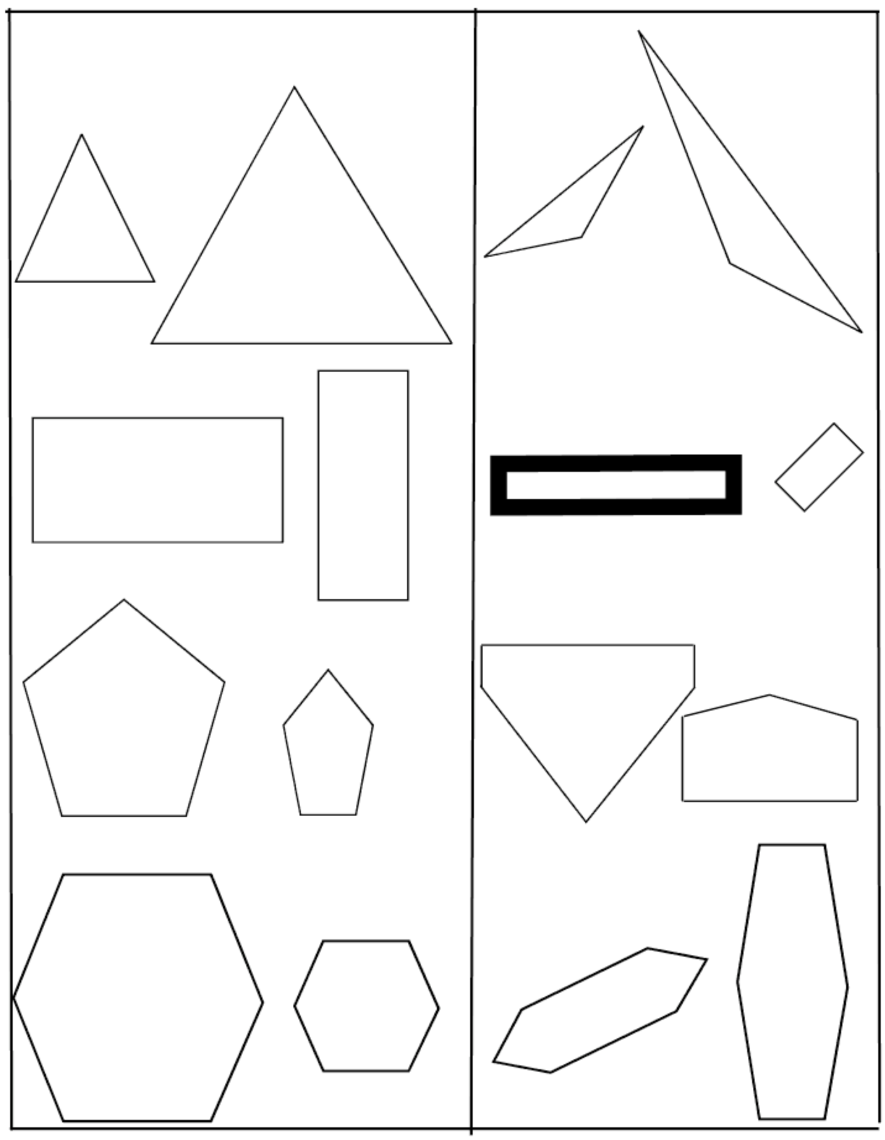
8. Have you or another person taught your child about shapes? (Circle all that apply)
   (a) Parent (b) guardian (c) teacher (d) sibling (e) camp (f) daycare or learning program
   (g) Other: ____
   ____

9. If your child draws in the presence of others, what does your child do while drawing? (check all that apply)
   ___ Describe the visual elements of his/her drawing (e.g., this is a cloud, this is a car)
   ___ Instruct how to draw the visual elements in his/her drawing (e.g., you draw a cloud with bumpy lines)
   ___ Tell a story about his/her drawing
   ___ Asks other individual's opinions about his/her drawing (e.g., whether they like it, how to draw something, etc)
   ___ Examine other's work (e.g., looking at another's artwork, commenting on it, getting ideas for their own artwork, etc)
   ___ Sits quietly while drawing
   ___ Other: ____

APPENDIX E

EXPERIMENT 3: SHAPE TRAINING STIMLUI

Typical Exemplars	Atypical Exemplars
(Hexagons-New)	*(Hexagons-New)*
(Others Original to Preliminary Study)	*(Others Original to Preliminary Study)*

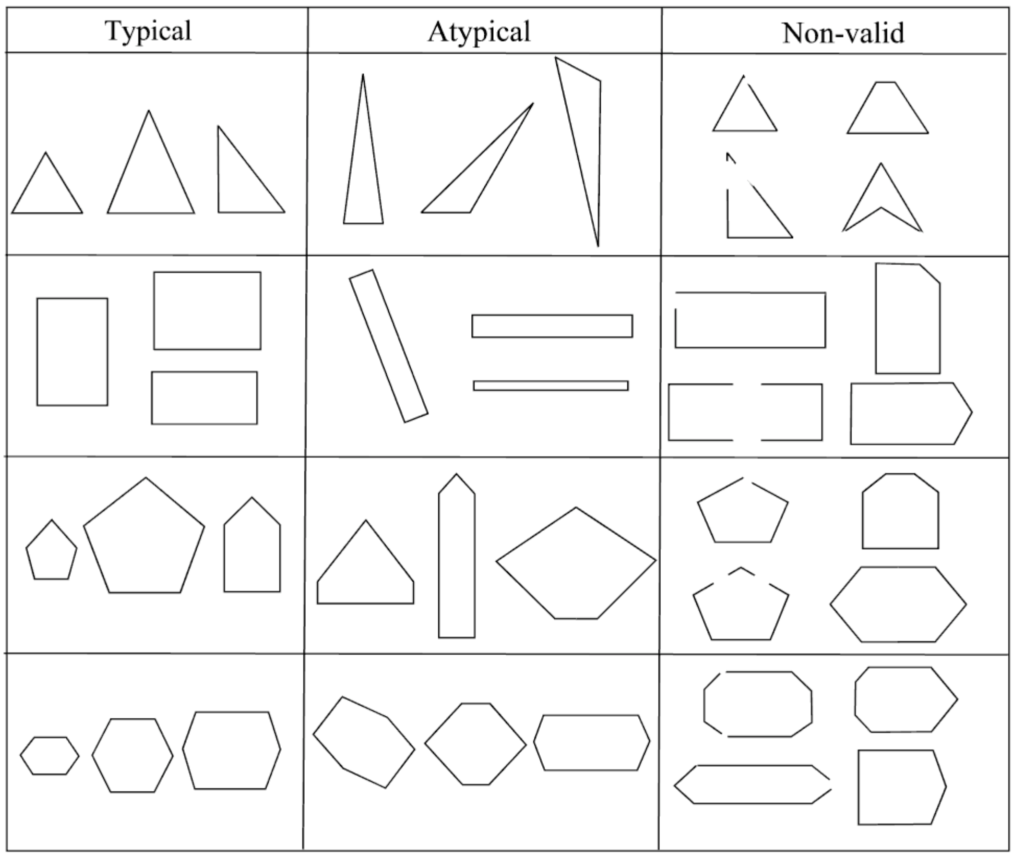


APPENDIX F

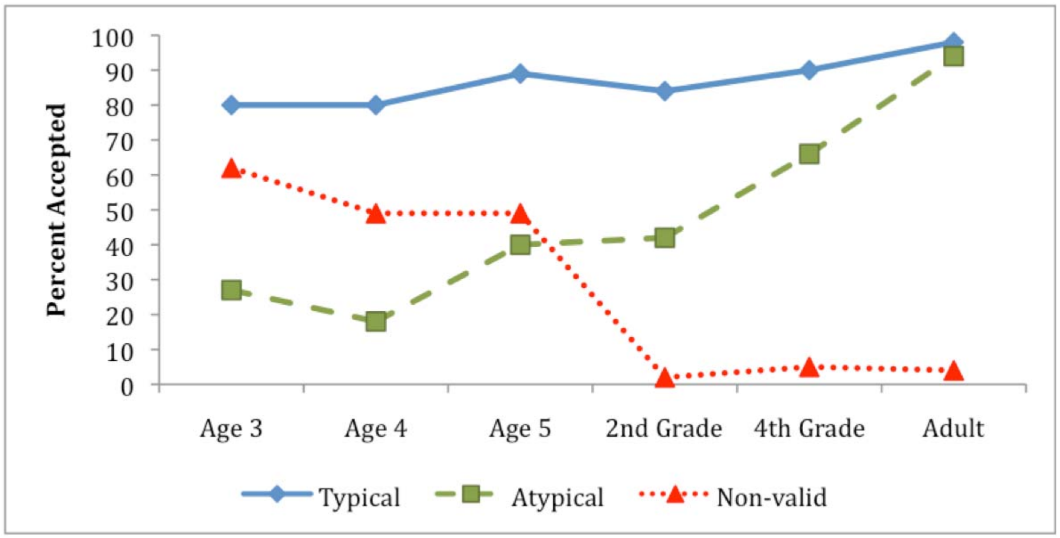
EXPERIMENT 3: SHAPE SORTING TASK STIMULI

Shape sorting cards used for shape knowledge test

(adapted from Satlow & Newcombe, 1998)



APPENDIX G
RESULTS FROM SATLOW & NEWCOMBE (1998)



Percent of instances accepted by all participants from Satlow & Newcombe (1998) across exemplar type.