

WAYS DIGITAL SCAFFOLDS ARE USED DURING COLLABORATIVE  
PROBLEM SOLVING IN THE PRESCHOOL CLASSROOM

By

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To my husband, Bill, and children, Cai and Lilianna, for their patience and encouragement; to the rest of my family and friends who supported me along my journey, thank you; and to my dear friend and colleague, Dawn Weinman, whose unwavering faith in me saw me through to the end

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By

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Chair: Kara Dawson  
Major: Curriculum and Instruction

This descriptive mixed-methods study examined the ways preschool dyads use scaffolds built in to the digital game Rush Hour® when problem solving. Twelve dyads of students played the game during learning centers within the natural classroom environment. Findings reveal preschool children use demonstration, reduction in degree of freedom, and frustration control scaffolds to reduce frustration and extend time spent problem solving. The use of digital scaffolds helped facilitate game play about 1/3 of the time.

In-depth analysis of video recordings and student interviews reveals overall tool use was more non-verbal than verbal, more personal than collaborative, and mostly intentional. Children identified as mid-level problem solvers used tools the most, and the demonstration scaffold (Solve) was used by the most number of dyads. While Solve provided some help, overall, it was found to be developmentally inappropriate for the age group of this study as the speed of the demonstration was too fast paced and the number of moves to be remembered too many.

Further analysis looked at the ability level of preschool dyads to determine in what ways ability level might impact how digital scaffolds are used during problem solving. Of the twelve dyads participating in this study, six were paired with same-ability partners (Class A) while six were paired with mixed-ability partners (Class B). Significant differences in how the two classes used digital scaffolds were found. Mixed-ability dyads displayed more help seeking behaviors by using more digital scaffolds (4:1). Same-ability dyads completed more puzzles, solved puzzles more efficiently, and displayed more collaborative behaviors.

This study is significant in that it provides insight into how early childhood educators can use gaming applications with built-in digital scaffolds within developmentally appropriate practice to promote problem solving. It confirms the important role teachers play in partnering students during collaborative work and affirms the need for teachers to explicitly teach students how to use help tools. Finally, it reminds teachers that they must critically examine all aspects of digital games including built-in help tools before integrating them into their classrooms.

## CHAPTER 1 INTRODUCTION

The last ten years has seen an increased call for ubiquitous computing in education via one-to-one laptop programs and handheld devices such as the iPad (Berson & Berson, 2010; Chatel, 2005; Couse & Chen, 2010; Johnston, Adams, & Cummins, 2012; Zevenbergen, 2007). These devices are seen not only as ways to promote technological literacy but also as learning tools with the capacity to increase student achievement (Clements & Sarama, 2003; Fishburn, 2008; Staudt, 2005; Johnston et al., 2012). The majority of current research on computers and other technology tools is related to the K-12 environment. Little attention has been paid to their potential role in the preschool setting focused on children ages three to five years, especially in how they support collaborative problem solving and peer learning (Kamil & Intrator, 1998; Lankshear & Knobel, 2003; McCarrick & Li, 2007; Yelland, 1999).

### **Developmentally Appropriate Practice**

#### **Definition**

Since 1986, the National Association for the Education of Young Children (NAEYC) has helped define high quality early childhood programs serving children from birth to age eight through its developmentally appropriate practice (DAP) framework (NAEYC, 2009). The principles and guidelines outlined in the framework are based primarily on Piaget's developmental stage theory proposing a "normative course of development" (Copple & Bredekamp, 2009, p. 11) in which children gain specific concepts, skills, and abilities in a sequential fashion, as well as constructivist views that learning is an active process in which learners build or construct new ideas or concepts based upon previous knowledge and

experiences (Schuh & Barab, 2008; Vygotsky, 1978). Both of these views promote play as the primary vehicle of engagement in the early childhood classroom and confirm the instrumental role classroom teachers play in planning and preparing the learning environment to foster developmentally appropriate experiences (Epstein, 2007; Johnson, Christie, & Wardle, 2005). It is the intentional teacher who purposefully plans learning experiences based on developmental stages, individual needs, and an understanding of the social and cultural contexts shaping children's lives both in and outside of the school environment (Berk & Winsler, 1995; Copple & Bredekamp, 2009; Epstein, 2007; NAEYC, 2009). The intentional teacher looks not only at *how* to teach but also thinks about *what* to teach (Epstein, 2007).

### **Role of Play**

Play is the means by which children learn new concepts through exploration and problem solving, express individual thoughts and ideas, and connect with others (Johnston et al., 2005). There are many types of play such as motor, object, collaborative, and symbolic, each with its own benefits to development (Johnston et al., 2005; NAEYC, 2009). Computers and technology tools such as the iPad offer new play possibilities, which can benefit development, when used appropriately (Johnson & Christie, 2009; NAEYC, 2009; NAEYC, 2012; Wright & Shade, 1994). As with any material or instructional tool introduced into the preschool classroom, teachers must first, ask if the tool is developmentally appropriate and consistent with the child's developmental stage, and second, determine what benefits are derived by its use

(Allen & Blake, 2010; Chiasson & Gutwan, 2005; Clements & Sarama, 2003; Haugland, 2000; NAEYC, 1996).

### **Role of Technology**

In 1996, NAEYC recognized computers as learning tools that can be used to compliment traditional hands-on learning activities such as art, blocks, musical explorations, and dramatic play when embedded within in a DAP framework (NAEYC, 1996). Fifteen years later, NAEYC along with the Fred Rogers Center for Early Learning and Children's Media, revised the 1996 technology statement because young children are being shaped by everyday interactions with technology and digital media (Berson & Berson, 2010). The need to ensure technology is developmentally, individually, and culturally appropriate and meaningful in this digital age of digital natives is more pressing than ever (Fleer, 2011; Palfrey & Gasser, 2008; Prensky, 2001b; Prensky, 2010; Zevenbergen, 2007). The NAEYC position statement recommends:

Early childhood educators provide a balance of activities in programs for young children and that technology and digital media be recognized as valuable tools to be used intentionally with children to extend and support active, hands-on, creative, and authentic engagement with those around them and with their world.  
(NAEYC, 2012, p. 11)

In addition to redefining the word 'technology' and emphasizing the importance of technological and media literacy, specific recommendations for early childhood technology beyond computer centers in the classroom were made. These include the use of handheld devices with touch screens, digital and video cameras, electronic books (e-books), digital storytelling, and video conferencing as ways for children to express creativity, participate in language experiences, and document learning (NAEYC, 2012).

## **Potential of Touch Devices**

Touch technologies, such as the iPad, are of particular interest to early childhood educators at this time. These devices, when embedded in developmentally appropriate practice, can expand play opportunities currently offered in early childhood classrooms (Geist, 2012; McManis & Gunnewig, 2012; NAEYC, 2012). Preliminary studies indicate the simple gestures needed to operate the touch screen are a more natural and direct way of interaction for young children (Geist, 2012; Hourcade & Hansen, 2009). The tactile interface is easy to use, and in line with how children learn through touch and exploration (Buckleitner, 2010; Chiong & Shuler, 2010; Couse & Chen, 2010; Geist, 2012; Lu & Frye, 1992; Yu, Zhang, Ren, Zhao & Zhu, 2010). The portability and size of the iPad allows students to be mobile, providing opportunities to extend exploration into many different contexts (Chen, Tan, Chee-Kit, Zhang, & Seow, 2008; Figg & Burson, 2005; Geist, 2012; Ng & Nicholas, 2009). This mobility also allows students to seek support from teachers and peers as needed (Fritz, 2005). Finally, the many educational apps available on the iPad offer students the ability to work at their own pace on tasks structured to meet individual learning goals, as well as explore and play games that offer collaborative opportunities to think critically and problem solve (Banister, 2010; Geist, 2012; Hisrich & Blanchard, 2009).

## **Problem of Practice**

Educators need 'research-based evidence' to help in the intentional planning of technology-related learning experiences in the preschool classroom so they are open-ended, promote discovery, and encourage problem solving



(Epstein, 2007; Lieberman, Fisk, & Beily, 2009; NAEYC, 2012). Additionally, these learning experiences need to be developmentally appropriate, built on the natural ways young children play and learn best (Lieberman et al., 2009). Therefore, during the 2011-2012 school year, the researcher conducted a qualitative study to examine the social interactions and scaffolding behaviors exhibited by preschool children when using the iPad to play the problem solving game Rush Hour<sup>®</sup>. Twenty-two random dyads (pairs) were observed playing the sliding-block puzzle game during learning centers in the natural classroom environment. Analysis of video and audio transcripts showed student dyads sharing one iPad exhibited more scaffolding and collaborative behaviors than students sitting side-by-side with two iPads, while students working side-by-side with two iPads displayed more positive social talk.

An unexpected finding emerging from the study was related to how some students used the built-in help tools within the game Rush Hour<sup>®</sup>, such as the Hint and Solve buttons, as a means to complete a puzzle. What was noteworthy about these behaviors was how many students figured out how to use these tools on their own through exploration or by observing and communicating with his/her partner rather than through direct instruction from the classroom teacher. These observed behaviors are in line with the theory of constructivism, which proposes children learn through assisted discovery while engaged in talk and collaboration with others (Schuh & Barab, 2008; Vygotsky, 1978). These behaviors also provide insight into the help seeking process. Learning how to independently seek help is an essential life skill that contributes to both social and cognitive development (Gall & Schieb, 1985). Help seeking also serves as a

strategy for self-regulated learning (Gall, 1981; Puustinen, 1998). As it appears, built-in help tools have the potential to serve as scaffolds and extend thinking, further investigation into how these digital game tools can foster problem solving and promote collaborative play in the preschool environment is needed (Aleven, Stahl, Schworm, Fischer & Wallace, 2003; Hung, Yu, Chang & Cheng, 2012; Karabenick, 2011; Sun, Wang, & Chan, 2011).

Collaborative play is the means by which students learn to take turns, negotiate with peers, problem solve, share their points of view and make decisions with others (Johnson et al., 2005). Additionally, opportunities for students to “solve problems together, talk about what they are doing, help and teach friends, and create rules for cooperation” are critical to language development (Epstein, 2007, p. 15). The examination of different strategies for creating collaborative partnerships when using iPads is needed to provide empirical data specific to best practices related to promoting cognitive, social, and language development with these handheld tools. The majority of research related to preschool dyads in collaborative problem solving found throughout the literature is not specific to problem solving in a technology-related play context nor does it capture preschool students in authentic child-centered settings (Azmitia, 1988; Holmes-Lonergan, 2003; Johnson-Pynn & Nisbet, 2002; Muller & Perlmutter, 1985; Perlmutter, Kuo, Behrend, & Muller, 1989; Ramani, 2005; Ramani, 2012; Verba, 1998).

## Capstone Description

### Purpose

The purpose of this research study was to examine the ways preschool children use digital scaffolds or tools built-in to problem solving games on the iPad, such as Rush Hour<sup>®</sup>, in naturalistic settings. In addition to identifying how the use of iPads and problem solving applications (apps) fit into developmentally appropriate practice, this capstone examined how student dyads with different problem solving abilities used digital scaffolds in daily learning centers during the school day. The following research questions guided this capstone project:

Research Question 1: In what ways do preschool dyads use digital scaffolds when playing the problem solving game Rush Hour<sup>®</sup>?

Research Question 2: In what ways does the ability level of preschool dyads impact how digital scaffolds are used when playing the problem solving game Rush Hour<sup>®</sup>?

### Context

This capstone project was conducted in two Junior Kindergarten (JK) (age 4/5) classrooms in the Early Childhood Center (ECC) of a college preparatory school with a total enrollment of 27 students. Each class was randomly assigned to one of two conditions by flip of a coin. Participants in one class (n=12) were matched with same-ability partners (high-high, middle-middle, low-low), while participants in the second class (n=12) were matched with mixed-ability partners (high-low, middle-low or high-middle). The ability groups, established by the classroom teachers, were created based on anecdotal records, observations, and ratings from academic progress reports. Three students were excluded from the study. One student did not have parental consent to participate. Two

students, who were repeating the JK year, participated in the researcher's study the previous year utilizing the game Rush Hour®.

## **Research Design**

As the purpose of this study was to capture what is happening in the natural classroom setting as preschool children work with the game Rush Hour® on the iPad, a descriptive research design with a mixed-methods framework was utilized. A review of journals within the field of educational technology finds descriptive research as holding “an important place in the study of human interaction and learning” because the educational experience cannot be fully analyzed in controlled settings (Knupfer & McLellan, 1996, p. 1196). The simple ‘what is’ approach of descriptive research provides a powerful framework to examine what takes place in educational settings without focusing on extraneous variables that cannot be easily controlled (Knupfer & McLellan, 1996). Sandelowski (2000) also acknowledges the comprehensive nature of descriptive research and its power to summarize “events in the everyday terms of those events” (p. 334).

Quantitative data via game statistics built into the Rush Hour® game and researcher observations was collected first to summarize data related to game play including the frequency with which students used digital help tools when playing the game Rush Hour®, variances between how different tools were used, and the ratio of puzzles completed with and without help. Qualitative analysis of the video recordings along with informal interviews of each partnership after game play looked more closely at the intent or why behind student actions (Creswell, 2009). Further analysis of both sets of data looked at differences in

behavior between homogenous (same ability) and heterogeneous (mixed ability) partnerships.

### **Limitations**

The size of this study is small (n=24), and the sample used is one of convenience. Therefore, the results are specific to the private preschool program described in the Context section above and described in greater detail in Chapter 4. Findings are most applicable to other preschool programs similar in size. It may also be difficult to generalize findings from this study to other preschool programs with different student demographics and/or academic programs not grounded in DAP. Nonetheless, the study offers insight into how young children use scaffolds built into digital games during collaborative problem solving.

### **Significance of Research**

#### **Supporting Developmentally Appropriate Practice**

The ever-changing technology landscape is transforming how people live their lives and communicate with each other and the world around them. Technology has also become ubiquitous in the lives of young children (Banister, 2010; Berson & Berson, 2010; Prensky, 2001b). Technology tools and interactive media such as the iPad are finding their way into early childhood classrooms, and teachers are being challenged to utilize these tools to enhance learning (McManis & Gunnewig, 2012). Unfortunately, these same teachers often have little to no training or support on how to fit their use into best practices and rely on anecdotal information to help with integration (Shifflet, Toledo, & Mattoon, 2012). While anecdotal information plays an important role in helping educators feel more comfortable with technology use in their classrooms,

empirical research in the early childhood context is needed to ensure technology and media tools are used effectively and appropriately (NAEYC, 2012).

Like NAEYC, Lieberman et al. (2009) call for more theory-driven research on digital media for young children, acknowledging many digital media and games are not developmentally appropriate nor do they “recognize or build on the ways young children play and learn” (Lieberman et al., 2009, p. 301). They suggest research teams be comprised of game designers as well as game scholars and recommend involving young children “as game design partners” (Lieberman et al., 2009, p. 301). There is also a call for “longitudinal studies of large numbers of children to identify long-term trends” as well as to determine how learning with digital media transfers to other learning activities and settings (Lieberman et al., 2009, p. 282). Hong, Cheng, Hwang, Lee and Chang (2009) also suggest developers, educators, and researchers collaborate to “ensure games are an effective learning tool” (Hong et al., 2009, p. 431). Finally, Cooper (2005) recommends the criteria used to evaluate digital environments follow the same criteria as other early childhood learning environments. Developmentally appropriate digital environments need to be active and user friendly, supportive of social interactions, and should offer opportunities to explore, experiment, make decisions, and problem solve. Additionally, quick feedback as well as progressive levels “offering new challenges built on previous learning” can help make digital games a powerful tool for learning (Cooper, 2005, p. 298).

### **Potential of Digital Scaffolds**

A prevalent behavior noted during game play in the preliminary study was related to the students using built-in tools such as the Hint, Solve, Reset, and

Next buttons as a means to complete a puzzle. These help tools can be viewed as digital or technical scaffolds with the potential to support students during game play and learning “by facilitating understanding and problem solving” (McManis & Gunnewig, 2012, p. 21). In an interview with classroom teachers, they considered the use of these help tools as a negative behavior of game play, going so far as to call the use of the tools as ‘cheating’. However, when examined from the perspective of constructivist learning these tools can serve as scaffolds to support and extend student learning.

Research related to the impact of digital scaffolds in games on problem solving behaviors is emerging in the literature. Sun, Wang, and Chan (2011) found digital scaffolds increase “the level at which puzzles could be solved” when sixth graders played a digital Sudoku game (Sun et al., 2011, p. 2118). Hung, Yu, Chang, and Cheng (2012) looked at digital scaffolds when elementary school children played a geography puzzle game on a multi-touch display. Their pre-test/post-test design found digital scaffolds supported “increased learning performance” and “prevented students from being stuck” (Hung et al., 2012, p. 37). Bottino, Ferlino, Ott, and Tavella (2007), in their longitudinal work with second graders using computer games, found software features such as backtracking tools and tips were supportive in helping students construct strategies while problem solving.

While these findings demonstrate the potential of digital scaffolds to support learning, developmental differences between school-aged children and preschool children along with how different ages approach learning tasks must be considered. As more and more digital games are used in the preschool

classroom, research is needed to better understand how digital scaffolds within games can support problem solving behaviors with young children.

### **Ability Groupings**

Ability grouping, the process of grouping students in groups by skill or achievement, is a recognized strategy for pairing students during collaborative problem solving activities across educational contexts (Azmitia, 1988; King, Staffieri, & Adelgais, 1998; Light & Littleton, 1998; Schmitz & Wimschel, 2008, Slavin, 1987). Several studies within the literature are specific to the early childhood classroom (Azmitia, 1988; Cooper, 1980; Fawcett & Garton, 2005; Johnson-Pynn & Nisbet, 2002; Ramani, 2005). Most of these studies suggest mixed-ability groups (dyads in which partners are at different cognitive levels) learn at a greater rate than same-ability groupings (dyads in which both partners are at approximately the same cognitive level) but the findings between the different mixed dyad combinations (low-high, low-middle, middle-high) are not consistent.

A voice supporting equal ability peers in preschool problem solving tasks is Ramani (2005). In her study of four- and five-year-old peer dyads completing a child-driven building task with cardboard blocks, she found preschool children benefited by working with a peer of equal ability. What makes her study different than those cited above is the play-like setting in which her findings occurred. Ramani did not look specifically at ability groups but rather focused on the condition in which children collaborated together. Homogenous dyads constructing in a more playful condition built more complex and complete



buildings and participated in more communicative behaviors than those groups working in a more adult-guided building environment.

Findings regarding best practices in creating dyads during collaborative problem solving lean heavily toward the creation of mixed-ability groups. Yet, it cannot be assumed these findings will be replicated in a technological play environment where digital scaffolds can potentially change how students problem solve and interact with each other as well as the game. It must also be noted that the majority of findings regarding mixed-ability groups took place in experimental settings rather than in more natural classroom settings such as Ramani's study and as proposed in this capstone project. Johnson-Pynn and Nisbet (2002) suggest "comparing peer-tutoring and joint problem solving in different dyadic compositions, including those related to age, skills, social statuses, and experience" (p. 251), especially since such a large range of tutoring abilities and helping behaviors can be displayed by young children. Therefore, it is important to look at the ways preschool students use digital scaffolds in different dyad configurations to help shed light on which method best supports learning with problem solving games on the iPad in the natural preschool classroom.

### **Organization of the Study**

This study is organized into six chapters (Table 1-1). Chapter 1 provides an introduction to technology use through a developmentally appropriate framework in the preschool classroom and discusses teacher interest in using touch technologies, such as the iPad, to support learning with young children. The chapter also presents the problem of practice driving this study, provides a

description of the capstone project including its limitations, and highlights significant areas of research. Chapter 2 provides an in-depth evaluation of iPads specific to the preschool context to better understand how they can be integrated into the daily curriculum in developmentally appropriate ways. Chapter 3 presents literature related to game-based learning, problem solving, and the potential of digital scaffolds to support collaborative learning supporting this study's research questions. Chapter 4 outlines the descriptive design of this capstone project utilizing mixed methods. A description of the context, digital game, and participants is included along with the methodology for data collection and analysis. The chapter concludes with a discussion of the study's trustworthiness. Chapter 5 discusses findings related to how young children use digital scaffolds built into the game Rush Hour® to support collaborative problem solving while Chapter 6 provides a conclusion and suggests avenues for future research.

Table 1-1. Organization of capstone project

Chapter	Title	Summary
1	Introduction	Introduction to how iPads apps can be used to support collaborative problem solving in the preschool classroom along with an overview of the capstone project.
2	Background	Context specific to technology within a developmentally appropriate framework. Evaluates iPad features through the literature related to computers and mobile devices.
3	Literature Review	Examines how preschool students can use digital games during play to develop collaborative problem solving skills through a constructivist theoretical framework.
4	Methodology	Describes the context of the study and includes a description of data collection procedures and data analysis.
5	Findings	Presents findings related to the capstone study regarding how digital scaffolds built into the Rush Hour <sup>®</sup> game support collaborative problem solving.
6	Conclusions	Reflects on the findings of this study and their impact on future research.

## CHAPTER 2 BACKGROUND

The purpose of Chapter 2 is to provide a contextual background for examining how the iPad, with its touch interface and educational apps, can be integrated into the preschool curriculum. The chapter presents the unique learning needs of young children, reviews the research related to technology use in a developmentally appropriate preschool curriculum, and examines current practices utilizing handhelds and touch technologies.

For the purpose of this review, early childhood is defined as the period of development from birth to age eight while preschool is defined as a learning environment for children ages three to five years. Mobile devices are defined as small, portable computers that allow anytime, anywhere access. Mobile devices utilizing a stylus are referred to as handhelds within the literature while mobile devices using a touch interface are called touch devices.

Technological advances in the last half-century have drastically changed how people live, work, and communicate (Deal, 2008; Druin, 2009; Fleer, 2011; Palfrey & Gasser, 2008; Wohlwend, 2010). Technology has become omnipresent in the lives of young children too (Banister, 2010; Berson & Berson, 2010; O'Malley & Fraser, 2004; Prensky, 2001b; Zevenbergen, 2007). The saturation of mobile digital devices such as smart phones, MP3 players, and tablets means technologies are embedded in the everyday lives of young children, and their experiences with these devices are “creating very different learners than previous generations” (Zevenbergen, 2007, p. 1). Using the term “technology constructed childhood” to spark conversation about how childhood is changing, Fleer (2011) urges early childhood educators “to consider the

contemporary experiences of children from the 21<sup>st</sup> century when defining current early childhood curriculums” (p. 1).

In 1979, Russian American psychologist Urie Bronfenbrenner recognized the powerful role external environments play in shaping child development. While the immediate physical environment in which children live is critical to learning, they are also influenced by different activities and experiences, many over which they have no control. These various systems interact with each other and have the potential to affect the child, both positively and negatively (Bronfenbrenner, 1979). Bronfenbrenner’s ecological systems theory uses a nested framework to demonstrate how the child is embedded in these different contexts (Figure 1-1). This framework is particularly relevant in showing how the entrenchment of technology and digital media within our culture is shaping our values and beliefs, ultimately impacting our children and how they learn from the world around them (Berson & Berson, 2010).

While Bronfenbrenner’s theory supports how digital technologies and media can impact future generations, a ‘digital divide’ does exist between those who have access and can fully participate and those who cannot (Zickuhr & Smith, 2012). This divide is apparent when we think globally of those countries in the developing world. It is less apparent in our schools, where many school children have access. Here the problem is not access but participation. A participation gap exists because children who don’t have regular access and therefore lack the necessary skills to effectively participate. This includes technical skills, social skills, media literacy skills, and an understanding of the rules that guide participation (Jenkins, 2006). Schools can play an important role

in bridging this gap by promoting positive experiences with digital technologies into the daily curriculum (Palfrey & Gasser, 2008).

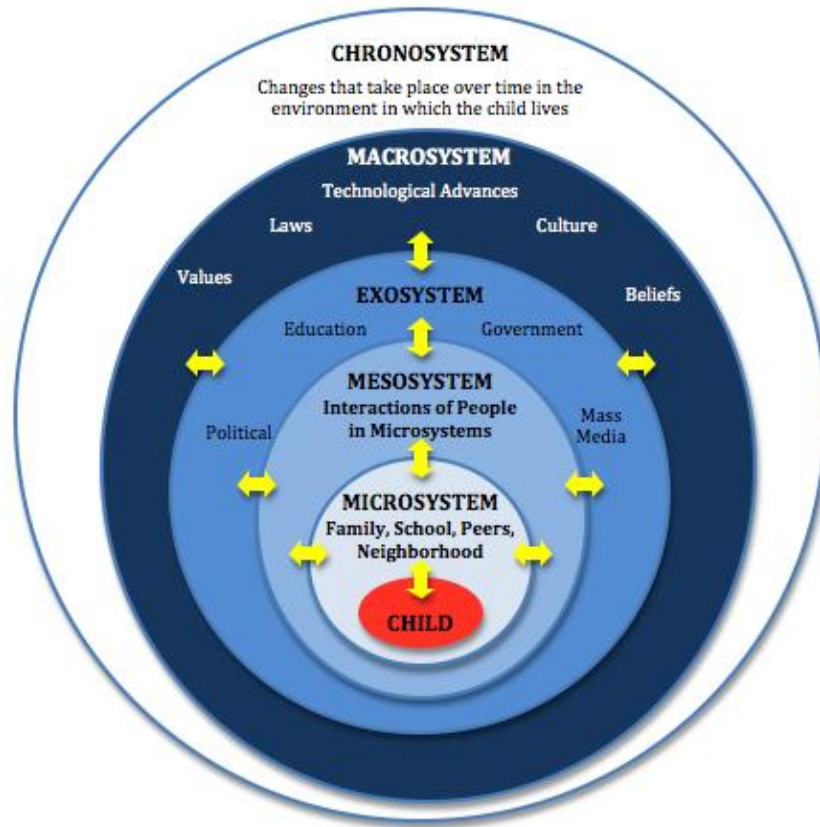


Figure 1-1. Model of Urie Bronfenbrenner's ecological systems theory

### **Developmentally Appropriate Practice**

#### **Definition**

Since 1986, the National Association for the Education of Young Children (NAEYC) has played an instrumental role in defining high quality early childhood programs serving children from birth to age eight through its framework, developmentally appropriate practice (DAP) (NAEYC, 2009). Subsequent position statements on curriculum, assessment, professional development, cultural diversity, media, and technology have also helped guide early childhood practitioners in creating learning environments responsive to the social,

emotional, physical and cognitive development of young children (NAEYC, 2009). DAP is built upon three key tenets grounded in the work of Jean Piaget and his Stage Theory of Cognitive Development and Lev Vygotsky's Sociocultural Theory.

1. Meet children where they are, both individually and as a group, by understanding learning and development and how they vary with age and developmental level (Copple & Bredekamp, 2006; NAEYC, 2009).
2. Identify challenging, achievable goals and help individual children meet them (Copple & Bredekamp, 2006; NAEYC, 2009).
3. Consider what is age, individually, and culturally appropriate for each child (Copple & Bredekamp, 2006; NAEYC, 2009).

Piaget believed young children move through fixed stages of development where they build a system to organize the world around them. Students assimilate similar objects and events or modify their mental structures to accommodate new ideas. Learning is always under construction and takes place through active manipulation of the world around them (Piaget & Inhelder, 2000). Children learn by exploring a variety of concrete materials, most often through play experiences (Copple & Bredekamp, 2009; Piaget & Inhelder, 2000).

Agreeing with Piaget, Vygotsky believed students form their own knowledge and that learning should correspond with the child's developmental level but did not believe this learning occurs in a vacuum (Vygotsky, 1978). Learning is also a social activity, and social and cultural factors are especially critical to the development of thinking and language (Vygotsky, 1978). He also promoted play as the primary vehicle of engagement for young children and discussed the instrumental role of classroom teachers in preparing the learning environment (Johnson et al., 2005). It is the early childhood educator who plans

experiences based on developmental stages, individual needs, and an understanding of the social and cultural contexts shaping children's lives outside of the school environment (Berk & Winsler, 1995; NAEYC, 2009).

### **Role of Play**

Play is at the heart of the DAP framework and is “considered a key facilitator for learning and development across domains and reflects the social and cultural contexts in which children live” (Isenberg & Quisenberry, 2002, p. 33). As a fundamental part of the early childhood curriculum, play is the avenue by which children learn new concepts and make sense of their world through exploration, express individual thoughts and ideas, and interact with others (Isenberg & Quisenberry, 2002; Johnston et al., 2005). Through play, children can “develop their symbolic and problem-solving abilities” (NAEYC, 2009, p. 14) as well as develop oral language skills and social competence.

There are many types of play such as physical, motor, social, pretend, symbolic, and constructive, each with its own benefits to development (Johnston et al., 2005; NAEYC, 2009). Computer and other technology tools also offer play possibilities that can enhance social, motor, emotional, and cognitive development when used appropriately (Clements, 1987; Haugland, 1992; Johnson & Christie, 2009; Wright & Samaras, 1986). Of course, as with any material or instructional tool introduced into the preschool classroom, teachers must first, ask if the tool is developmentally appropriate and consistent with the child's developmental stage, and second, determine what benefits are derived by its use (Allen & Blake, 2010; Chiasson & Gutwan, 2005; Clements & Sarama, 2003; Haugland, 2000; NAEYC, 1996).



## **Technology Embedded within DAP**

In 1996, NAEYC released its first position statement related to computers in the early childhood classroom. The key message of the statement proposes technology tools be used alongside traditional manipulatives and play materials such as sand and water, blocks, puzzles, play dough, arts and crafts, and dramatic play found in the classroom. “Computers do not replace highly valued early childhood activities and materials” (NAEYC, 1996, p.1) but rather serve as a viable option to enhance learning and development when embedded in DAP.

In 2012, NAEYC, supported by the Fred Rogers Center for Early Learning and Children’s Media, updated the 1996 technology statement because young children “are coming of age surrounded by information and communication technology” (Berson & Berson, 2010, p. 1). Recognizing computers are no longer the only technology available to young children, the updated statement broadens the concept of technology to include interactive media and asserts intentional use. Other key positions relate to the need for ongoing research and professional development, focused attention on digital citizenship and equitable access, and special considerations for technology and media use with infants and toddlers.

## **Historical Perspective of Technology Use**

Most research on computers and other technology tools is related to the K-12 environment. Little attention has been paid to their potential role in the preschool setting focused on children ages three to five years (Kamil & Intrator, 1998; Lankshear & Knobel, 2003; McCarrick & Li, 2007; Yelland & Masters, 2007). This lack of research is due in part to a long-standing debate amongst

educators, parents, and physicians about the possible negative effects of technology use.

Concerns related to computer use and young children cover the four developmental domains – cognitive, social/emotional, motor, and linguistic development. Threats include repetitive stress injuries; potential for obesity due to sedentary activity; visual strain from flickering and glare on the computer screen; reduced social skills due to isolation from peers; behavior issues related to reduced social skills; and language delays from limited social interactions (Alliance for Childhood, 2004; Cordes & Miller, 2000; Cuban, 2001; Elkind, 1996; Healy, 1998; Miller, 2005; Pendleton, 2001). Empirical and theoretical literature has shown, however, that computers and technology tools engage young children (Chang, Mullen & Stuve, 2005, Ng & Nichols, 2009; Trella, Barros, & Conejo, 2008); can help them learn (Fritz, 2005; Ketamo, 2002; Murphy, DePasquale, & McNamara, 2003; Roskos, Burstein, You, Brueck, & O'Brien, 2011); foster early literacy skills (Fishburn, 2008; Kuhlman, Danielson, Campbell, & Topp, 2006; Lieberman et al., 2009) encourage positive social interactions between peers (Heft & Swaminathan, 2002; Kumtepe, 2006; Muller & Perlmutter, 1985; Tsantis, Bewic & Touevenelle, 2003); and promote peer scaffolding (Ahmad & Assim, 2003; Freeman & Somerindyke, 2001) when used in developmentally appropriate ways.

Contemporary views are moving away from the use-or-not-use debate as they recognize the relevancy of technology in the lives of young children (Chatel, 2005; Edwards, 2005; Parette, Quesenberry, & Blum, 2010; Schomburg & Donohue, 2009; Van Scoter, Ellis, & Railsback, 2001). According to Edwards

(2005), “positioning the computer as separate from children’s development and learning within the early childhood educational context is arguably akin to denying the role it plays in their socio-cultural experiences outside the educational setting” (p. 25). Educators need to make professional judgments and utilize technology as instructional tools to enhance learning and development while paying close attention to pedagogy and appropriate practice (Tsantis, Bewic, & Thouvenelle, 2003). Allen and Blake (2010) recommend educators carefully develop “specific developmental stages for technology use including play explorations and creative projects” (p. 143) to ensure balanced, appropriate use while using touch devices in the preschool classroom.

### **Theoretical Framework Supporting iPad Use in the Preschool Classroom**

During the preschool years, all learning is interdependent (Tomlinson & Hyson, 2009). Development and learning in the cognitive domain is affected by the development and learning taking place across the social, linguistic, and physical domains and vice versa (Tomlinson & Hyson, 2009; NAEYC, 2009). It is this connected learning which guides educators in developing programs that meet the developmental needs of children across the cognitive, social/emotional, motor, and linguistic domains (Copple & Bredekamp, 2009; NAEYC, 2009). Therefore, two theories help outline how touch technologies such as the iPad can be used in the preschool classroom - information processing theory driven by cognitivism, and Vygotsky’s sociocultural theory rooted in constructivism.

### **Cognitivism and Information Processing Theory**

Cognitivism focuses on the mental processes of language, problem solving, and concept formation. Learning is a conscious, active process of

thinking where “learners use their memory and thought processes to generate strategies as well as store and manipulate mental representations and ideas” (Robinson, Molenda, & Rezabek, 2008, p. 25-26). Cognitivists look at how problem solving skills and higher mental functions change and grow over time as children take in, organize, use, and retain information (Schuh & Barab, 2008).

The cognitive information processing theory uses the metaphor of the ‘mind as a computer’ to explain how students transfer information through the memory system (Lohr & Gall, 2007). Information is first registered through the senses as the brain responds to external stimuli. Information then moves through the memory channel, from working memory to long-term memory. Working memory is where information is internally processed and problem solving occurs. Once information is processed it is transferred to long-term memory, where information is permanently stored and available for future use (Robinson, Molenda, & Rezabek, 2008).

During the preschool years, “children gradually develop their mental representation capacities, reasoning skills, classification abilities, attention, memory, and other cognitive capabilities” (Tomlinson & Hyson, 2009, p. 137). Sustained play experiences with hands-on materials such as puzzles, blocks, games and manipulatives are cognitive activities that help build these capabilities as well as develop mathematical skills in areas such as number and operations, geometry, spatial relationships, and measurement (Tomlinson & Hyson, 2009; NCTM, 2012). The use of iPads and educational apps in the classroom can provide additional opportunities for students to explore mathematical concepts,

engage in problem solving through digital games and puzzles, and work on spatial skills as they manipulate virtual shapes and objects.

### **Constructivism and Vygotsky's Sociocultural Theory**

Constructivists believe children create meaning by building upon previous experiences. The acquisition of knowledge is a learner-centered, hands-on process where students construct new ideas or concepts and fit those ideas and concepts into their existing knowledge (Schuh & Barab, 2008). Construction of knowledge takes place during play as children learn through exploration, manipulation of objects and materials, and imitation at their own developmental pace (Johnson et al., 2005). Hands-on exploration of the learning environment and its materials through problem solving as well as opportunities for creative expression are keys to learning (Bodrova & Leong, 2005).

Vygotsky (1978) believed students construct their own knowledge and that learning should correspond with the child's developmental level but did not believe this learning occurs in a vacuum. Learning is a social activity, and Vygotsky's sociocultural theory looks at the profound impact social experiences and language opportunities play in shaping thinking (Berk & Winsler, 1995; Vygotsky, 1978). Adults or other more knowledgeable children can help extend students beyond current levels of performance by aiding and guiding them through the learning process. This concept is known as the zone of proximal development (ZPD). As the learner becomes more comfortable and demonstrates competence with new or advanced concepts and skills, support by adults or more knowledgeable others is gradually withdrawn (Berk & Winsler, 1995; Vygotsky, 1978).

Studies have shown collaborative computer use by young children can foster the critical social interactions needed for cognitive development as reasoned by Vygotsky (Heft & Swaminathan, 2002; Kumtepe, 2006; Muller & Perlmutter, 1985) as well as provide opportunities for students to support their peers through scaffolding (Ahmad & Assim, 2003; Freeman & Somerindyke, 2001; Fritz, 2005; Lee, 2009). Through these collaborative exchanges, students talk about their actions, ask for information, learn to take turns and cooperate. These social interactions increase the use of language, which Vygotsky considers the ultimate 'tool of the mind' (Clements & Sarama, 2003; Hisrich & Blanchard, 2009; Johnson & Christie, 2009; Robinson, 2003; Shute & Miksad, 1997; Thurlow, 2009). The use of language "leads to higher mental processes" and influences what individuals think as well as their behavior (Berk & Winsler, 1995, p. 22). Of course, teachers play a critical role in preparing the learning environment to ensure activities meet the developmental needs of all children and in supporting children by asking questions, giving suggestions, modeling actions and providing the necessary guidance to extend the development process (Chang, 2001; Haugland, 2000; Heft & Swaminathan, 2002; Nir-Gal & Klein, 2004; Vygotsky, 1978).

The multitude of apps available on the iPad provide opportunities for teachers to meet the varied individual differences found in the typical preschool classroom. Apps targeting specific skills or those with various built-in levels can provide learning experiences that fit into each individual child's zone of development. Additionally, there are many ways to enhance language experiences through apps specific to phonemic awareness, rhyme, and

vocabulary development. Audio and electronic books can be used as additional tools in building a language-rich environment. Finally, video and audio recording features of the iPad can be utilized by children during their play and used to engage children in digital storytelling, which can enhance language development.

### **Summary of Research on Handheld Devices**

Literature related to the use of handhelds (stylus-based mobile devices) in education has emerged over the last ten years. Much of the literature is anecdotal in nature but several studies from various educational contexts suggest there is potential for these technology tools to increase motivation (Chang et al., 2005; Couse & Chen, 2010; Kuhlman et al., 2006; Magagna-McBee, 2010); engage students in their learning (Chen et al., 2008; Couse & Chen, 2010; Fishburn, 2008); increase cognitive skills (Fishburn 2008; Ketamo, 2002; Magagna-McBee, 2010; O'Malley & Fraser, 2004; Ng & Nicholas, 2009); foster collaboration (Figg & Burson, 2005; Fritz, 2005; Kuhlman et al., 2006) and promote the development of new technology skills (Fritz, 2005; O'Malley & Fraser, 2004). Additionally, these studies showed the stylus was easy to use (Couse & Chen, 2010; Fishburn, 2008; Magagna-McBee, 2010) and the small screen size of the handheld not an issue for young children (Chang, 2001).

Only two studies specific to handhelds in the preschool context were identified in the literature (Couse & Chen, 2010; Geist, 2012; Matthews & Seow, 2007). Couse and Chen (2010) examined the use of stylus-based tablets by three- to six- year olds to determine if these technological tools align with early childhood curriculum standards set forth by NAEYC and the International Society for Technology in Education (ISTE). Using a mixed-method approach,

electronically drawn self-portraits produced on tablets with a stylus were compared to traditional drawings made with crayons. Utilizing assessment tools commonly used to measure fine motor development such as the Draw-a-Man Test, Couse and Chen (2010) determined the student drawings were consistent between the two platforms. The authors cite the work of Matthews and Seow (2007) who also explored electronic painting and drawing on tablet PC's with children ages 2 to 11. They found the stylus a better tool than a mouse for young children as it allows for “expressive action in drawings to create dashes, dots, blobs, and spots” not achievable with a mouse (Matthews & Seow, 2007, p.255). Drawings are one way early childhood children represent their thinking, thus it is essential the tools they use enhance this experience. While these findings are descriptive in nature and limited to two small samples (n=41; n=12), these studies serve as a starting point for the examination of iPads in the early childhood curriculum since the iPad and stylus-based tablet share the same interface and a similar input device.

### **Evaluating iPad Features Through the Literature**

Each year the research organization New Media Consortium looks at current technology trends with potential to impact teaching and learning practices. Trends are ranked “according to how significant each will likely be for learning-focused institutions over the next five years” (p. 2). In their 2011 edition of *The Horizon Report*, digital media continues to rise in importance. Much of this rise can be attributed to the proliferation of mobile devices like the iPad (Johnson, Smith, Willis, Levine, & Haywood, 2011). The iPad's small size, interactive touch interface, access to thousands of educational apps, built-in



functionalities and connectivity to the Internet via a wireless network are driving educators to consider their use in the classroom (McManis & Gunnewig, 2012).

In this section, possible benefits and potential threats of iPad use in the preschool classroom are considered. Due to the iPad's recent appearance, some of these benefits and risks mirror those in the literature related to computer use, handheld use with a stylus input, and research on other touch surfaces as only two studies to date have been identified specific to iPads in early childhood classroom (Bebell, Dorris, & Muir, 2012; Geist, 2012). Others are related specifically to design features of the device and software design principles associated with potential applications. Finally, some are suggestions from articles in non-refereed journals, which are anecdotal in nature, but provide insight into how educators are currently exploring iPads (Banister, 2010; Ostashewski & Reid, 2011; Waters 2010).

### **Overall Design**

In his book, *The Design of Everyday Things*, Norman (2002) proposes the function of a device is directly related to its design. If a device is designed well, it will provide natural signals that will help dictate how it is to be used. The better the signals or properties, called affordances, the easier the device is to use. Norman's design philosophy is based on the work of J.J. Gibson who first proposed the concept of affordances (Greeno, 1994). Gibson's framework provides a general guideline on how visual perception leads to action and how these actions dictate the ease with which objects are actually used (Gibson, 1986). Examples of Gibson's affordances in the world includes "knowing that knobs are for turning, switches are for flipping, levers are for sliding, and buttons

are for pushing” (Learning Theories, 2008). Examples of Gibsons’s affordances in regards to using iPads includes intuitively knowing the slide bar is for unlocking the device, the square button icons are for selecting apps, and other shapes such as arrows within apps are for left and right movement. As young children are non-readers, these natural affordances of the iPad help facilitate its use with little to no technical support (Geist, 2012).

Of course the affordances of the iPad do not automatically extend to the apps loaded on the device. Teachers will need to critically evaluate the interface of each specific application to ensure “it has appropriate amounts of cognitive complexity and high play quality” as well as ease of use (Johnson et al., 2005, p. 25). Features such as icon size and spacing, text placement, graphics, and navigation tools must be evaluated for each individual application (Lieberman et al., 2009; Revelle, 2009). Related to size and spacing, Chiasson & Gutwin (2005) recommend “interfaces for young children should include on-screen items large enough to compensate for some inaccuracy in targeting” (p. 5).

In their qualitative study of three- and four-year olds, Romeo, Edward, McNamara, Walker and Ziguras (2003) compared the mouse and keyboard with a touch screen attached to a computer, paying particular attention to fine motor issues specific to the touch screen. Students became more competent with the touch screen over time as they learned how to use their fingers to select, drag, and move objects, but researchers noted difficulties due to design that impacted the use of the touch interface. For example, “the placement of icons on the screen and the proximity of icons to each other” as well as the size of icons is important in ensuring young children have success with a touch interface

(Romeo et al., p. 335). This study demonstrates young children can use a touch interface easily and helps advise the selection of potential iPad apps used in the classroom based on developmentally appropriate design features.

### **Touch Screen**

The iPad's touch interface is a natural fit for the physical explorations typical of the preschool classroom as it has "direct mappings to the actions on the screen" (Chiasson & Gutwan, 2005, p. 2). The ability to directly manipulate tools and apps with their fingers is supportive of the constructivist theory of children learning best by building knowledge thorough discovery and exploration. The touch interface supports active inquiry and provides a tool more advantageous to the fine motor needs of young children (Lu & Frye, 1992; Wood et al., 2004). Apps with simple interfaces, which utilize single touch or click gestures, are especially beneficial to students with weak motor skills (Chiasson & Gutwan, 2005). Chiong & Shuler (2010) and Geist (2012) found children as young as two could easily use touch tablets with little to no help.

Revelle (2009) believes the touch interface is easier for young children to use, especially when tapping is the primary method to operate the device and apps. Potential issues with the touch interface include the need to touch and lift versus touch and hold (Revelle, 2009). Young children may apply too much pressure, which impacts how the device and application will work. The need to pinch and slide simultaneously with two fingers may present challenges for children with weaker fine motor skills as well. Apps requiring tap, release and slide movements are easier (Chiong & Schuler, 2010; Geist, 2012; Revelle, 2009). Cooper also discusses how touch interfaces utilizing simpler movements

than those required to operate a mouse can “equalize the playing field” for some students with special needs (Cooper, 2005, p. 296).

In the earliest study examining touch interfaces with preschool children, Lu and Frye (1992) observed the amount of time children took performing four different tasks utilizing both a mouse and touch screen. Twelve children were observed selecting objects as well as selecting and moving objects to a specified place by dragging and then releasing the object. The children required less time to complete the activities on the touch screen as compared to the mouse. Children had more trouble coordinating the operation of the mouse button with movement than when utilizing their finger, although errors arose when children made multiple touches on the touch surface. In addition, students initially had trouble moving their fingers “across the screen at a constant speed” so as not to lose contact with the object they were moving (Lu & Frye, 1992, p. 424). When interviewed, the students were divided in which device they liked best, but 10 of the 12 students agreed the mouse was harder to use. Lu & Frye (1992) commented on the connectedness of the touch interface with the actual action being completed, which is also noted throughout later literature (Chiasson & Gutwan, 2005; Couse & Chen, 2010; Druin, 2009; Geist, 2012; Hourcade & Hansen, 2009; Reville, 2009). They found there was a greater physical connection with object manipulation with a touch interface than with the indirect input of the mouse, which is more inline with how young children learn (Piaget & Inhelder, 2000).

Yu, Zhang, Ren, Zhao and Zhu (2010) conducted a qualitative pilot study to evaluate how a vertical multi-touch screen would support multi-user learning

while playing interactive games with eight kindergarten students in China. A vertical multi-touch display (42 inch wide screen) was placed on a table at student height. Four games were designed “utilizing various gestures – drag, click, rotate, and zoom” (Yu et al., 2010, p. 370). Playing in pairs, students had opportunities to compete against each other as well as collaborate on gaming tasks. A noted disadvantage of the interface was “unwanted contacts” by other body parts such as arms (Yu et al., 2010, p. 372). While this large-scale touch device used in this pilot study is very different in size than the iPad, findings related to how students found the touch interface easy to use are relevant to this review. Simple gestures, such as click and drag, are most appropriate for young children and should be checked when selecting apps.

Wood et al. (2004) also noticed usage issues related to body part placement in their observations of 80 preschoolers using four different computer input devices (mouse, EZ ball, touch pad and touch screen) to play educational computer games. While the touch screen was the best interface when dragging static objects to targets, the mouse and EZ ball were better in activities requiring the tracking of objects. This appears to be partly due to the location of the arm blocking part of the vertical screen obstructing objects from the children’s view. The mouse, EZ ball, and touch pad were located on a horizontal table surface away from the monitor, which did not obstruct the view of the screen. While this study indicates the mouse and EZ Ball were easier for students to use, it supports the touch interface for simple tasks, especially for young children with less-defined motor skills. Chiasson & Gutwan (2005) suggest text should be placed above objects rather than below objects when designing software to

minimize such issues. It should also be noted the horizontal interface of the iPad as opposed to the vertical interface used in the cited studies may not pose these same problems. Further investigation would be needed to determine if arm placement might also impact how the iPad's touch screen is used.

In a two-part study, Geist (2012) first observed his own son's use of the iPad over five months. This allowed Geist to observe spontaneous use of the device in a variety of settings both in and out of the home. He then observed 20 children in two university lab preschool programs. Findings from both environments were consistent. First, young children could easily use the device with little to no assistance and the touch interface was a natural way for students to interact with technology (Geist, 2012). Second, "using the device resembles how children play with other developmentally appropriate toys" (Geist, 2012, p. 30). Third, children learned to quickly navigate and "figure out how to make the iPads do things that they were not directly taught" (Geist, 2012, p. 31). Finally, children were much more independent using the iPad than when using computers. This is the only study to date that discusses the iPad's touch interface and design.

Overall, studies showed time to complete tasks with a touch interface was shorter than with traditional input devices such as the mouse and keyboard (Lu & Frye, 1992; Wood et al., 2004) and found simple gestures could be used to accomplish tasks (Wood et al., 2004; Yu et al., 2010). Issues related to unwanted contacts with other body parts (Yu et al., 2010) and multiple touch errors (Lu & Frye, 1992), along with time needed to adjust to the sensitivity of the interface (amount of pressure for the touch and speed of finger movement) were

identified but found to decline quickly (Geist, 2012; Hourcade & Hansen, 2009; Lu & Frye, 1992; Yu et al., 2010). This research also provided insight into design qualities such as icon placement and icon size, which can cause user errors (Romeo et al., 2003). Overall, the studies found the touch interface easy to use and inline with the developmental fine motor needs of young children.

### **Screen Size**

The studies found in this review related to handhelds utilized smaller devices with screens less than half the size of the iPad interface. Except for viewing Web sites with significant amounts of text, children had no issues interacting with the small size. Chang et al. (2005) found young children could easily manipulate a stylus on handheld devices. In their small qualitative study of four kindergarten students, they set out to determine if lack of motor coordination would impact how students used personal digital assistants (PDAs). Four kindergarten students used PDAs to play games and write letters in the device's NotePad. Students had no issues managing the limited screen space.

Kuhlman, Danielson, Campbell & Topp (2006) describe the use of handheld computers (Palm Pilots) by 17 first grade children during pre-writing activities. Sample activities included creating individualized, personal spelling lists using the handheld's address book, using the notepad feature for brainstorming ideas with pictures and words, and using the memo pad for grammar practice. Kuhlman et al. (2006) found "students responded differently to the writing task with handhelds as a pre-writing tool, all first-graders demonstrated comfort and competence when using the handhelds" (p. 182). The students also used graphic organizer software and drawing software to

brainstorm. Students had no trouble creating bubbles and links to organize their ideas in a pre-writing brainstorming session on the small interface. Researchers also found drawings and charts created by the children detailed and easy to read.

### **Mobility**

Mobility is defined as “the degree to which the technology is accessible and portable” (Inkpen, 1999, p. 81). The benefit of mobility is that it allows for easy integration of technology into a child’s world. The iPad’s mobility allows students to seek support from teachers and peers as needed throughout the classroom setting, and as no special furniture is required, the iPad can move from center to center, whether it be at a table, on a cushion in the reading corner, or the circle rug on the floor, with ease. It can also be used outdoors, extending learning outside of the classroom walls. While other devices such as laptops offer this portability, the iPad is a better choice for young children due to its light weight (1.33 pounds) and long battery life (eight to ten hours), which can last an entire school day (Apple, 2011).

Fritz (2005) conducted an ethnographic study to investigate how 21 first grade students used handhelds for collaboration. Through interviews, students remarked learning how to use the new tool and the mobility of the devices were important in helping them share and work with peers from around the classroom, not just those sitting near them. Through additional observations and collection of student artifacts, she concluded students learned new content while using the devices and collaborating with their peers, as well as practiced technology skills related to state standards. Eighty-five percent of the students said handhelds



helped them learn with 54% citing specific concepts learned. Assessment of learning artifacts confirmed these interview findings.

Figg and Burson (2005) shared examples of how handhelds in elementary and middle school classrooms complemented other activity structures already in place within the learning environment. Reviewing the work of teachers participating in the Palm Education Pioneers (PEP) evaluation study, they cited “increased student collaboration” (Figg & Burson, 2005; p. 133) and integration across the curriculum as the biggest benefits to the use of handhelds. Students used handhelds in science labs to help document observations and predictions and to record their understanding of scientific concepts during data collection. Figg and Burson (2005) stressed handheld technologies are most powerful when they are integrated in a “problem-based, performance assessment environment” (p. 133) in which children can dictate when and how they are used.

Chen et al. (2008) investigated the use of handhelds as cognitive tools to facilitate inquiry-based learning among primary students on a field trip exploring the environmental issues of reduce, reuse, and recycle. A total of 480 students from six schools participated in the study over a two-week period. An increase in learning of 33% was documented between pre- and post-tests. Researchers found “the use of the handheld computer allows greater opportunities for learning in context of the subject otherwise would not be possible in the classroom” (p. 249). Increase in motivation along with improved organization was also noted as benefits to using the handhelds.

Ng and Nicholas (2008) conducted a qualitative study over ten months on the use of pocket PC’s in five primary schools (grades 3 to 7) in Australia.

Through both observations and student and teacher interviews, they found increased student engagement, promotion of good behavior, and personal ownership of the students over their learning. The students used the devices instinctively and were very willing to share and help others. Teachers liked the interactive potential of the devices and the “small size of the pocket PC’s was seen as a real advantage by the students because of their ability to take them outside the classroom or to walk around in the classroom” (Ng & Nicholas, 2008, p. 476). The multimodal aspect of the tools was also seen as beneficial. The small-screen size was noted as an issue for some of the activities such as viewing Web pages but special tools such as the audio recorder and notepad were beneficial to students with low literacy skills. While this study is not specific to the preschool context, its findings support the use of iPads as a way for teachers to engage students in their learning as well as a means to differentiate instruction and provide individualized learning experiences.

Geist (2012) found the mobility of the iPad enhanced the ability to “conduct investigative projects in classrooms that would not be possible without the devices or with traditional computers” (p. 32). He observed preschool teachers utilizing multimedia features such as videos and educational apps within learning centers to provide a richer, more concrete experience for the children. What was powerful about these experiences was the ‘just-in-time’ capability of the devices to meet students’ needs. Teachers could pull new materials as needed based on student questions and inquiries as well as provide access to materials to support and “promote independent investigations and group interactions” (Geist, 2012, p. 33).

While the mobility of the iPad is considered one of its best features, it may also present limitations. The preschool classroom is a busy, often loud place. The noise level of the classroom may prompt children to complain they cannot adequately hear apps compelling teachers to use headphones with the devices. This may be applicable in some situations, such as when a student is listening to an e-book, but overuse of headphones can impact the potential for social interactions, a worry of many educators (Alliance for Childhood, 2004; Cordes & Miller, 2000; Elkind, 1996; Healy, 1998; Miller, 2005; Pendleton, 2001).

### **Display Orientation**

iPads offer the ability to adjust the viewing screen to an angle comfortable for each individual child. Studies show a horizontal display is easier to read than a vertical one and eye strain can be reduced if the screen is ten to twenty degrees below the horizontal plane of a user's eye level (Healy, 1998; Pendleton, 2001). Stands, such as the Big Grips Frame built specifically for young children, not only offer a protective case with an easy grip for little hands but can help set the display at an appropriate viewing angle (KEM Ventures, 2011). However, until additional long-term research is conducted, concerns related to visual strain from flickering screens, glare from fluorescent lights in the classroom, and eye strain related from staring too long without taking breaks as well as posture issues related to where the devices are used are still valid concerns (Cordes & Miller, 2000; Healy, 1998; Pendleton, 2001).

### **Applications**

The thousands of apps currently available for download, along with access to the Internet, offer educators increased options to personalize instruction

(Chiong & Shuler, 2010; Geist, 2012). Apps utilizing various instructional strategies such as demonstrations, stories, interactive questioning, explorations, and challenges can be used (Lieberman et al., 2009). In addition, iPads allow both students and teachers to easily create custom content. These are important features of the iPad as individualization is a key component of developmentally appropriate practice and supports Vygotsky's ZPD (NAEYC, 2009). Apps for young children should use few menus and sub-menus and minimal text, and a visual interface with icons and pictorial clues is more appropriate (Chiasson & Gutwan, 2005; Chiong & Shuler, 2010; Inkpen, 1999; NAEYC, 2012; Revelle, 2009).

Chiasson & Gutwan (2005) have catalogued an extensive list of design principles to guide educators when selecting software based on how children naturally learn. These principles, "categorized into three main areas: cognitive, physical, and social/emotional" (Chiasson & Gutwan, 2012, p. 1) can also be applied to the selection of apps for the iPad. Cognitive apps need to meet the different developmental needs of its users with audio and video clues, provide feedback to guide children through learning new concepts, and expand in complexity to support children as they gain understanding. They also recommend "interfaces should provide scaffolding and guidance to help children remember how to accomplish tasks" (Chiasson & Gutwin, 2005, p. 2). In regards to physical development, Chiasson & Gutwin (2005) agree with the research that direct input devices such as touch interfaces are appropriate tools for young children. iPads are tangible and offers students the opportunity to manipulate

objects in a different way than indirect devices. Finally, apps need to keep children interested, allow them to set the pace, and facilitate social interactions.

### **Other iPad Features**

There are several other features on the iPad that can help support its use in a developmentally appropriate preschool program. The iPad display can be changed into 34 languages and keyboard characters, which allows for customization for non-English speaking students or enrichment in teaching new languages. Security features such as adding a passcode lock to limit access and turning off content features such as Internet access or apps featuring videos, help educators keep children safe and prevents accidental access to inappropriate material.

In addition to the potential apps that can be downloaded to the device to support the preschool curriculum, the iPad's built-in camera, video capabilities, and recording features makes it an all-in-one device. Potential examples of developmentally appropriate practices (both student and teacher driven) utilizing these features include:

- Using the camera to photograph constructions in the block center.
- Video recording students at work or play to aid in assessment.
- Recording stories for playback in a literacy center, or recording student stories or reflections to share with families.
- Utilizing the camera and video conferencing software to expose children to different people and cultures.

### **Potential of iPads for Learning.**

The purpose of introducing new teaching tools and strategies into the classroom is with the hope learning will be impacted in a positive way. While the majority of studies located on mobile devices demonstrate power in motivating students, fostering collaboration, and contextualizing learning, they are less clear

about the impact on cognitive development. Some studies have emerged showing mobile devices can help lower performing students make academic gains (Ketamo, 2002; Kuhlman et al., 2006) and increase understanding of new concepts (Bebell, Dorris, & Muir, 2012; Fishburn, 2008; Fritz, 2005; Chen et al., 2008), while other studies show 'no significant difference' in learning outcomes (Magagna-McBee, 2010).

Hourcade and Hansen (2009) discuss the potential of multi-touch displays to support learning across the curriculum. Their article is anecdotal in nature, but argues how the touch interface allows children to manipulate objects in a similar way to physical objects. Their suggestions for the touch display as a natural way to trace shapes and letters, practice handwriting, manipulate puzzles, make shapes out of other shapes, sort objects, and play digital musical instruments are examples of developmentally appropriate practices.

Kuhlman et al. (2006) noted handhelds motivated struggling first grade writers. In their study, handhelds were integrated into everyday writing experiences and used as a supplemental learning tool to other literacy activities. The new tools motivated the students to participate more actively in brainstorming sessions, which increased their use of vocabulary in final writing products. Ketamo (2002) also found students with lower skills benefited the most from using handhelds. His small study of six-year-olds learning geometry concepts through leveled games found "all low skilled pupils reached the level of the group represented by average skilled pupils" (p. 2) after use.

Fishburn (2008) set out to determine if there is a difference between students who use a mobile reading device and those who receive traditional

reading instruction in a kindergarten classroom. Using a causal-comparative research design, 292 kindergarten students from four schools in Delaware along with 14 teachers participated in the final study. The students were evenly split between the treatment and non-treatment groups. Five subtests from the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) were used as pre- and post-tests. The highest gains were found in the areas of phonemic awareness, vocabulary, word fluency and comprehension. In addition, girls significantly outperformed the boys in word fluency. The most significant finding was related to the amount of time the devices were used. Higher gains were related to higher mobile device usage.

Unlike Fishburn, Magagna-McBee's (2010) analysis of pre- and post-DIBELS scores on phonemic awareness found "no significant differences between the group using the handheld devices and the group not using the handheld devices" (p. 94). Using a mixed methods approach, four classes of kindergarten students were evaluated in two schools over the course of four months. Two classes used handheld devices for literacy activities, while two classes did not. A total of 92 students participated. While the handheld group did not show increased gains over the traditional group, it was concluded handhelds could be used as tool to compliment instruction.

Preliminary results from the first large-scale integration of iPads in the United States also suggest iPads can be used as a tool to compliment learning but the statistical significance of this relationship is still unclear (Bebell, Dorris & Muir, 2012). iPads were introduced into eight kindergarten classes over nine-weeks as a way to increase student's early literacy skills. A total of 266

kindergarteners (n=129 iPad; n=137 comparison) participated from six elementary school in Maine. The researchers utilized three different pre- and post-assessments (Rigby Benchmark Assessment, Children’s Progressive Academic Assessment (CPAA), and Observation Survey of Early Literacy Achievement (OSELA)) to gauge learning. Students in both the iPad group and control group made gains on the Rigby and CPAA although “performance across the two groups was not large enough to be considered statistically significant” (Bebell et al., 2012, p. 1). When looking at OSELA scores, they were significantly higher for the iPad group, especially on the subtest measuring phonemic awareness.

### **Chapter Summary**

The rapid influx of mobile technologies is changing how young children live and learn. Preschool educators acknowledge this quick pace and its impact on their students but are often unsure of how to use technology meaningfully for teaching and learning in ways that are developmentally, individually, and culturally appropriate. Initial research on mobile learning through the use of handheld devices is positive across all developmental domains. Although research on handhelds in the preschool context is limited, findings from elementary classrooms indicate handhelds increase motivation, engage students in their learning, foster social interactions and peer collaboration, and promote the development of new technology skills. Additionally, young children have found the small size of handheld screens and input via stylus appropriate for use.

Emerging reports on iPad use indicate they can be used like other developmentally appropriate learning activities such as blocks, puzzles and



games, painting, playing musical instruments, and dramatic play and have the potential to support learning through a cognitive-constructivist framework guiding developmentally appropriate practice. A watchful, balanced approach to iPads in the preschool classroom can reduce potential risks while affording opportunities to support the overall development of young children.

### CHAPTER 3 LITERATURE REVIEW

Utilizing a constructivist framework, this literature review evaluates how peer and digital scaffolds are used to support collaborative problem solving in the preschool classroom. The connection between help seeking behaviors and scaffolding is discussed as are strategies for partnering young children to promote effective collaboration. The benefits and challenges of game-based learning are also presented.

Studies have shown technology use by young children can foster positive social interactions, promote cognitive and linguistic development, and support collaborative problem solving in the early childhood classroom (Ahmad & Assim, 2003; Clements & Sarama, 2003; Freeman & Somerindyke, 2001; Heft & Swaminathan, 2002; Hisrich & Blanchard, 2009; Kumtepe, 2006; Lee, 2009; Muller & Perlmutter, 1985; Robinson, 2003; Shute & Miksad, 1997; Thurlow, 2009). NAEYC supports technology and media use as a means to foster social connections and shared learning and recommends computers and other technology tools be located in the main instructional area of the classroom with room for multiple children to “solve problems together, talk about what they are doing, help and teach friends, and create rules for cooperation” (Epstein, 2007, p. 46). Anecdotal evidence shows students prefer to work with a partner when using technology (Clements, 1987; Cooper, 2005; Epstein, 2007; Muller & Perlmutter, 1985) and these interactions provide many opportunities for peer-supported and scaffolded learning to occur (Ahmad & Assim, 2003; Freeman & Somerindyke, 2001; Heft & Swaminathan, 2002; Muller & Perlmutter, 1985;

Sharma & Hannafin, 2007). Introducing digital games into the early childhood curriculum is one way to promote collaborative problem solving.

### **Theoretical Framework**

The theory of constructivism serves as the foundation for this capstone study. Constructivists, such as Jean Piaget, believe learning is student-centered, and support children as builders of their own cognition through active discovery of the world around them (Berk & Winsler, 1995; Piaget & Inhelder, 2000; Schuh & Barab, 2008). Students acquire new ideas or concepts through personal experiences, and then fit those notions into their current knowledge system (Schuh & Barab, 2008). For young children, play is the vehicle for knowledge construction as it allows them to explore, manipulate objects and materials, and test their thinking at their own pace, in their own way (Copple & Bredekamp, 2009; Johnson et al., 2005). Opportunities for problem solving are also critical to the knowledge construction process.

Like other constructivists, Russian psychologist Lev Vygotsky (1978) believed students shape their own knowledge, and concurred learning corresponds with the child's developmental level. Unlike his counterparts, he did not believe this learning occurs in isolation (Vygotsky, 1978). Vygotsky expanded the ideas of Piaget by looking more closely at how social interactions and collaboration impact learning. Vygotsky found adults or other more knowledgeable children play an important role in the learning process by aiding and guiding learners, stretching them to exceed what they can do independently. This concept is known as the zone of proximal development (ZPD).

Vygotsky (1978) defined the ZPD as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (p. 86). Also known as scaffolding, adults or more knowledgeable others can help learners “bridge the gap between their current abilities and the intended goal” (Rosenshine & Meister, 1992, p. 26). Scaffolding behaviors are unique to each learning context, but there are three characteristics that always exist, the interaction(s) must be collaborative, the scaffolding takes place within the learner’s ZPD, and scaffolding is gradually withdrawn as the learner becomes able to complete the task alone (Yelland & Masters, 2007; Wood & Wood, 1996).

Influenced by Vygotsky’s ZPD, Wood, Bruner, and Ross (1976) were the first to use the term scaffolding in reference to tutoring as a means to support increased cognitive performance by young children (Davis & Miyake, 2004). They believed “tutoring interactions are, in short, a crucial feature of infancy and childhood” (Wood et al., 1976, p. 89) and set out to examine how young children ages three to five respond to different types of assistance while problem solving including direct intervention, verbal correction, and verbal directions when building a wood pyramid with blocks. They found scaffolding behaviors by a tutor decrease as students get older and the youngest students require the greatest amount of assistance via direct intervention or showing of how to complete a task. They also found that the type of scaffolding behavior used by a tutor shifts as young children get older from showing (direct instruction and modeling) to telling (reminders and suggestions) (Davis & Miyake, 2004; Wood et al., 1976;

Yelland & Masters, 2007). Wood et al. (1976) identified six different forms of scaffolds, each with its own function within the scaffolding process, including recruitment, reduction in degrees of freedom, direction maintenance, marking critical features, frustration control, and demonstration (Table 3-1).

Table 3-1. Functions of scaffolding as defined by Wood, Bruner & Ross (1976)

Scaffolding Function	Description of Function
Recruitment	Engages student in the task and ensures there is understanding by the student of the task's objective(s).
Reduction in degree of freedom	Simplifies the task by reducing the number of moves or acts required for a solution.
Direction maintenance	Keeps the child focused on the task and moves them progressively forward as he/she experiences success.
Marking critical features	Makes note of task features to bring attention between the child's current actions and potential actions as a means to improve the problem solving process.
Frustration control	Reduces the amount of stress or fear exhibited by a child while working through a task.
Demonstration	Models the process of completing a task either partially or completely with the hope the child will try again.

### Categories of Scaffolding

While the initial work of Wood et al. (1976) was specific to tutoring interactions between adults and young children, research concerning the scaffolding process within different contexts is also present within the literature (Lajoie, 2005). Research related to peer scaffolding and collaborative problem solving in early childhood contexts emerged in the 1980s (Azmitia, 1988) with scaffolding specific to computer or technology-enhanced learning environments (TELEs) emerging soon after (Sharma & Hannafin, 2007; Pea, 2004). More recently, the concept of scaffolding has been broadened in TELE's to include different tools and resources that can be used by students when working

independently to solve problems and moves beyond the idea of scaffolds serving solely as cognitive tools (Brush & Saye, 2002; Yelland & Masters, 2007).

### **Peer Scaffolding in Computer Environments**

Scaffolding is also noted within the literature by student dyad interactions in the preschool and elementary classroom in many learning situations including computer contexts. These behaviors, both verbal and non-verbal, include pointing out important details, showing how to complete a task, proposing a suggestion, giving direct instruction, and providing encouragement (Ahmad & Assim, 2003; Ellis & Rogoff, 1982; Heft & Swaminathan, 2002; Hyun & Davis, 2005; Sharma & Hannafin, 2007; Verba, 1998). Differences in the types and amounts of scaffolds provided changes depending on the age of the individual providing support, the age of the student receiving the support, and the task itself (Reiser, 2009; Yelland & Masters, 2007; Verba, 1998; Wood et al., 1976; Wood & Wood, 1996). Many of these behaviors are noted by Ahmad & Assim (2003) in their small study of student dyads (5-year-olds) in a Kuala Lumpur preschool. Data were collected via observations and videotape as children worked on the computer and through interviews regarding interactions within the dyads. Scaffolding behaviors coded from the interactions included directing one's partner (23%), providing information (19.8%), giving explanations (10.3%), suggesting ideas (3.7%), and correcting a peer (1.2%).

Ellis and Rogoff (1982) examined how scaffolding strategies differ between adults and elementary children. While they concluded adults are better at "perceiving the 'zone of proximal development' or 'region of sensitivity' for optimal instruction" they acknowledge the potential of children to provide support

on materials and/or activities of which “they are an expert” (Ellis & Rogoff, 1982, p. 734). They found elementary children use demonstration or modeling the most via physical acts of help and “seem to concentrate more on task completion than on the transmission of general rules” (Ellis & Rogoff, 1982, p. 731). Non-verbal behaviors were also more prevalent in peer interactions than verbal ones. The behaviors noted by Ellis and Rogoff (1982) are also found in the literature related to scaffolding during computer play in the preschool classroom (Ahmad & Assim, 2003; Freeman and Somerindyke, 2001; Heft & Swamanithan, 2002; Lee, 2009; Muller & Perlmutter, 1985).

In one of the first studies related to computer use, problem solving, and peer interactions related to young children, Muller and Perlmutter (1985) investigated how social interactions differ when children work at the computers as compared to working on a jigsaw puzzle. They discovered increased peer support while children worked together on the computer to complete problem solving tasks, and assistance was most often “instigated by the children themselves rather than requested by teachers or peers” (Muller & Perlmutter, 1985, p. 177). Likewise, Heft and Swaminathan (2002) found children very comfortable asking neighboring peers for assistance when working at a computer center. During direct observations, children commented on their work and the work of peers, imitated students working next to them, and asked questions on how to complete tasks.

As with older students, expert and novice roles emerge when preschool students work with peers on the computer. Freeman and Somerindyke (2001) discovered computer use can “affect young children’s peer-mediated cognitive

development as well as their social play” (p. 203). When working side-by-side, some students took on the role of expert. Peers subsequently turned to these experts for guidance and support, even calling to the experts for assistance as they work across the room. Lee (2009) also found “the more proficient child helped the less competent child by explaining procedures and pointing to the screen” (p. 304) in the classroom setting. Likewise, Pange & Kontozsis (2001) observed the emergence of more knowledgeable others assisting their peers with little or no computer experience in kindergarten classrooms in Greece both in learning how to use the mouse and in understanding how to operate the software.

### **Scaffolds in Technology-Enhanced Learning Environments**

Many aspects of scaffolding in TELEs are similar to scaffolding strategies observed in face-to-face interactions. Just as experts match scaffolds to meet a learner’s developmental and cognitive needs, so must digital scaffolds. But unlike face-to-face scaffolding experiences, the “design of TELE scaffolds requires consideration of a learner’s ability to interact with and use scaffolding tools” (Sharma & Hannafin, 2005, p. 28). The quality and level of scaffolding use is often determined by the learner in TELEs rather than by an expert, especially when the scaffolds are built-in. Learners must not only know about the existence of scaffolding tools built-in to programs and apps but must also know how to use them as technology tools are not always capable of providing appropriate scaffolds based on the developmental needs of a learner (Kim & Hannafin, 2011; Sharma & Hannafin, 2007). Learning how to use scaffolds is an important help seeking behavior that needs to be fostered by the teacher.



Brush and Saye (2002) refer to the use of 'hard' and 'soft' scaffolds in TELEs. Soft scaffolds are "situation-specific aids" providing just-in-time help and are most often provided by teachers and peers. These scaffolds are dynamic and adjust to each individual (Molenaar, Roda, Boxtel, and Slegers, 2012). In contrast, hard scaffolds, also called static scaffolds, are fixed supports that are "anticipated and planned in advance based upon typical student difficulties with a task" (Brush & Saye, 2002, p 2). They do not change over time and are the same for all students (Molenaar et al., 2012). These types of scaffolds are not unique to the learner but rather supportive of "common learning needs" (Sharma & Hannafin, 2007, p. 30). Hard scaffolds are the most prevalent form of scaffolds in TELEs, especially in the simple games and apps used by preschool children.

### **Cognitive scaffolds**

In their work, Yelland and Masters (2007) looked at scaffolding strategies used with and by young children in technologically based contexts. They found cognitive scaffolding was used to build understanding of concepts and procedures and considered this a 'traditional' form of scaffolding whereby a more knowledgeable other supports the individual learner by modeling, questioning, explaining, cueing, and providing feedback (Lajoie, 2005; Rosenshine & Meister, 1992; Wood et al., 1976; Yelland & Masters, 2007). Cognitive scaffolding typically occurs when teachers or peers provide direct support, but some games are designed to provide prompts or questions that can guide students while they work.

### **Affective scaffolds**

Affective scaffolding relates to those strategies, which provide encouragement and positive feedback, and are tied to the emotions and feelings of the learner (McManis & Gunnewig, 2012; Yelland & Masters, 2007). This type of scaffolding is also referred to as motivational scaffolding within the literature and would be considered a type of soft scaffold (Brush & Saye, 2002; Lajoie, 2005). Affective scaffolds help children stay on task and “encourage higher levels of thinking when using technology” (McManis & Gunnewig, 2012, p. 21). Teachers can provide affective scaffolds by staying close to children as they work with technology. Software programs and apps can also provide affective scaffolds through feedback, music, and visual displays during game play.

### **Technical scaffolds**

Yelland and Masters (2007) define a third type of scaffolding specific to TELEs, technical scaffolds. Technical scaffolding pertains to the “inbuilt constructs” within the design of an activity or program that “facilitate understanding and problem solution” (Yelland & Masters, 2007, p. 6). Examples of technical scaffolds include an instructional video at the beginning of a computer game showing how to use specific keystrokes to operate the game, hint tools built within games to help students solve a puzzle, or computer programs that automatically adjust their difficulty based on student responses so that game play occurs at the learner’s developmental level (McManis & Gunnewig, 2012). There is great potential for built-in scaffolds to “shape how people interact with a task and affects what can be accomplished” but there is

much literature recognizing students need direct instruction on how to use these tools effectively (Reiser, 2004, p. 280).

### **Embedded versus non-embedded scaffolds**

According to Clarebout and Elen (2009), hard scaffolds within digital environments can come in two forms: embedded or non-embedded. Embedded support scaffolds “are totally integrated in the learning environment” and are given to the learner “without them having to request or ask for them” (Clarebout & Elen, 2009, p. 390). An example of an embedded scaffold is feedback automatically generated during game play. Non-embedded support scaffolds require action on the part of the learner. This means the tools are used as needed or on just-in-time. Examples of non-embedded tools include hints or access to additional information such as graphics or videos that are requested by the learner during game play (Clarebout & Elen, 2009).

### **Digital scaffolds within Rush Hour®**

The digital game Rush Hour® has six built-in tools available to students with various functions to facilitate game play (Table 3-2). All of the tools are considered non-embedded digital scaffolds. Two of the buttons, Prev and Next, allow students to move within a game level to find easier or more challenging puzzles. The Undo button takes away the last move made and can be pressed repeatedly as it remembers every move since the start of the game. The Hint button provides a single clue each time it is pressed. The Solve button solves the puzzle (a play-by-play sequence of the steps from the beginning) and then resets the game so it can be played again. The Reset button sets the vehicles back to their original position and resets the move counter to zero.

When examined through a constructivist lens and the work of Wood et al. (1976), the Hint button has the potential to serve as a *reduction in degree of freedom* scaffold by “simplifying the task and reducing the number of constituent acts required to reach a solution” (Wood et al., 1976, p. 98). The Next, Prev, Undo, and Reset buttons can serve as *frustration control* scaffolds to reduce stress or fears related to not completing puzzles, while the Solve button has the potential to serve as a *demonstration* scaffold by “modeling solutions to a task” with the “expectation that the learner will then imitate” (Wood et al., 1976, p. 98). These scaffolds are all considered ‘high-leveled scaffolds’, which are found in the literature to be especially effective tools for young children (Shute & Miksad, 1997; Wood, 2001).

Table 3-2. Summary of digital scaffolds within the problem solving game Rush Hour®

Type	Purpose	Scaffolding Function	Type of Scaffold
HINT	Provides a single clue each time; moves one vehicle at a time	Reduction in degree of freedom	Non-embedded, hard
NEXT	Moves player to the next game within a level	Frustration control	Non-embedded, hard
PREVIOUS	Moves player to the previous game within a level	Frustration control	Non-embedded, hard
RESET	Sets all vehicles back to their original position; starts the game over	Frustration control	Non-embedded, hard
SOLVE	Provides a step-by-step video of movements needs to complete a puzzle	Demonstration	Non-embedded, hard
UNDO	Takes away the last vehicle moved;	Frustration control	Non-embedded, hard

### **Summary of Research on Digital Scaffolds**

The use of support devices in TELEs has the potential to positively impact the learning process. Software and app designers are building digital scaffolds into games to help reduce player frustration, increase the amount of time spent playing, and improve overall problem solving performance. Research related to how young children use digital scaffolds is limited but studies in other contexts confirm they can be used successfully. Patterns related to overreliance on digital scaffolds to facilitate problem solving must, however, also be considered.

#### **Early Childhood Context**

Some of the first technological tools used by young children incorporating digital scaffolds were electronic storybooks (e-books). E-books, such as the *Living Book* series published by Broderbund in the 1990s, have long been used in the early childhood classroom to engage students in the storytelling process and to promote literacy skills (Shamir & Korat, 2006). E-books allow children to read and listen to a book and frequently include “digital features that can assist the reader such as word pronunciations, text highlighting, text-to-speech options, and hypermedia” (Moody, 2010, p. 27). These features can be viewed as digital scaffolds with the potential to engage reluctant readers while supporting vocabulary development, one-to-one word correspondence, and the development of phonological skills. Some of these features are embedded throughout the digital texts, while others are available to students upon request.

Today, a multitude of interactive e-books are available online and through apps built for the iPad (Anderson, 2012).

In addition to e-books, educational software have been used in early childhood contexts (Wright & Shade, 1994). Software for young children typically fits into two types: open-ended and drill-and-practice and much research on software at this age focuses on the developmental effects of its use rather than on the scaffolds built into the games (Haugland & Shade, 1994). Reference is made within the literature about the need for 'good support' while students use software but many checklists created to evaluate software do not explicitly look at built-in tools (Haugland & Shade, 1994). Shute and Miksad (1997) were one of the first to review scaffolding features in software used by preschool children and found their use increased language-related cognitive skills. In their study comparing level of scaffolds when preschool children use computer-assisted instruction (CAI) versus traditional resources in Australia, they found software with appropriate scaffolds just as effective as traditional (adult) resources utilizing similar scaffolding structures. Specifically, they looked at Wood's five levels of scaffolded instruction, which include full demonstration, intervention in selection and arrangement (i.e. partial demonstration), intervention by indication (i.e. hint), establishment of parameters (verbal guidance), and verbal encouragement. Games utilizing all five levels of Wood's scaffolds were the most effective at enhancing learning (Shute & Miksad, 1997).

Chiasson and Gutwan (2005) reviewed research related to software for young children and developed a catalogue of design principles specifically oriented towards their needs. They discuss immediate feedback and hints as

key principles of software design. Built-in feedback is critical, with audio and/or video feedback most appropriate for young children. Text “is not an effective means to convey information or provide help” to non-readers (Chiasson & Gutwan, 2005, p. 2). Chiasson and Gutwan (2005) also suggest feedback should be immediate and simple and discuss the need for “interfaces to provide scaffolding and guidance to help children remember how to accomplish tasks” (p. 3). Sarama and Clements (2007) also believe that built-in prompts and hints within digital games are important for young children finding they can reduce frustration as well as build confidence.

### **Elementary/Middle School Context**

Three studies specific to digital scaffolds in the elementary and middle school context have emerged in the last few years that are relevant to this review. While these studies involve older students who approach learning in developmentally different ways, they share many similarities with this capstone study, specifically in the functions of the scaffolding tools within the programs and how the tools are being used. In observing sixth graders playing the number puzzle game Sudoku, Sun, Wang, & Chan (2011) found non-embedded digital scaffolds increased the number of total puzzles completed by students. Their study looked not only at the types of scaffolds most beneficial to students during game play (frustration control, demonstration) but also the effects of these scaffolds on “strategy development and learning” (Sun et al., 2011, p. 2119). They found tools such as error checks and simple hints can reduce frustration and thus extend time students spent problem solving but did note overreliance on these types of support is possible. Sun et al. (2011) also found demonstration

tools showing next steps or more detailed help aided the development of problem solving strategies. Overall, they concluded “different scaffold types play different roles in learning,” cautioned overuse of some scaffolds can inhibit learning problem-solving principles (Sun et al., 2011, p. 2124).

In a second study, Hung, Yu, Chang and Cheng (2012) studied the effect of digital scaffolds while elementary students played a geography puzzle game on a multi-touch display. Demonstration, reduction in degrees of freedom, and frustration control scaffolds were built into the game, as was instant feedback. The demonstration scaffold was used the most and found to reduce the number of times students were ‘stuck’ when solving puzzles. Use of scaffolds did increase learning performance, too (Hung et al., 2012). Like Sun et al. (2012) and Sharma and Hannafin (2007), Hung et al. (2012) also discussed the challenges of finding a balance between availability of scaffolding tools and use of those tools. Teachers should encourage learners to accept some degree of frustration when playing digital games so as not to “engender dependence impeding ownership of and responsibility for one’s own learning” (Sharma & Hannafin, 2007, p. 30).

Finally, Bottino, Ferlino, Ott, and Tavella (2007) performed a qualitative analysis of second and fourth grade students using computer games to determine “to what extent specific features” built-into games can support the development of cognitive skills. Like Sun et al. (2011) and Hung et al. (2012), Bottino et al. (2007) found scaffolding functions within games such as direct feedback, backtracking, tips, and graduation of levels can support learning but



cautioned how they “can also be used by the student to reduce effort and teach the solution by trial and error” (p. 1280).

### **High School Context**

As research related to digital scaffolds is still emerging in the literature, it is important to take a look at literature specific to the high school context to identify any emerging patterns. Like younger students, high schoolers find built-in tools such as feedback and hints beneficial. Pol, Harskamp, and Suhre (2008) compared a traditional mathematics program with an interactive computer program providing both feedback and hints. The students using the computer program outperformed students in the traditional program on a post-test, especially in their ability to analyze and find different solutions or approaches to problems. Their increased performance correlated to their use of embedded planning and verifying hint tools built within the game. Pol, Harskamp, Suhre, and Goedhart (2009) compared traditional (textbook-based) and computer-based environments in a physics classroom but focused on the timing of hints during the problem solving process: before, during, or after problem solving. Students with access to hints during problem solving and examples after problem solving performed best on a post-test.

### **Gaps in the Literature**

As previously stated, research related to built-in help tools within digital games is sparse across all contexts. As more and more digital games are used in the preschool classroom, more research is needed to better understand how digital scaffolds can potentially support problem-solving behaviors in young children. While short-term research is important to help educators utilize new

technologies in their curriculum today, long-term research is needed to help understand how the use of digital scaffolds can assist students in generalizing acquired skills across different problem solving contexts over time. Additionally, as studies from both the elementary and high school contexts caution about the potential overuse of digital scaffolds, it is important to determine if these behaviors also exist in the preschool context so that educators can find ways to help students appropriately and effectively use digital tools.

### **The Role of Help Seeking Behaviors**

The appropriate and effective use of digital scaffolds in TELEs cannot stand on its own. The help seeking skills of learners using the scaffolds is directly correlated to their effectiveness. While the research advises software designers provide varied, developmental, and appropriate digital scaffolds within computer games and apps, the research also discusses the need for learners to know how to solicit, secure, and use help received to solve problems on their own (Gall, 1981; Puustinen, 1998). “Of the many social skills a child can employ to cope with learning situations, one of the most important is the ability to obtain help from adults and peers when it is needed” (Gall & Glor-Schieb, 1985, p. 58). Help seeking is considered a powerful strategy for self-regulated learning enabling both children and adult learners to perform independently (Karabenick, 2011; Puustinen, Volckaert-Legrier, Coquen & Bernicot, 2009).

As with the literature related to students overreliance on digital scaffolds (Bottino et al., 2007; Hung et al., 2012; Sun et al., 2011), help seeking is not always instrumental. When students are more interested in outcomes rather than process or use help to avoid work, help seeking can be detrimental to the

learning process (Gall, 1985). Yet when help is “limited to the amount and type needed to allow learners to solve or attain goals for themselves” the help seeking behaviors are instrumental (Gall, 1985, p. 67). Instrumental help can promote learning and understanding and utilizes indirect help, hints, and examples (Puustinen, Volckaert-Legrier, Coquen, & Bernicot, 2009).

Despite the important role help seeking can play in the learning process, students of all ages struggle to effectively seek and use help when problem solving (Gall, 1981; Gall, 1985). An overall finding throughout the literature related to all classroom contexts was the need for teachers to provide explicit instruction on how to use built-in help tools (Alevén et al., 2003; Bartholomé, Stahl, Pieschl, & Bromme, 2006). Students “do not always make adequate choices for their learning process” (Clarebout & Elen, 2009, p. 389). This is especially the case for students with low prior knowledge or novice learners (Harskamp & Suhre, 2007).

The bulk of research related to help seeking behaviors is specific to older learners in secondary and tertiary classrooms (Alevén et al., 2003; Bartholomé et al., 2006; du Boulay & Luckin, 1999; Schworm & Renkl, 2006; Shute & Gluck, 1996) and only within the last twenty years is the research specific to digital contexts (Karabenick, 2011). In the early childhood context, two small studies were identified related to how young children seek help in a technological environment. Both studies support the role teachers and/or adults play in providing explicit instruction and modeling so that children can understand the design elements and their functions.

Luckin, Connolly, Plowman and Airey (2003) evaluated the use of built-in help within interactive plush toys connected to software on desktop computers. The researchers observed four to six years olds playing with the toys and software in three different contexts: in the home, in the classroom, and in an after school club. Even though children were given direct instruction on the types of help available before game play (by squeezing the toy's ear or through the help icon on the computer screen to receive hints), they found children still needed prompts from adults to use the built-in help tools during game play. Likewise, in their study of preschool children playing the literacy computer game *I Spy School Days*, Roberts, Djonov, and Torr (2008) found younger children could play e-games with more success only if they had the ability to ask for help in utilizing built-in scaffolding tools but caution educators not to assume young children will innately learn how to use help and remind us all that "the software alone cannot teach children these skills" (p. 255).

As it relates to elementary students, Kreutzer, Leonard, Flavell, and Hagen (1975) found children used help to aid in memory, which allowed them to engage longer on problem-solving tasks. Myers and Paris (1978) examined differences between second and sixth grade students and found requests for help increased as students got older and were involved in more in-depth problem solving situations. Copper, Ayers-Lopez, and Marquis (1982) observed kindergarten and second graders working during problem solving tasks and found they often sought out peers using both verbal and non-verbal strategies while they worked. Verbal help strategies included asking directly for assistance, soliciting information through questions, and making statements. Non-verbal

help strategies included establishing proximity and/or eye contact, watching the actions of others, and using physical expressions to convey frustration.

In their study of students in first, third, and fifth grade classrooms, Gall and Glor-Schieb (1985) set out to identify characteristics of children who seek help, the types of help they seek, who they turn to for help, and how the classroom environment impacts help seeking behaviors. They found students often ignore help or use it inefficiently and direct instruction on how to find help is needed for all students, no matter their age. They also learned the type of task or activity impacted help seeking behaviors. Activities requiring the use of critical thinking, reasoning, and problem-solving strategies increased the amount of help requested. Puustinen (1998) also found students of all ages need assistance in learning how to seek help and noted that experience was an important factor as well. In observing second and fourth graders, she noted “the level of self-regulation depended on both age and academic achievement” (Puustinen, 1998, p. 271.)

Help seeking behaviors and the use of scaffolds to support learning are intertwined. In order for students to successfully and effectively use built-in tools and other forms of on-demand help within digital games, the majority of the research indicates direct instruction must take place on how to effectively use them. Therefore, educators of young children should constantly model help seeking behaviors and provide students with strategies to seek help on their own, especially as help-seeking is linked to motivation, self-monitoring, and connected to both language and social development (Thompson, 2012).

## **Collaborative Problem Solving**

When thinking about peer-supported learning, it is important to distinguish between the concepts of collaboration and cooperation. These terms are often used interchangeably within the literature, as they are both strategies for grouping students, yet they can offer very different experiences for learners (Shih, Shih, Shih, Su, & Chuang, 2010; van der Meij, Albers, & Leemkuil, 2011). While these two concepts both involve “two or more people working together to co-construct knowledge in solving a problem” (van der Meij et al., 2011, p. 657), they differ in how peers participate. In cooperative learning contexts, each member has a specific role and amount of work for which he/she is responsible. The work of each individual member is then combined to contribute to the whole (Shin et al., 2010). In collaborative learning, peers are involved in the “whole” process from start to finish together. Work is not distributed between group members and there are “no distinguished ranks” (van der Meij et al., 2011, p. 656).

According to the National Council of Teachers of Mathematics (NCTM), collaborative problem solving is a major process essential to developing mathematical thinking (Charlesworth & Leali, 2012). Young children need to recognize there are many ways to solve problems, and through collaboration with others, they are given opportunities to share their thinking (NCTM, 2012). ‘Socially shared talk’ during collaboration is essential to the development of problem solving strategies and is one way young children can make sense of mathematical concepts in the world around them (Hagstrom & White, 2006). According to a joint position statement written by NAEYC with NCTM, educators

need to “use curriculum and teaching practices that strengthen problem solving and reasoning processes as well as representing, communicating, and connecting mathematical ideas” (NAEYC, 2010, p. 3).

Many studies throughout the literature discuss how children working with partners have increased performance over those working individually on problem solving tasks such as completing puzzles, building with blocks, programming, and playing computer games (Azmitia, 1988; Fawcett & Garton, 2005; Hagstrom & White, 2006; Huang, Cheng, & Chan, 2007; Inkpen et al., 1995; Ramani, 2012; Verba, 1998). For example, Inkpen, Booth, Klawe, and Upitis (1995) looked at children playing alone or with partners while completing puzzles. Children working with a partner solved more puzzles and engaged in more verbal interactions than those working alone. Likewise, Fawcett and Garton (2005) found children “who collaborated collectively obtained a significantly higher number of correct sorts than children who worked individually” on a block sorting activity (Fawcett & Garton, 2005, p. 157).

While many collaborative learning experiences occur naturally as children play, classroom teachers must intentionally plan experiences to foster these interactions (Johnson-Pynn & Nisbet, 2002). The early childhood teacher has the challenge of understanding how young children learn and develop in order to meet the learning needs of each individual student in the classroom (Epstein, 2007; NAEYC, 2009). Therefore, it is essential for teachers to find the best possible way to group students so “all children benefit from the collaborative learning experience” (Schmitz & Winskel, 2008, p. 582). Simply putting children together in collaborative situations will not always promote cooperation, problem

solving, or learning (Fawcett & Garton, 2005). Assuming all environments are conducive to the same types of groupings is also not a guarantee.

### **Summary of Research on Ability Groupings**

Throughout the literature related to collaborative problem solving across early child and elementary contexts, several studies emerge discussing methodologies for partnering students to optimize learning. Most findings suggest mixed-ability, asymmetrical groupings increase cognitive performance at a greater rate than same-ability, symmetrical, groupings (Azmitia, 1988; Cooper, 1980; Johnson-Pynn & Nisbet, 2002; Fawcett & Garton, 2005; Perlmutter et al., 1989; Verba, 1998). Some find same-ability partnerships more conducive to learning (Cooper, 1980; Light & Littleton, 1998; Ramini, 2005). Both types of groupings confirm that working collaboratively with a partner often increases motivation and time on task, and that “the presence of a partner can prevent a person giving up prematurely when the task becomes difficult” (Schmitz & Winskel, 2008, p. 582).

### **Mixed-Ability Partnerships**

The majority of research related to ability groups and collaborative problem solving supports mixed-ability partnerships. Mixed-ability partnerships have the potential to increase learning, support low-ability learners, and help learners generalize their skills across problem solving settings (Azmitia, 1988; Fawcett & Garton, 2005; Schmitz & Winskel; Verba, 1998). All the mixed-ability studies identified in this review discuss the use of language to support learning and reinforce Vygotsky’s theory that “cognitive change depends on social interaction with more knowledgeable others” (Fawcett & Garton, 2005, p. 165).



What is less clear about these groupings is what constitutes an ideal partnership, and what are the benefits to middle-ability and high-ability partners.

Verba (1998) looked at preschool dyads involving mixed-ability partners and found less advanced partners not only improved performance on their current task of assembling a block cargo truck, but also generalized skills to later problem solving tasks. She found that young children move between asymmetrical and symmetrical interactions, and that high ability students also benefit by “consolidating his/her own know-how” when guiding his/her partner (Verba, 1998, p. 195).

Azmitia (1988) looked at expert/novice partnerships when students built replicas of a Lego model to see if “collaboration led to greater learning than solitary work” (p. 94). Eighty children were randomly assigned to three conditions: alone, same-ability or mixed-ability. She found the building accuracy of same-ability dyads was no different than same-ability students who worked independently on the same challenge, but did find mixed-ability dyads built more accurate models than those children working alone. Collaboration proved to be “more conducive to learning than independent work” especially for novice or low-ability students, and these students generalized their skills to a post-building task (Azmitia, 1998, p. 87). Novice students observed experts, and experts gave explanations and demonstrations during tasks. Experts were also found to observe other experts and maintain their scores across tasks.

Fawcett and Garton (2005) observed seven-year old students (n=100) working first on a block sorting activity and then on a card sorting activity and found children who collaborated obtained a higher number of correct sorts over

those who worked alone. Like Azmitia (1998), lower-ability students working with higher students “showed a significant improvement in sorting ability from pre-test scores,” and they made the largest gains on the task of sorting cards into categories (Fawcett & Garton, 2005, p. 157). Novice learners who worked with experts were also found to generalize their skills to other activities when they were on their own, but students working with same or lesser ability partners showed no improvements from pre-test to post-test and high-ability students regressed unless they worked with low-ability children who “talked” during sorting tasks.

Schmitz and Winskel (2008) observed single sex partnerships comprised of 10-12 year olds (n=27) to understand how assigning roles impact the collaborative learning experience and the level of talk that occurs between dyads when working on math problem solving tasks. Specifically, they were looking for levels of ‘exploratory talk’ defined as “disagreement with one another’s ideas while suggesting a positive alternative solution” (Schmitz & Winskel, 2008, p. 583). Half of the mixed-ability dyads were asked to simply ‘work together’, while high-ability students in the other half were asked to provide help. Students in the low-middle condition showed more high quality exploratory talk than those in the low-high condition, and students in the low-high help condition “showed more exploratory talk than dyads who were asked just to work together” (Schmitz & Winskel, 2008, p. 581).

While these studies promote mixed groupings, they also recognize that many factors such as type of task, type of learning environment, level of student motivation, level of student confidence, assignment of roles, and gender can

impact interactions (Azmitia, 1988; Cooper, 1980; Johnson-Pynn & Nisbet, 2002; Fawcett & Garton, 2005; Perlmutter et al., 1989; Verba, 1998). Some studies have found high-achieving students can negatively impact the work of low-achieving students by taking over the problem solving process (Light & Littleton, 1998; Schmitz & Winskel, 2008). Light and Littleton (1998) found mixed groups can be too asymmetrical resulting in power struggles, negative conflict, and less negotiation. They believed symmetrical partnerships allowed both members of the dyad to present their views and question each other in constructive ways (Light & Littleton, 1998).

### **Same-Ability Partnerships**

A voice supporting equal ability peers in preschool problem solving tasks is Ramani (2005). In her dissertation, four- and five-year-old children were placed into one of two conditions, a playful child-driven building task or an adult-driven building task. Children were first read a short story in which a problem was presented. Dyads in the playful condition were then told they could pretend to be the children in the story, while dyads in the adult-guided condition were told to work together and were then given specific instructions on how to build. Ramani (2005) found preschool children working with a same-ability partner benefited more than those children working with mixed-ability partners, especially in the less formal, play-like setting (Ramani, 2005). Same-ability partners in the playful condition built more complex and complete buildings and participated in more communicative behaviors than those groups working in the more adult-guided building environment. These same-ability dyads also showed “higher

levels of task performance and more cooperative problem-solving behaviors and communication” in subsequent building tasks (Ramini, 2012, p. 159).

An early study conducted by Cooper (1980) observed three to five-year old same-ability dyads as they used a balance scale to locate matching block pairs. In the study, each child in the dyad was viewed as a potential “director” of the problem solving activity. Findings show productive communication behaviors such as suggestions, requests, and modeling between all dyads and found these behaviors increased as dyads got older. Cooper found “neither differentiated nor symmetrical styles proved to be distinctively advantageous” but did suggest further research be conducted on how teaching by one partner might contribute to the dyad’s effectiveness (Cooper, 1980, p. 439).

Other studies supporting same-ability groupings are found in the elementary and middle school context. Light, Littleton, Messer, and Joiner (1994) observed 11- and 12-year-old students working together on an adventure quest game on the computer. Students were required to search for information to help plan a solution to a task while reacting to obstacles. Over the course of three gaming sessions, symmetrical pairs made the greatest progress “both in terms of pair performance and individual learning” (Light et al., 1994, p. 103).

King, Staffieri, and Adalgais (1998) found same-ability dyads advantageous in promoting the scaffolding process when students are given guidelines on how to provide support. Seventh grade students learned how to be mutual peer tutors and used hints and probing strategies to extend thinking and strengthen problem solving during science inquiries. The highest levels of engagement and talk were found in the condition in which students were given

the most guidelines and training. While the context of this study is far-removed from the early childhood context, the training aspect of the study is an interesting parallel to the potential training aspect that can be provided by digital scaffolds, especially if children are taught to explicitly use the tools.

### **Gaps in the Literature**

The majority of research on mixed-ability and same-ability partnerships is not specific to a technological context nor did they occur in the natural classroom environment. When looking specifically at the early childhood context, none observed children working with technological tools such as computers. The bulk of studies related to technology use are specific to how technology tools fit into DAP and can support growth across the developmental domains, especially social development (Kumpete, 2006; Heft & Swaminathan, 2002; Muller & Perlmutter, 1985). They also focus on differences between independent and dyadic problem solving. At this time, there is no literature related to young children working collaboratively playing problem solving games on mobile devices, much less literature related to ability groups using these devices with built-in digital scaffolds.

### **Game-Based Learning**

Digital games are recognized across the literature as a central part of modern culture (Azli, Azan, & Bahri, 2008; Hong, Cheng, Hwang, Lee, & Chang, 2009; Johnson, Adams, & Cummins, 2012; Mitchell & Savill-Smith, 2004; Oblinger, 2006). Important in the lives of young children as well as adolescents, they are considered a “prominent 21<sup>st</sup> century activity that engages the minds of children” (Kafai, 2006, p. 36). According to Miller, Robertson, Hudson, and Shimi

(2012), the use of digital games can “serve as a link between the classroom and children’s lives outside of school” (p. 234), and they have the potential to engage and motivate learners while impacting how they learn (Tuzun, Yilmaz-Soylu, Karakus, & Kizilaya, 2009).

Digital games are receiving great attention within early childhood literature as more games become available to young children both at home and at school, on the computer and through apps on mobile devices (Gee, 2003; Gros, 2007; Johnson, Adams, & Cummins, 2012; Lieberman et al., 2009; Oblinger, 2006; Prensky, 2001a). Part of this interest stems from recent support of the use of touch technologies and apps by NAEYC in its latest position statement regarding technology in the preschool classroom (NAEYC, 2012). It is also spurred by the connection between the play qualities inherent in games so valued by educators of young children (Fails, Druin, Guha, Chipman, Simms, & Churaman, 2005). Games are fun, voluntary, intrinsically motivating, and active (Amory, Naicker, Vincent, & Adams, 1999). They allow children to learn new concepts through exploration and problem solving, and they utilize a user-centered, interactive, and multi-sensory interface (Gros, 2007; Hong et al., 2009). Games also provide opportunities for structured, creative, and free play, which can augment traditional play offerings in the early childhood classroom (Johnston et al., 2012; NAEYC, 2012).

### **Benefits of Digital Games**

Many benefits to the use of games in preschool educational contexts exist within the literature. Games are one way to promote social development and collaborative learning in the classroom. When children are partnered during

game play, they learn to “take turns, cooperate, be sensitive to other players’ viewpoints, and delay gratification” (Johnson et al., 2005, p. 212). Games can also be used to learn basic math skills (shapes, patterns, number recognition, counting), problem solving and reasoning skills, visual skills (visual literacy, visual tracking, spatial awareness) and early literacy skills (alphabet recognition, phonemic awareness, sight word development) (Din & Calao, 2001; Miller et al., 2012; Muller & Perlmutter, 1985; Shute & Miksad, 1997). Din and Calao (2001) examined the effects of educational video games on kindergarten achievement and found students who played video games 40 minutes a day over 11 weeks at school gained language skills (spelling, reading, and decoding) over their non-gaming peers but found no significant gains were made in math skills. This study confirms earlier findings by Shute and Miksad (1997), that computer aided instruction (CAI) software is successful in increasing language and verbal skills. Finally, games can be used to support differentiated instruction. Gros (2007) found games have the potential to ‘even the playing field’ for less advanced students, and Fails et al. (2005) believes the increased complexity of games can meet the needs of many different learners. Through the use of leveled games with increasing levels of difficulty, there is potential to match game experiences to extend children within their ZPD.

### **History of Digital Games**

Although the use of digital games in educational contexts has been discussed within the literature for more than twenty years, there remains skepticism about their potential to positively and significantly impact learning (Johnson et al., 2012). According to Gros (2007), research prior to 2007 was

disjointed. Lack of a common research language related to gaming, absence of a clear definition, and studies limited to impact on 'soft skills' such as collaboration, communication, critical thinking, and problem solving, kept many educators away from investigating their potential for cognitive learning on a large scale (Gros, 2007; Johnson et al., 2012). Additionally, efforts to integrate games without carefully considering the underlying design and learning principles behind the games fell short. Some educators tried to simply add games to the curriculum without evaluating their educational value (Hong et al., 2009).

The work of Azli et al. (2008), provided a much needed definition for game-based learning and called for educators to examine more deeply how games can help students learn new concepts and skills. According to Azli et al. (2008), games are “digital applications that can be controlled by individuals or groups of players using a computer or video console” (p. 1) and game-based learning (GBL) “is the marriage of educational content and computer/video games” (Azil et al., p. 1). Johnson et al. (2012) mirrors this earlier definition calling GBL “the integration of games or gaming mechanics into educational experiences” (p. 19). Recent work by An and Bonk (2009), Chiasson and Gutwin (2005), and Gros (2007) has been instrumental in helping with design principles within the gaming industry. Additionally, their work provides a framework for educators to evaluate digital games and select those that are most suitable for young children.

### **Types of Games**

Based on a review of the literature from many different contexts (industry, game developers, academics), Gros (2007) categorized games into seven



genres. While not an exhaustive list, the genres include action, adventure, fighting, role-playing, simulation, sports, and strategy games (Table 3-3).

Within these categories, games can be serious, where there is a primary purpose beyond entertainment, or developed for pure entertainment. Simple or mini-games allow players to achieve quick outcomes, while complex games involve the achievement of many goals and sub-goals over an extended period of time (Gros, 2007). Fails et al. (2005) support game use with young children and recommend simple games with fewer rules and more structure most developmentally appropriate.

Table 3-3. Main genres of digital games (Gros, 2007)

Genre	Description
Action	Players use reflexes, accuracy, and timing to complete challenges <i>Example: Angry Birds</i>
Adventure	Players solve tests or challenges to progress through virtual worlds <i>Example: World of Warcraft</i>
Fighting	Involves fighting against computer-controlled characters or characters controlled by other players; emphasis is on one-to-one combat <i>Example: Halo</i>
Role-Playing	Human players take on the role or assumed the traits of a person, character, or creature <i>Example: Liberty Kids</i>
Simulations	Simulates aspects of a real or fictional reality <i>Example: SimCity</i>
Sports	Games based on sporting activities and or events <i>Example: Fifa</i>
Strategy	Require careful thinking to achieve a goal, includes puzzle games <i>Example: Rush Hour®</i>

As it relates to this capstone project, the game Rush Hour® falls into the category of strategy games. According to Gros (2007), strategy games often refer to “games that recreate a historical or fictional situation to allow a player to devise an appropriate strategy to achieve a goal” (p. 26) but can also include

games like brainteasers, puzzles, and mazes. Strategy games are usually more casual than other games. They are also simpler, allowing them to be played within short time frames. When playing strategy games, the learner is in control and must make decisions to reach a specific outcome.

### **Qualities of Good Games**

As any gamer can tell you, not all games are good, and not all games are meant to be used in the classroom. First, games are only effective learning tools if they are designed to “reflect pedagogy and learning needs in a real educational setting” (Hong et al., 2009). Instead of playing games to learn, educators need to find games made for learning (Kafai, 2006; Prensky, 2001a). These games need to teach more than just skills. They need to promote critical thinking, and the integration of content should be at the heart of game play (Fisch, 2005; Kiili, 2007; Prensky, 2001a). Next, games need to be challenging while still allowing players to achieve its goals. Games must be age-appropriate and clearly presented with an easy to use interface (Fisch, 2005). They should promote problem solving with sequential tasks built upon previously acquired knowledge and operate on the edge of a child’s ZPD (Gee, 2003). Third, games need to provide feedback and hints. Scaffolds within games should be extensive so learners can use them when they need them (An & Bonk, 2009; Fisch, 2005). According to An and Bonk (2009) good digital games “ provide embedded scaffolding by distributing knowledge needed to play” (p. 44) within the environment as well as support through ‘just-in-time’ access. Schute and Miksad (1997) also cite scaffolding as essential to good games. The higher the levels of scaffolding provided within games, the greater the cognitive gains, especially for

young children (Shute & Miksad, 1997). In their study of preschool students using early literacy software, scaffolding strategies of full and partial demonstration were found fundamental to the learning process for children as young as two years old. Finally, games should be played in teams to provide opportunities for shared learning (Kiili, 2007).

The game Rush Hour<sup>®</sup> was selected for this study because it incorporates many of the suggestions within the literature related to features of developmentally appropriate digital environments and good games (An & Bonk, 2009; Chiasson & Gutwin, 2005; Cooper, 2005; Gee, 2003; Gros, 2007; Johnston et al., 2012; McManis & Gunnewig, 2012). The game is easy to use, leveled, and responsive to the child's input. It encourages critical thinking through sequential levels that can operate within a player's ZPD. The game provides a variety of 'just-in-time' scaffolds to support students as they play, and Rush Hour<sup>®</sup> allows children to be active participants throughout game play. Finally, the game lends itself to collaborative problem solving, which provides opportunities for student to think and work together.

### **Assessment of Digital Games**

Design principles related to game-based learning environments are appearing in the literature. Chiasson and Gutwin (2005) were one of the first to catalogue design principles specific to the technologies of young children. Organized according to three main areas of child development, cognitive, physical, and social/emotional, their catalogue is useful to early childhood educators who want to ensure technology use is natural and inline with how

young children learn best. Sections related to literacy, feedback, and guidance are especially relevant when thinking about digital scaffolds within games.

On a more comprehensive scale, Hong et al. (2009) set out to develop a tool to guide software developers in the creation of educational games. Working with game scholars as well as professional game designers, they identified 74 indices sorted into seven categories that serve as guidelines during the game development process. The seven categories include mentality change, emotional fulfillment, and knowledge enhancement, thinking skill development, interpersonal skill development, spatial ability development and bodily coordination. Their work provides an excellent framework for teachers to evaluate the educational values of games as well.

### **Chapter Summary**

This literature review began with a synopsis of the constructivist theory and how tutoring interactions with more knowledgeable others can support student learning. Different forms of support, or scaffolds, were discussed including methodologies for grouping students to promote scaffolding behaviors as well as the emergence of digital scaffolds in technologically enhanced learning environments. Research related to help seeking behaviors and its relationship to using scaffolds effectively was also presented. The chapter ends with a discussion on game-based learning and the prominent role digital games are playing in the lives of even our youngest children. Woven throughout the review is analysis on how the problem solving game Rush Hour<sup>®</sup> and its built-in scaffolding tools fits within the literature.

## CHAPTER 4 METHODOLOGY

Chapter 4 presents the descriptive research design of this capstone project, which examines the ways digital scaffolds are used by preschool children when playing the problem solving game Rush Hour<sup>®</sup>. A description of the context, digital game, and participants is included along with the methodology for data collection and analysis. The chapter concludes with a discussion of the study's trustworthiness and limitations.

### **Research Questions**

iPads are one of the newest technology tools being used in educational settings to promote learning, and preschool teachers are searching for developmentally appropriate ways to integrate these tools into their classrooms. A study conducted by the researcher in Spring 2012 found play with iPads can provide opportunities for rich social interactions and collaborative problem solving. The study also revealed the potential of built-in help tools or digital scaffolds to extend thinking. Therefore, the purpose of this descriptive research study was to examine the ways digital scaffolds are used by young children during collaborative problem solving in the preschool classroom. The following research questions are answered:

Research Question 1: In what ways do preschool dyads use digital scaffolds when playing the problem solving game Rush Hour<sup>®</sup>?

Research Question 2: In what ways does the ability level of preschool dyads impact how digital scaffolds are used when playing the problem solving game Rush Hour<sup>®</sup>?

## **Background on the Researcher**

The researcher has been an educator for eighteen years in various roles at the private school in which this study took place. At the time of this study, the researcher was the Instructional Technologist within the early childhood and elementary divisions of the school and served in this capacity for eight years. In this role, the researcher worked collaboratively with the faculty to facilitate the advancement of technology by developing curricular materials and lesson plans that integrate technology, co-taught in classrooms to model effective and appropriate integration of technology in all curricular areas, and aligned technology resources with grade-level curriculum and national technology standards. The researcher has been working with the Junior Kindergarten (JK) teachers for three years on developmentally appropriate ways to implement touch technologies within the daily curriculum.

## **Context**

This descriptive research study was conducted in two JK classrooms over the course of eight weeks in the Early Childhood Center (ECC) of a college preparatory school in Florida. The school had an enrollment of approximately 985 students from early childhood (age 3) to 12<sup>th</sup> grade. During the 2012-2013 school year, 27 students enrolled in the JK program. The ECC is accredited by NAEYC and the Florida Kindergarten Council (FKC) and runs a five days per week program. Students may be full-day participants (8:10am – 2:50pm) or half-day participants (8:10am – 12:45pm). The first JK class had 13 students while the second had 14 students. Both classes are led by state-certified teachers with

a Bachelor of Arts in Early Childhood Education and a full time instructional assistant.

### **Curriculum and Planning**

The JK curriculum is designed to promote growth through active, hands-on learning with a balance of play and discovery, as well as self-initiated and teacher-initiated activities. Subjects taught during the school year include literacy, language, math, science, social studies, art, music, physical education, Spanish, and technology.

The development of the curriculum and daily learning experiences is shared between the two classroom teachers with guidance and support from the Early Childhood Director. Lead teachers meet at least two times a week during rest time to plan activities, organize project work, and discuss instructional strategies for accommodating individual learners.

The entire team, including lead teachers from the Alpha (3-year-old) program and instructional assistants, meets every Tuesday afternoon to plan vertically as well as to engage in professional development. The team's current professional development focus is an in-depth study of the Project Approach model developed by Lillian Katz and Sylvia Chard.

### **Learning Space and Daily Activities**

The early childhood facility is a communal space consisting of an open Exploratorium (shared exploration space) connected to the classrooms. Sliding glass doors between classrooms can be opened to allow students to flow back and forth between the spaces, and each classroom is connected to an outdoor

covered deck and playground. There are no walls between any of the educational spaces.

A typical school day includes time for student choice, instructional circle time, exploration in classroom centers, lunch, rest, and outdoor play. Students work in classroom centers each morning with the classroom teacher, instructional assistant, and parent volunteers facilitating different activities. During this time, students rotate independently between four to five centers with activities typically tied to thematic units of study, student-led project work and/or specific skills. Classroom teachers may also call students, as needed, to work at a center. Twice per week (Mondays and Wednesdays), the classes are combined and co-taught by both teachers.

iPads are used in the preschool classrooms on a daily basis during center rotations and are often used by classroom teachers as a way to enhance instruction at learning centers. Students also used the iPad independently to record their work, create projects, or play digital games. For example, during a recent unit of study on Native Americans, classroom teachers used the iPads to display videos of traditional dances as well as slideshows of Native American artifacts. Students accessed these multimedia artifacts as they worked. During a cooking activity, students used the built-in camera to document the steps needed to make gingerbread cookies. The photos were then added to a slideshow with text to make a 'How To' book. A final example of iPad use is when teachers use e-books and rhyming and alphabet apps to enhance language development.



## Participants

The majority of students attending the JK program come from families of middle to high socioeconomic status. No academic or social evaluation is conducted before entrance into the program, and upon exiting, students are typically ready to perform successfully in the school's kindergarten program. None of the children enrolled in the JK program during the 2012-2013 school year spoke English as a second language and the majority of students were Caucasian. Participants for this study (n=24) were those students whose parent(s) or guardians(s) received the Study Introduction Letter (Appendix A) and signed the Consent Form (Appendix B). Table 4-1 highlights basic demographics of each class participating in the study.

Table 4-1. Participant demographics

	Total # of Students	Total # of Boys	Total # of Girls	Age of Youngest Participant	Age of Oldest Participant	Mean Age
Class A (Same)	12	4	8	4.3	5.4	4.8
Class B (Mixed)	12	6	6	4.4	5.3	4.9

Each intact class was randomly assigned to one of two conditions by a flip of a coin. Subjects in Class A (n=12) were matched with partners of similar problem-solving ability (high-high, middle-middle, low-low) while participants in Class B (n=12) were matched with partners of different problem-solving ability (high-low, middle-low, high-middle). The ranking of students was completed by the classroom teachers based on current assessments and anecdotal notes. Problem-solving ability was determined through observations on puzzle tasks, during block construction, exploration with math manipulatives, and displays of

higher order thinking skills when asked open-ended questions. Students in each class were ranked in order from one to twelve on a problem-solving continuum. Students with a ranking of 1-4 were considered to have low problem-solving ability, 5-8 middle problem-solving ability, and 9-12 high problem-solving ability. Utilizing a shared Google document, each teacher provided input regarding problem solving ability and ranked the students based on the above scale. This Google document was also used to keep track of the student consent forms.

### **Task**

Rush Hour<sup>®</sup> invented by Nob Yoshigahara and distributed by ThinkFun Inc ([www.ThinkFun.com](http://www.ThinkFun.com)) is a sliding block puzzle game for children ages 4 and up (Appendix K). The objective of the game is to move the 'Red Car' out of the 'Exit Gate' by moving blocking cars and trucks out of the way with one's finger on the iPad screen. Cars and trucks can move in only one direction, vertical or horizontal, depending on their initial position in the 'parking lot' (Figure 4-1). The application consists of four levels (easy, medium, hard, expert) with 650 puzzles in each level. The difficulty level of each puzzle increases with the completion of the previous puzzle. Hint and Solve features are available through all levels of the game. Additionally, students can Reset the puzzle if they feel the need to start a game over, use the Next button to move on to the next game, select the Prev button to move back to the previous game, or choose the Undo button to remove the last move. During the study, participants only played games within the easy level and moved sequentially through puzzles for 10 minutes of playing time.



Figure 4-1. Screenshot of Rush Hour® game and help tools (printed with permission from ThinkFun Inc, a leading creator of mind challenging games) (Appendix K)

## General Procedures

### Introduction Development

Prior to the start of the study, the researcher met with the classroom teachers to develop an informal lesson plan/checklist to introduce the game to the students (Appendix C). At that time, it was decided that initial instruction on how to play Rush Hour® along with training on how to use the six built-in tools would be led by one teacher to both classes in the Exploratorium space. Combining classes for instruction eliminated the threat of students receiving different levels of instruction. Half an hour before the beginning of the study, the teachers and researcher met again to review the protocol and to confirm final student rankings for the study.

## **Game Introduction to Students**

The implementation of this capstone project began on the last Monday in April. Monday is one of two days during the week in which both JK classes rotate through centers together and teachers alternate planning activities. The lead teacher for the week introduced the game Rush Hour® during morning circle to both classes as they were seated on the floor in the Exploratorium space. The teacher followed the checklist to explain how to access the application as well as the objective of the game (See Appendix C). She modeled the game experience using the first three levels of the game while the iPad was connected to a projector. Projection allowed for each child to easily see the game board. Throughout the lesson, the teacher explained each of the four buttons across the bottom of the game screen – (H) Hint, (R) Reset, (◀) Undo, and (\*) Solve – along with the Prev and Next buttons used to navigate between puzzles on the top of the game screen.

## **Game Play**

Prior to each dyad visiting the iPad center, the researcher prepared the iPad through the game settings. This included resetting the data collection tools back to factory settings, setting the game to the easy level, and choosing puzzle #4. The researcher also spent a few minutes to check that the video cameras were still recording and complete dyad information (date, class, dyad name) on the observation form (Appendix D). There were two instances during the study in which one of the cameras failed. Fortunately, a second video camera and audio recorder captured game play.

Each dyad played the game for 10 minutes. A digital timer with an alarm was used to keep track. During each session, the researcher sat with the children but tried to be as unobtrusive as possible. The goal for the researcher was to remain engaged and responsive but provide no help, although some support and direction was needed. Minor interventions with the dyads included a) being directly questioned by a student on how a tool worked or how to play the game, b) helping with technical difficulties such as the game freezing, or c) redirecting a dyad member that was distracted and off task for longer than 30 seconds. Direct guidance such as providing a verbal hint to move along game play when a dyad was frustrated (for longer than two minutes) or to stop inappropriate behaviors occurred on four occasions. For example, one student wanted to press the Next button to get all the way to the end of the puzzles in the easy level. A second example included asking a dyad member to stop playing with a toy on a nearby shelf and work with his partner on playing the game.

### **Research Design**

Descriptive research focuses on discovering what is happening within a particular context by gathering data that “describes events and then organizes, tabulates, depicts, and describes the data collection” (Knupfer & McLellan, 1996, p. 1197). According to Knupfer and McLellan (1996), descriptive research plays an “important role in education research” (p. 1196) because it captures the human experience within the natural classroom environment or educational context in which it occurs. Unlike other research methods that seek cause-and-effect relationships between variables, descriptive research helps paint an overall picture of a phenomenon by searching for patterns that can describe

relationships between them. The nature of these relationships can be found through the use of quantitative methodologies, qualitative methodologies, or mixed methods (Knupfer & McLellan, 1996).

Mixed methods collect, analyze, and mix both quantitative and qualitative data in a single study to understand a problem (Creswell & Clark, 2007). The purpose for using mixed methods is to capture the strengths of each individual research method to help “understand a phenomenon more fully than is possible using either quantitative or qualitative methods alone” (Gay, Mills, & Airasian, 2009, p. 462). There are many types of mixed methods design models. Each model is dependent on the weight or importance given to the type of data collected, the order in which the data is collected, and how and when the data is analyzed and interpreted within the research timeline (Creswell, 2009).

An explanatory mixed methods research design was used for this descriptive study (Figure 4-2). In this design, quantitative data were collected during the first phase of the research via statistics available through the game itself and through observations of game play to organize data in numerically meaningful ways (Sandelowski, 2000). Subsequent collection and analysis of qualitative data occurred in the second phase to provide an in-depth explanation of initial quantitative results through a more comprehensive account of the happenings surrounding each use of a digital scaffold during game play (Creswell, 2009). Qualitative data were gathered through videotaping of observations as well as face-to-face interviews. The merger of the results took place during the interpretation with qualitative results providing support or a clearer understanding of both the role of digital scaffolds in the problem-solving

process as well as any variances in how different ability groups used the help tools built-in to digital games (Creswell, 2009; Creswell & Clark, 2007).

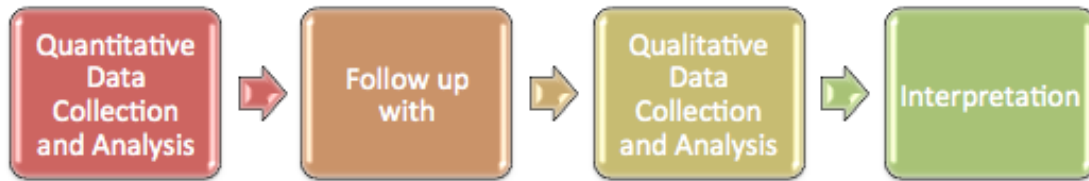


Figure 4-2. Mixed methods research design for capstone project (Creswell, 2009)

### **Data Collection**

This descriptive study utilized both quantitative and qualitative data sources. Quantitative data related to game play by student dyads were collected through statistical features built into the Rush Hour<sup>®</sup> game and observations of each dyad by the researcher. Qualitative data were collected through a field journal, video recordings, and face-to-face interviews with the children. These data were reviewed, coded, and analyzed to identify how digital scaffolds are used when children play the problem solving game Rush Hour<sup>®</sup>.

### **Game Statistics**

The game Rush Hour<sup>®</sup> has several built-in features allowing for the collection of quantitative data related to game play and the use of one of its digital scaffolds. This information was recorded after completion of each puzzle and at the end of game play on an observation form (Appendix D). The main statistics collected through the game itself included:

- The total number of levels completed by each dyad, which was indicated by a yellow check mark on the Challenges screen after ten minutes of game play (Figure 4-3).
- The total number of puzzle levels completed with and without using the Hint button indicated by an 'H' on the Challenges screen recorded after

game play to indicate how many times the reduction in degree of freedom scaffold was used (Figure 4-3).

- The minimum number of squares needed to complete each puzzle and the total number of moves actually made by the dyad to complete each puzzle. These scores will be used to help calculate the level of problem solving efficiency for each dyad (Figure 4-3).
- The number of puzzles, if any, completed with a perfect score (moves made by dyad match the minimum moves needed to complete the puzzle).



Figure 4-3. Screenshots of game statistics captured after each puzzle is completed and after 10 minutes of game play (printed with permission from ThinkFun Inc, a leading creator of mind challenging games) (Appendix K)

### Observations and Video Recordings

While the reporting feature within Rush Hour® did provide some useful information, it did not track the total number of times digital scaffolds were used nor did it provide data on all six tools. When 'H' appeared next to a completed level on the Challenges summary screen, it only referenced that the Hint button was used. The 'H' did not appear when any of the remaining five tools (Solve,



Next, Previous, Undo and Reset) were used. Therefore, the individual dyad observation form was used to collect the frequency with which each of the six tools was used by student dyads via observation of game play by the researcher (Appendix D). Data collected from each individual observation form were then transferred to a summary form for all scaffolds organized by class (Appendix E).

As game play was quick and tracking of moves difficult with multiple hands on the iPad screen at the same time, video recordings were used to confirm the number of times each scaffold was used by dyads during game play on the observation form (Appendix D). A small Flip camera on a tabletop tripod focused specifically on the iPad screen was used to document student moves. Once tallies were confirmed, total information for each digital scaffold was transferred to the final data report in preparation for statistical analysis (Appendix F).

A second video camera (a larger camera on a floor tripod) was directed at the dyads to capture the overall game playing experience including both verbal and non-verbal interactions between the partners while using the various scaffolding tools. Transcription of both sets of video recordings were used to confirm who used digital scaffolds, which specific tools were used, and how often they were used. Additionally, they also played a critical role in helping the researcher understand the intent or why behind student actions when using the built-in scaffolding tools. Videos served as a powerful data source as they could be “replayed several times for continued study and analysis” (Fraenkel & Wallen, 2006, p. 450).

## **Field Journal**

A field journal was used in several ways throughout this study. During observations of student dyads, it served as a tool for recording descriptions about the dyads, the classroom environment, conversations between partners, and other activities related to students playing the game Rush Hour® on the iPad. It also included analytic notes, becoming “a place for ideas, reflections, hunches, and notes about patterns that seem to be emerging” (Glesne, 2011, p. 71). Each observation and interview began on a new page in the journal and room was left within the margins for expansion of notes including the researcher’s “own feelings, reactions to the experience, and reflections about the meaning and significance of what has occurred” (Patton, 1987, p. 95). Field notes during observations were taken in short hand and later transferred to an online notebook for easier review.

## **Informal Interviews**

Qualitative data were also gathered through informal interviews of student dyads. It was the hope these interviews would paint an overall picture of the problem-solving process, specific strategies used by dyads when problem solving, and information regarding their understanding of the purpose and/or function of each built-in tool. According to Patton (1987), “the informal conversational approach to interviewing allows the interviewer to be highly responsive to individual differences and situational changes” (p. 110). This is very much aligned with literature specific to interviewing young children.

Therefore, the following protocol was established:

- The researcher spent time in the early childhood classrooms several times a week for four weeks before the start of the study as a volunteer during

class centers, on exploring days, and on the playground to minimize issues of reactivity (Fraenkel & Wallen, 2006). Students from each class also visited the researcher's computer lab as part of their project work, spending time using an interactive white board as well as a computer. All of these interactions allowed the participants to become more comfortable with the researcher prior to the interview and allowed the researcher to become familiar with the linguistic development of individual students to facilitate the interview process (Hatch, 1990; Irwin & Johnson, 2005; Kortessluoma, Hentinen, & Nikkonen, 2003; Krähenbühk & Blades, 2005).

- Each interview took place right after game play as young children typically provide more accurate information immediately after an event (Hatch, 1990; Krähenbühk & Blades, 2005). This also ensured the interview took place in a safe, comfortable place (Hatch, 1990; Irwin & Johnson, 2005).
- It was important to build a relationship with each dyad before the interview began. This includes letting them know why they were being interviewed as well as assuring them there was no right or wrong answer to any of the questions (Hatch, 1990; Irwin & Johnson, 2005; Kortessluoma, Hentinen, & Nikkonen, 2003). Children need to understand that everything they say within the interview process is important (Fraenkel & Wallen, 2006).
- Initial interview questions were closed-ended. These types of questions were used to build rapport with the young participants and helped make them feel more comfortable with the interview process (Docherty & Sandelowski, 1999; Kortessluoma, Hentinen, & Nikkonen, 2003).
- An informal, loosely structured question protocol was utilized (Appendix G). This allowed the researcher to modify the pace of questions, adjust questions to match the verbal ability of participants, and allow the dyads to talk with few interruptions. The researcher adjusted questions based on information provided by the student dyads and used closed-ended questions as needed to keep the interview flowing (Hatch, 1990; Krähenbühk & Blades, 2005). Many of the interviews were successful, but it was a challenge for some students to answer questions, especially those who were a bit shy with the researcher.
- Cards with graphics of each of the built-in tools were used during the interview process. They served as retrieval cues and helped the participants stay focused on questions related to the specific tools (Docherty & Sandelowski, 1999; Hatch, 1990).

Following these guidelines, the interview protocol consisted of six core questions with several follow up questions dependent on which tools dyads used or did not use during game play (Appendix G). The first question was related to

game play in general: Did you have fun playing the game Rush Hour® today? The second question addressed previous experience with the game Rush Hour® as a way to determine if prior experience with the digital or physical game impacted how dyads problem solved together: Have you every played the game Rush Hour® before? The next two questions were again related to game play and were asked to solicit information about strategy and to see if dyads made connections between the use of scaffolding tools and ease of game play: What was the easiest part about playing the game? What was the hardest part of playing the game? The remaining questions were specific to each scaffold. Cue cards were used as prompts to see if dyads could identify the tools and then explain how each tool worked. Follow up questions based on which tools were used during play were also asked. For example, if a dyad was found to have used the Hint tool often, they were asked to explain how the Hint tool worked and why it was used.

While there was a specific set of questions within the protocol, the interview was loosely structured so that each dyad co This study is significant in that it provides insight into how early childhood educators can use gaming applications with built-in digital scaffolds within developmentally appropriate practice to promote problem solving. It confirms the important role teachers play in partnering students during collaborative work and affirms the need for teachers to explicitly teach students how to use help tools. Finally, it reminds teachers that they must critically examine all aspects of digital games including built-in help tools before integrating them into their classrooms.

uld dictate the conversation. This informal structure was especially important, as some dyads were unable to proceed sequentially through the entire interview protocol. Transcripts of the interviews were analyzed, coded, and categorized to help assess student perceptions and their overall understanding of digital scaffolds.

## **Data Analysis**

### **Research Question 1**

#### **Quantitative analysis**

Results from individual observation data forms of all 12 dyads were transferred to Excel spreadsheets in preparation for analysis (Appendix E and Appendix F). Measures of central tendency were computed to provide a set of descriptive statistics for the overall data set. The frequency with which each digital scaffold tool was used was analyzed for the entire group to determine which tool dyads used most often. The ratio of games completed with and without the use of the help tools was also computed.

As the data set of this study is small and most likely will not meet the assumptions of a normal distribution, the nonparametric chi-square test was used for further analysis. The chi-square test “allows you to determine if what you observe in a distribution of frequencies would be what you would expect to occur by chance” (Salkind, 2008, p. 263). The larger the chi-value, the larger the difference between the observed and expected values; therefore, a large chi-value would indicate a statistically significant difference in how students used the different digital scaffolds (Salkind, 2008). For the purpose of this analysis, it was assumed that dyads would use tools equally across the three scaffolding

functions – demonstration (Solve), reduction in degree of freedom (Hint), and frustration control (Next, Prev, Undo, Reset).

### **Qualitative analysis – video recordings**

Once descriptive statistics were calculated and reviewed to identify patterns in the data, in-depth qualitative analysis of verbal and non-verbal behaviors surrounding the use of digital scaffolds (i.e. facial expressions, movements, gestures, language) was performed on the video recordings. The video transcripts of the dyad from Class A that used the most digital scaffolds (highest total of all scaffolds from Class A) were transcribed first (High-Middle #2), and the video transcripts of the dyad from Class B that used the most digital scaffolds (highest total of all scaffolds from Class B) were transcribed second (Middle-Middle #1). Then, before systematically categorizing the data, the researcher read through both sets of transcripts to add memos on emerging themes, behaviors, and relationships in the field journal.

Next, the researcher began the categorization process by “creating tags or labels for assigning meaning to chunks of data” (Fraenkel & Wallen, 2006, p. 436). This process is called coding and the following scheme consisting of three parts was developed to analyze game play and the use of digital scaffolds by dyads (Appendix H). Coding of events was then indexed in three phases, with each phase focused on one of the three scaffolding functions associated with the six digital tools (Table 4-2).

- Part 1 of each event identified the use of a digital scaffold.
- Part 2 of each event examined the behavior(s) that occurred immediately before the use of a digital scaffold. Was the behavior(s) verbal or non-verbal? What was the purpose behind the act? Was the behavior(s)

personal or collaborative? Intentional or exploratory? Purposeful or for fun?

- Part 3 of each event examined the behavior(s) that occurred immediately after the use of a digital scaffold. Was the behavior(s) verbal or non-verbal? Was there evidence of learning? What other assistive behaviors emerged?

Table 4-2. Summary of review and coding procedures

Phase	Description
Transcription	Transcription of video
Initial Review	Quick read of each transcript to identify emerging themes and patterns; record memos in field journal
Coding – Phase 1 (Yellow)	Coding for verbal and non-verbal behaviors and speech surrounding the use of the Solve button (demonstration scaffold) only
Coding – Phase 2 (Blue)	Coding for verbal and non-verbal behaviors and speech surrounding the use of the Hint button (reduction in degree of freedom scaffold) only
Coding – Phase 3 (Pink)	Coding for verbal and non-verbal behaviors and speech surrounding the use of the Next, Prev, Undo, and Reset buttons (frustration control scaffolds) only

Each code identified during the coding phases was transferred to a spreadsheet based on scaffolding function, printed on colored card stock (blue, pink, yellow), and turned into index cards (Table 4-2). Each card was marked with a code indicating the specific tool used, the class from which the transcript was obtained, the ability group of the dyad associated with the code, and the location of the code within the transcript (Glesne, 2011). For example, a code card from Phase 3 was pink and had the following notation written in the top left corner of the card: R-A-HH1-215 (Reset, Class A, High-High Dyad #1, Line 215). Each card was also labeled as to the verbal interactions that occurred (if any), the level of collaboration between the dyad, the purpose for using the tool, and whether or not the use of the tool helped game play.

By using cards, data codes could be easily sorted into different categories multiple times to give the researcher varying views of the data set and to help define rules for how data fit together. Cards were first sorted by scaffolding type (tool). Then they were sorted by scaffolding function (color). Next they were sorted by type of behavior, verbal versus non-verbal. Finally, they were sorted into overall themes to make sense of the data set as a whole. The above pattern of transcription, review, and coding was then followed for each set of transcripts, one from Class A and then one from Class B based on the next highest number of total digital scaffolds used. In addition to looking at how data fit together throughout the process, outliers were also noted in the field journal.

To increase dependability of the coding procedures, the researcher asked the Early Childhood Director to code two sets of transcripts, one from each class. Using a tally sheet, the Director listed each instance of a scaffold and then coded the instance on four factors: type of verbalization, level of collaboration, reason for tool use, and level of help provided. The initial percentage of agreement on a total of 142 factors was 95.77%. After follow up discussion clarifying the qualifications of help for each of the specific tools, the percentage of agreement increased up to 98.6%.

### **Qualitative analysis – interviews**

Transcription of interviews followed the same alternating pattern that was used during video transcription beginning with the dyads from Class A utilizing help tools the most. The researcher then used thematic analysis to search through the data connecting responses from interview questions about tool use to the actual use or non-use of a specific tool as noted through the observations



(Glesne, 2006, p. 187). This review helped validate codes that emerged through analysis of the video transcripts and aided in the refinement of those codes as data were compared across the two data sources. Additionally, the researcher looked for new patterns and themes that emerged solely from the interviews.

### **Qualitative analysis – field journal**

Throughout the study, the researcher used a field journal to capture details about the environment, game-play, use of digital scaffolds, and interactions between dyads and reflect after each observation and interview. Journal entries pertaining to each dyad were reviewed throughout the study and before/after data analysis to allow the researcher to compare findings across the different sets of data. This third data source helped strengthen the analysis by confirming emerging themes and patterns, revealing new dimensions, and providing richer data.

### **Research Question 2**

#### **Quantitative analysis**

Previous analysis of quantitative data were for the entire data set (12 dyads) and was specific to how preschool students use digital scaffolds when playing the problem solving game Rush Hour®. In order to answer the second research question, descriptive statistics were computed for each class data set independently (mixed ability vs. same ability) to determine how dyads of varying ability levels used digital scaffolds overall and how dyads of varying ability levels used individual scaffolding tools (Appendix I, Appendix J). The researcher also analyzed data related to the actual number of moves made by dyads to complete each puzzle level as opposed to the minimum number of moves needed to

complete each puzzle level to determine if a correlation exists between the types of digital scaffolds used, the number of digital scaffolds used, and the number of puzzle levels actually completed by dyads of different abilities with and without help.

### **Qualitative analysis**

Codes recorded on index cards during analysis of RQ1 were then sorted a fifth and sixth time to look more closely at how mixed ability and same ability groups used digital scaffolds while playing the game Rush Hour<sup>®</sup>. During the fifth sort, the researcher sorted the cards by class, creating a concept map for each class. A sixth sort was conducted solely of codes related within Class A (dyads of same ability) to look for differences between high-high, middle-middle, and low-low dyads.

As was discussed in Chapter 3, research to date related to the partnering of students during collaborative problem solving in early childhood classrooms supports mixed-ability groups. Yet none of this research is specific to technological contexts. Additionally, emerging research related to gaming contexts presents evidence that mixed-ability grouping may not always be the best choice for partnering students (Miller et al., 2012; Shih et al., 2010).

### **Trustworthiness of Study**

The goal of this capstone study was to describe the ways preschool dyads use digital scaffolds when playing the problem solving game Rush Hour<sup>®</sup> on the iPad in the natural classroom setting. While a combination of quantitative and qualitative data was collected to help answer the study's research questions, it was the qualitative data obtained from observations and interviews that provided

the greatest insight into the phenomena. According to Guba (1981), researchers utilizing qualitative research methods must ensure their study is rigorous. This means researchers must address the study's credibility, transferability, dependability, and confirmability in order to establish its trustworthiness.

### **Credibility**

Credibility is related to how confident the researcher is about how true or valid the findings of a study are. Efforts to increase the credibility of this study included developing a rapport with the participants prior to the start of the study through prolonged engagement, utilizing multiple data methods and data sources, and collecting data on different days and at different times (Guba, 1981; Krefting, 1991; Shenton, 2004). The researcher spent time in both classrooms prior to the start of the study as a volunteer to become familiar with routines and to help the children feel comfortable with the researcher in their classrooms. This immersion also allowed the researcher to develop a deeper understanding of the daily classroom experience in order to provide rich, detailed descriptions of the context and participants. The researcher also met with the classroom teachers and Early Childhood Director to determine how students would be partnered for the study as well as discuss how data would be collected to understand how teachers intentionally plan. The use of observations and interviews conducted during varying times during the day helped present multiple perspectives of the data "to ensure that all aspects of the phenomenon have been investigated" (Krefting, 1991, p. 218).

## **Transferability**

Transferability refers to how findings from a study can be applied to other contexts outside of the study. The results of this study are most applicable to other preschool programs similar in size and context (private school) with participants with similar demographics. It may be difficult to generalize this study's findings to other preschool programs in different settings with more heterogeneous populations or in programs that do not follow a DAP framework. However, the researcher provided a detailed description of the context and participants so others can see if findings are transferable. In qualitative studies, the need to prove generalizability is not as great as in quantitative studies. There just needs to be enough information provided so that others may do so (Krefting, 1991).

## **Dependability**

Dependability means that the findings of a study are consistent and can be reproduced. To accomplish this task, the researcher provided a clear description of methods so that other researchers could easily track or follow the study's research design, implementation, data collection and data analysis (Shenton, 2004). The researcher also implemented the following controls to help clarify procedures:

- As a way to control instruction on how to use the game Rush Hour<sup>®</sup> between the two classes, one of the JK teachers conducted the introductory lesson for both classes at the same time using a projection system. The lesson was taught during a regular Monday morning gathering, which is already part of the JK routine.
- Student dyads in each condition began with the same game level, easy puzzle #4. The classroom teacher used the first three puzzles of the game during instruction on how to play the game as well as a way to demonstrate how the built-in help tools worked.

- Student dyads in each condition played the game Rush Hour® on the iPad for 10 minutes. This time limit is near the maximum time students in the preschool program spend at a single activity during daily classroom center rotations and provided equal time for each student dyad to problem solve. A timer was kept by the researcher throughout the study.
- All observations of student dyads were conducted during classroom centers so learning conditions were comparable across both classes each day of the study. All observations and interviews took place as students rotated independently through teacher-prepared activities.

Additional strategies implemented to improve the study's dependability included utilizing an external peer to review the study's methods and use of the code-recode procedure. The researcher asked peers from a doctoral cohort to review the methods section of the study prior to implementation for feedback on data collection and analysis and to verify that the track of the study was clear from start to finish. During data analysis, as a way to check consistency in the coding process, a code-recode procedure was followed on two sets of transcribed observations (one from each class) and two sets of transcribed interviews (one from each class). Two weeks after initial codes were recorded, the observation and interview transcripts were recoded to see whether the results were the same. Finally, an external peer coded two sets of transcripts to confirm consistency of the coding procedures.

### **Confirmability**

Confirmability is the degree of neutrality or objectivity of a study and is used to help ensure findings are related to the study itself and not solely perceptions or ideas from the researcher. As the researcher is both personally and professionally vested in this study, it is essential the researcher reflect throughout all phases of the study to identify potential biases and "to help ensure extreme involvement does not occur" (Kreftig, 1991, p. 219). Therefore, the

researcher participated in reflective analysis as recommended by Guba (1981). A field journal was used to summarize daily experiences. The journal was also used to record the researcher's thinking throughout the study. After viewing video recordings, the researcher reflected on how her participation, the participation of the students, the setting, and the research procedures "interacted and influenced each other" (Glesne, 2011, p. 151).

### **Limitations**

Several limitations were associated with this capstone project. The first limitation was related to the selection of the dyads. As stated in the Participants section earlier in this chapter, this study used a convenience sample with students placed in one of two JK classrooms. While efforts were made to create academically similar classes at the beginnings of the year, no measure of cognitive ability was used for class placement. A second related limitation involves the way students were ranked by problem solving ability and how dyads were created. Designation of ability was subjective, based on teacher observations. No formal instrument was used to measure problem solving ability.

A third limitation of this study is related to previous experiences with the game. It is possible that previous experience with Rush Hour<sup>®</sup> did impact some of the results of this study, although it is not clear to what extent. In an effort to reduce exposure, students were not introduced to, nor did they play the digital version of the game Rush Hour<sup>®</sup> in the classroom prior to the beginning of the study. Additionally, the physical version of the game was removed as an activity in the classroom to minimize exposure. It was not known until after each dyad participated in the study if either member had previous exposure with the game.

During follow-up interviews, members of each dyad were asked about their previous experiences. Eight of the twelve dyads had at least one member with previous experience, and each class had four dyads with previous experience (although the recency and depth of their experiences was not determined).

A final limitation was related to the timing of observations. As mentioned in the General Procedures section, student dyads rotated through the iPad center over the course of a month. While unintentional, the six dyads from Class B rotated through the center during the first two weeks of the study with the six dyads from Class A following the next two weeks. It is unclear if this order of participation impacted the use of digital scaffolds by Class A as there was a longer time between instruction on how to use the scaffolding tools and actual participation in the study.

## CHAPTER 5 RESULTS

The results of this analysis are divided into two sections based on the research questions guiding this study. Section I will present data that addresses the first research question: In what ways do preschool dyads use digital scaffolds when playing the problem solving game Rush Hour®? Section II will present data that addresses the second research question: In what ways does the ability level of preschool dyads impact how digital scaffolds are used when playing the problem solving game Rush Hour®?

Section I presents data both according to function as well as by individual tool. It includes the frequency with which tools were used along with other descriptive statistics. It also presents examples from game play transcripts and student interviews to provide a richer account of student interactions. Section II compares tool use between Class A (same-ability partners) and Class B (mixed-ability partners) and presents similarities and differences in how the different ability groups use digital scaffolding tools. The frequency with which tools were used as well as other descriptive statistics is shared and anecdotal information specific to individual dyads is presented. Data related to the efficiency of problem solving between the two classes are also shared.

### **Research Question 1: In What Ways Do Preschool Dyads Use Digital Scaffolds When Playing the Problem Solving Game Rush Hour®?**

#### **Overall**

During the 10 minutes of game time allotted for each dyad to play Rush Hour®, a total of 97 puzzles were completed with 30 of those puzzles being solved utilizing help tools. Digital scaffolds were used a total of 155 times over



the course of game play by 10 of the 12 student dyads that participated in the study (Figure 5-1). When looking at scaffold use by function, demonstration scaffolds (Solve) were used 55 times (36%), reduction in degree of freedom scaffolds (Hint) were used 42 times (27%), and frustration control scaffolds (Next, Prev, Reset, Undo) were used 58 times (37%). Chi square was used to determine statistical significance. No significance was found between function categories ( $X^2 [df=2, n=155] = .247, p > .05$ ).

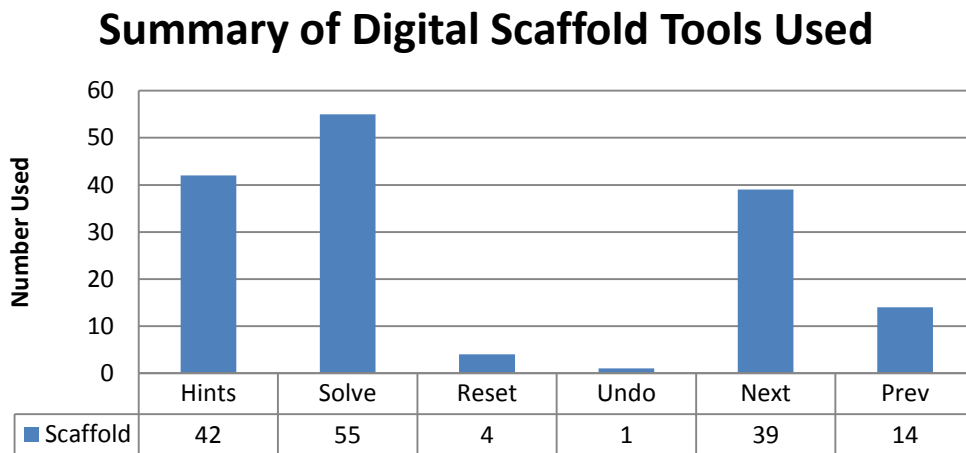


Figure 5-1. Summary of digital scaffold use by tool

Further analysis of tool use was based on four factors: type of verbalization (verbal vs. non-verbal), level of collaboration (personal vs. collaborative), reason for tool use (intentional, playful, exploratory, accidental), and the level of help provided during game play (full help, partial help, no help). Each use of a digital scaffold looked not only at the actual use of the tool but also at the events that occurred before and after tool use related to these factors. The majority of tool use was personal (79%) rather than collaborative (21%) in nature. This means students often used a tool without discussing its use with his or her partner. Likewise, the majority of tool use was intentional (65%). While, there

were a few isolated incidents of playfulness within one of the dyads, the remaining dyads used the tools as intended. Only a few incidents of accidental use occurred (3%) (Figure 5-2).

The use of a scaffolding tool helped facilitate or advance game play 34% of the time (Figure 5-2). This figure was calculated by assigning each use of a tool a degree of help, which varied depending on scaffold function.

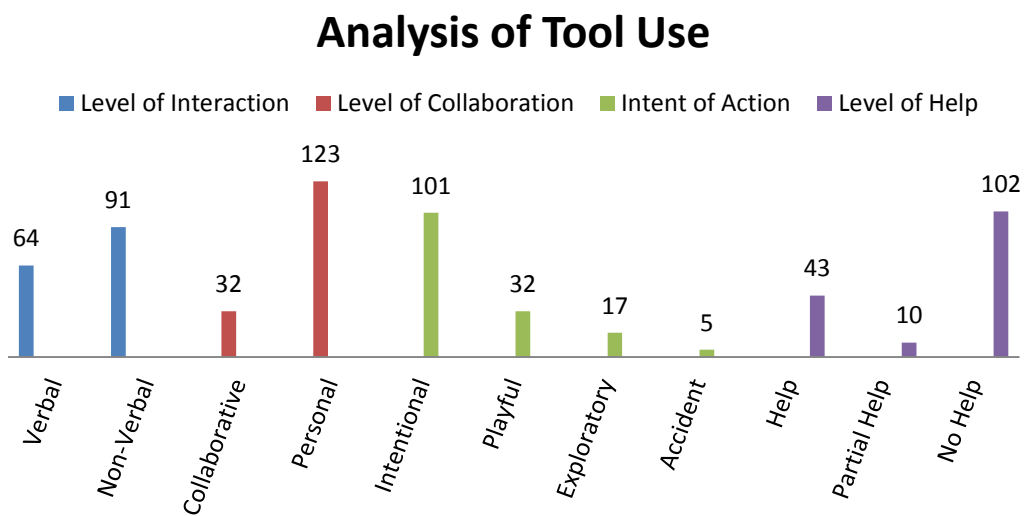


Figure 5-2. Analysis of tool use based on level of interaction, level of collaboration, intent behind actions, and level of help provided

The use of the Solve or Hint tool was considered helpful if it aided the dyad in solving the puzzle with no more than six additional moves after using the tool. If the use of the Solve or Hint tool helped the dyad continue the problem solving process but did not help them solve the puzzle in less than six moves, or if the dyad used another tool after three moves, the use of the tool was considered to give partial assistance. If the use of the Solve or Hint tool was ignored or if another tool was immediately used, its use was considered not helpful. The Next, Prev, Undo, and Reset tools were considered helpful if they assisted the dyad to continue game play and matched the intent of the student's action. For

example, if a student declared a puzzle was too hard and wanted an easier puzzle, pressing the Prev or Next button in that instant was considered to help facilitate game play.

### Demonstration Scaffold (Solve Tool)

The function of a demonstration scaffold is to model the process of completing a task either partially or completely with the hope the student or dyad will continue the problem solving process. In Rush Hour®, the Solve tool provided a step-by-step video of movements needed to complete a puzzle. It was used a total of 55 times by 10 of the student dyads and was found to facilitate game play at a rate of 29%. It could also be said that this tool served as a frustration control as students would display, through both verbal and non-verbal behaviors, their frustration with the game and/or their lack of progress before pressing the button (Figure 5-3).

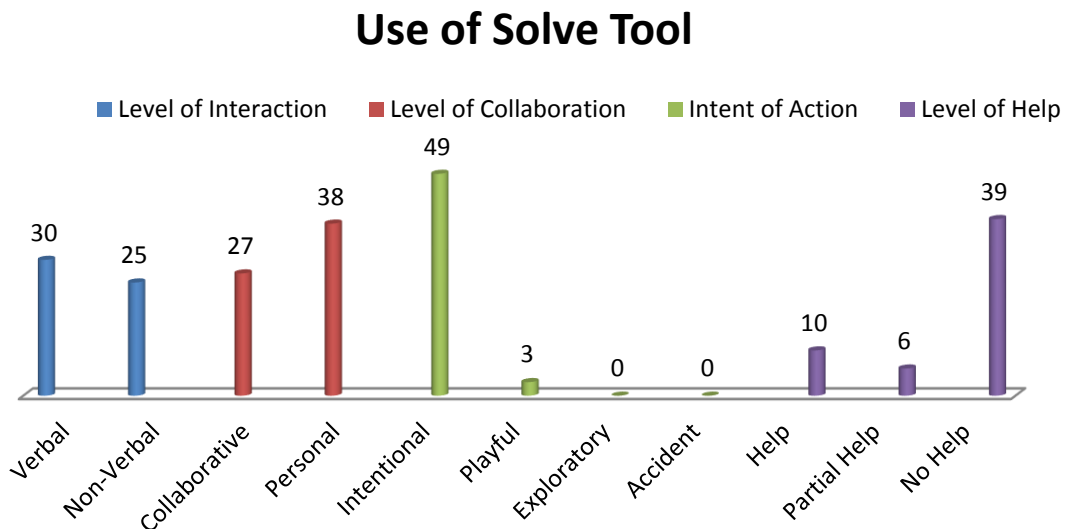


Figure 5-3. Behaviors surrounding the use of the Solve tool during game play

## Verbalizations surrounding use of Solve tool

Verbal declarations either by students stating they needed to use the Solve tool (personal), suggestions from partners (collaborative), or requests for help (collaborative) were highest for this tool at 54%. These declarations indicate that students understood using the tool would provide help and facilitate game play. Examples of verbalizations included:

- B-MK(8):** “Click this if you need help,” pointing out the Solve button to his partner. His partner then responds, “Press this one here?” (asked as a question). Points to Solve while asking and then presses button when partner nods. [MM#1-B-MK(8)-120] [*PARTNER SUGGESTION*]
- B-LB(11):** “This one is going to be easy. No, wait. Maybe we should press the Solve button.” Partner B-JS(12) presses the button. [HH#1-B-JS(12)-110] [*PARTNER SUGGESTION*]
- C-NC(2):** Points to the Solve button [and looks up as if asking a question]. C-JM(8) responds, “Then do it. I don’t know how.” C-NC(2) presses the Solve button. [ML#1-C-NC(2)-236] [*PARTNER SUGGESTION*]
- B-MB(9):** “I’m stuck. Oh, I can press Solve.” [HH#2-B-MB(9)-97] [*SELF DECLARATION*]
- C-EH(6):** “How do we get these guys out? We need an explanation.” [C-EH(6) presses the Solve button.] The movie plays. “Did you see that?” [ML#2-C-EH(6)-247] [*SELF DECLARATION*]
- C-BS(9):** “Do you want to do it for us? Let’s do Solve.” [HL#2-C-BS(9)-248] [*SELF DECLARATION*]
- B-AO(7):** Works on the puzzle while B-MK(8) is asking questions of the researcher. She says to her partner, “Can you help me now?” Partner then presses the Solve button. [MM#1-B-AO(7)-181] [*REQUESTS FOR HELP*]
- C-EW(3):** C-BS(9) says to his partner, “C-EW(3), you tell me what to do.” Partner says, “Okay, look” and presses Solve. [HL#2-C-EW(3)-278] [*REQUESTS FOR HELP*]
- C-MB(9):** [The dyad has just used the Hint tool but it did not advance game play.] N-IE(10) declares, “We just can’t do this one. It’s all stuck.” M-MB(9) responds, “Oh, I can press Solve.” [HH#2-B-MB(9)-97] [*DECLARATION MADE IN FRUSTRATION*]

**C-EW(3):** “This won’t work out. I can’t. We can’t do this.” “Look,” says C-EW(3) as she presses the Solve button. [HL#2-C-EW(3)-157]  
[DECLARATION MADE IN FRUSTRATION]

**C-EH(6):** Moves the red car back and forth. She puts her hands up in the air and says with frustration, “It can’t get out.” She then rests her chin in her hands. “Hmmm.” She presses the Solve button again. [ML#2-C-EH(6)-176] [DECLARATION MADE IN FRUSTRATION]

### **Understanding the Solve tool’s purpose**

Follow-up interviews confirmed students found the Solve tool helpful.

They were able to clearly discuss how the tool worked as well as why it was used. When asked *what* the Solve tool does, B-MB(9) responded, “It helps us try and find out how to do it. It shows you how to move the cars to get the red car out.” [HH#2-B-MB(9)-424-430]. Another student referred to the Solve tool as the “Show you button. It shows you how to play it.” [HL#1-C-TD(10)-421-427].

When asked why the tool was used, C-BS(9) stated, “It gave me help when it was hard.” [HL#2-C-BS(9)-600] and C-KD(7) said she used it “Because the game was too tricky.” [HM#1-C-KD(7)-362].

It is interesting to note that while 10 of the dyads used the Solve tool, there were some students within those dyads that did not want to use the tool personally and would sometimes become upset if their partner used it (even if they themselves had used Solve earlier in the game). These students wanted to figure out puzzles on their own. B-AO(7) stated to her partner, “I know how to do it without asking the question. I don’t need help.” when her partner suggested the Solve tool [MM#1-B-AO(7)-141]. C-TW(1) nudged his partner’s hand away from the Solve button while he was working and declared, “No. No Solve.” [ML#2-C-TW(1)-357]. Another student remarked, “I have my own brain.” when his partner tried to press the Solve button [HH#1-B-JS(1)-181]. Despite these comments, it

does not appear that students thought the use of the tool was negative or bad, rather they were asserting their independence and stretching themselves to work without help. The majority of talk surrounding the use of the Solve tool was positive and the tool was seen as providing help.

### **Successive use of the Solve tool**

The Solve tool was often used in succession. Of the 55 instances in which the Solve tool was used, fifteen of them occurred back to back (27%). When looking more closely at the behaviors surrounding this back-to-back use of the tool, two major patterns emerged. The first was related to students not carefully watching the Solve movie to completion. On several occasions, one member of a dyad would press the Solve button and during the middle of the demonstration, the other member of the dyad would interrupt the demonstration by trying to take over the game or by distracting the partner from watching the movie. This would then cause the member who pressed the Solve the first time to press it again. For example, when working on puzzle #11, B-AO(7) pressed the Solve button. Her partner tried to move cars while the Solve movie was playing so B-AO(7) tried to grab her arm to stop her. Neither of the girls saw the movie so B-AO(7) pushed Solve again [MM#1-B-AO(7)-274].

The second pattern that emerged was related to the speed and length of the demonstration movie itself. Many students discussed the need to see the movie over again because it was too fast. When working on puzzle #12 B-IE(10) said to her partner, "It's so fast, we can't even do it. I think they moved these. (Pause) No, they moved these two down." [HH#2-B-IE(10)-134]. Others would remark on how too many cars got moved and how they would need to press the

button again. During game play, C-EH(6) says to her partner, “How do we get these guys out. We need this.” and pressed Solve. She then questions, “How did it do that?” before pressing the button again [ML#2-C-EH(6)-247]. Most dyads had a difficult time following more than two or three moves after the Solve button was pressed.

### Reduction in Degree of Freedom Scaffold (Hint Tool)

Within Rush Hour®, the Hint tool served as a reduction in degree of freedom by providing a single clue each time it was pressed. It was used 42 times by 5 of the 12 dyads with one dyad using it a total of 17 times (Figure 5-4). Hint was used more non-verbally (74%) as a personal tool when one member of the dyad had control over the board than the Solve tool, but there were occasions when partners would recommend its use. Its use facilitated game play at a rate of 23.6% (Figure 5-4).

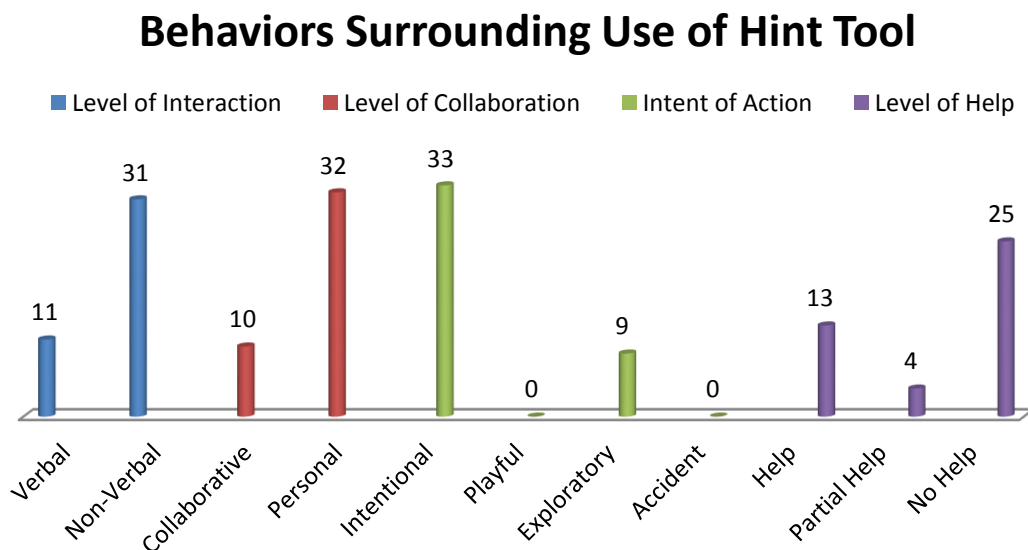


Figure 5-4. Behaviors surrounding use of the Hint tool during game play

## Verbalizations surrounding use of the Hint tool

Like the Solve tool, verbal statements during game play suggest students understood the tool's purpose. This became evident during interviews as well.

C-LF(5) discussed how the Hint tool would "Move one of the cars out of the way."

[MH#2-C-LF(5)-415] and C-TD(10) talked about the Hint tool being helpful

because "It shows you where you can go, where you can move a car" [HL#1-C-

TD(1)-454]. Examples of other verbalizations include:

**C-EH(6):** "This car is blocking the way." [C-EH(6) has not made progress in 45 seconds]. "These guys are blocking the way." [Starts moving the red car back and forth but the yellow car is blocking]. "It has to get out of here." [Makes a fist with her hand in frustration banging the table]. "What do we do?" [Said with a sigh]. Then to her partner, "TW(3), you know what, I have an idea. We need a hint." [ML#2-C-EH(6)-153]

**C-LF(5):** "Whoa. This one looks like a hard one. I need a hint." [MM#2-C-LF(5)-108]

**C-EH(6):** Says to her partner, "The truck is blocking the exit. We need help." Her partner suggests, "Push the Hint." C-EH(6) pushes the Hint button. [ML#2-C-EH(6)-418]

**B-IE(10):** Stops working for a second. She looks to her partner and says, "How about the button?" B-IE(10) shows B-MB(9) which button to push [points to Hint]. B-MB(9) says, "Yeah, we really need a hint" [presses the button]. [HH#2-B-MB(9)-85]

There was also a playfulness associated with this tool that was not seen with the Solve tool such as when B-IE(10) chants to her partner, "Hint. Hint. Hint. Hint." while pumping her arms up and down, to which her partner B-MB(9) responds, "Okay, we can get a hint." [HH#2-B-IE(10)-296]. While this event was playful in nature, the act was still intentional as the students were stuck and needed assistance to move on.



### **Repeated use of Hint tool**

There were several times during game play in which a student would use the Hint tool in succession three or more times. In some of these instances, there were non-verbal cues such as sighing, shoulder shrugging, and resting of hands on chins that showed students were frustrated. In other cases, students realized the Hint tool would help them finish the current puzzle and move on to the next one. For example:

**C-LF(5):** C-SK(11) tells C-LF(5) to move the red car. C-LF(5) presses the Hint tool seven times until the puzzle is solved and states, "I needed a hint" to his partner. His partner responds, "Yeah, lots of them."  
[HM#2-C-LF(5)-115]

**C-TD(10):** C-TD(1) had pressed the Solve button but the game froze. Once the game was restarted, he made a few moves but then said, "Oh darn it. Uhhh." He then proceeds to press the HINT button six times to finish the game. [HL#1-C-TD(10)-27]

### **Missing the Hint**

There were occasions during game play in which students would miss the hint and therefore its use did not enhance game play. The miss typically came because the student pressing the button either became distracted and turned away from the game or was not focused on the part of the game board where the hint occurred. Hints were also missed by partners because they were unaware that the hint tool was being used. This is most likely related to the high personal use of this tool. Many of these instances are evidenced by the number of times the hint car was moved back to the location it was just in. For example:

**C-EH(6):** Says, "Get help. I need help. C-TW(1) can you help me?" C-TW(1) whispers softly, "No. We need a hint." C-EH(6) presses the Hint button. After the hint car moves up, C-EH(6) moves it back to its same position as before the use of the tool. [ML#2-C-EH(6)-238]

**B-IE(10):** Presses the Hint button for her partner [which moves the orange car]. MB(9) moves the orange car back to its original spot. “Oh, that just moved.” B-IE(10) says, “Yeah, that was a hint. It is a really one. You need to move it back.” B-IE(10) moves it back to the hint position. B-MB(9) says, “Okay, okay” then continues came play. [HH#2-B-IE(10)-296]

**Frustration Control Scaffolds (Next, Prev, Reset, Undo Tools)**

The Next, Prev, Undo and Reset tools were categorized as frustration control scaffolds that could potentially reduce the amount of stress or fear exhibited during problem solving tasks. These tools were used by seven dyads during game play. Overall use was personal (91%) and often playful (50%) (Figure 5-5).

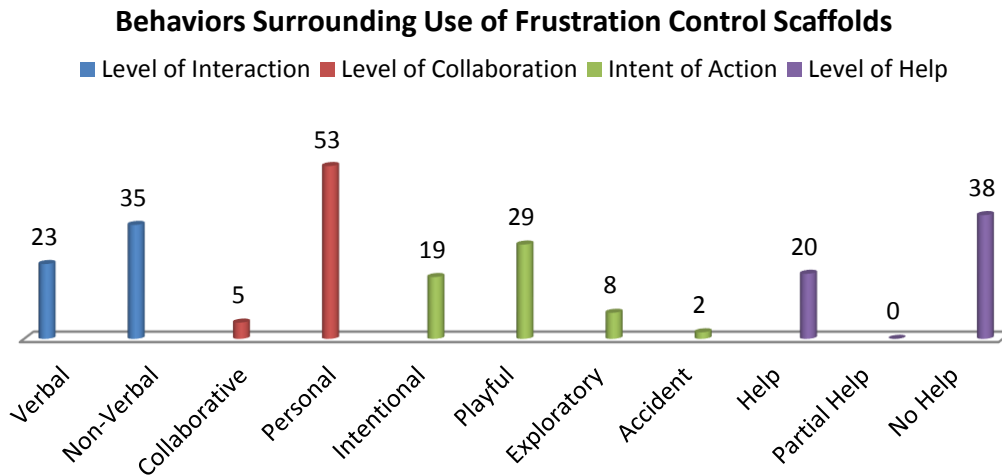


Figure 5-5. Behaviors surrounding use of frustration control scaffolds (Next, Prev, Reset, and Undo) during game play

**Next and Prev tools**

The Next and Prev tools were used by students to move back and forth between puzzles. The Next tool was used a total of 39 times while the Prev tool was used 14 times. Despite the high number of times these tools were used, just two dyads accounted for 92.5% of their use. Analysis of intentional use of the tool shows they were used to change the level of difficulty of a puzzle, to find

another puzzle when game play was stalled, to avoid repeating levels that had already been played, or to replay a level that a partner had just played. The tools were considered to be helpful (37.7%) when they assisted in accomplishing how the student or dyad wanted them to be used. The following list highlights some of the ways the Next and Prev tools were used by preschool students:

**C-LF(5):** While the music plays after completion of a puzzle, C-SK(11) presses the Try Again button. [The Try Again button sets the game to the same level just completed.] C-LF(5) gets the board and presses the Next button. [MH#2-C-LF(5)-323]

**C-NC(2):** Moves the pink car and says, “This is a hard game. I’m going to press the Next button.” [ML#1-C-NC(2)-274]

**C-AS(12):** “This is going to be tricky.” C-AS(12) moves two cars then says, “I want to do level #9.” Presses the Prev button. [HM#1-C-AS(12)-185]

**C-LF(5):** “What!” as he pulls the iPad closer. “But it is my turn and I would like to go back to the other one.” He then presses Prev to go back. [MM#2-C-LF(5)-214]

### **Undo and Reset tools**

The Undo tool was used just once during game play while the Reset tool was used four times. The tools were used by just two dyads, and it is evident they were used by accident or during exploration of the tools rather than intentionally. They did not impact game play in any way, and it is unclear if the students even realized anything happened when the buttons were pressed. For example, C-EH(6) pressed the Reset button by mistake with no response when her partner suggested she use the Hint tool [ML#2-C-EH(6)-83]. When B-MK(8) pressed Undo after her partner’s suggestion to use the Solve tool, her partner B-AO(7) responded, “No, the red button.” [B-MM#1-B-MK(8)-129].

## Previous experience with Rush Hour®

While it was predicted there would be some study participants with previous Rush Hour® experience, the researcher did not expect there to be so many. One-third of the participants had previous experience with the game. Seven had played the digital version of the game while two had played the physical version of the game. These nine participants were distributed between eight of the twelve dyads as noted by an asterisk in Table 5-1. It is important to note that the amount of experience with the game for each individual is not known nor is the recency of the experiences. Nonetheless, it appears that previous experience played a role in how digital scaffolds were used in this study by preschool dyads when problem solving.

When looking at the total number of puzzles solved as compared to the total scaffolds used, there is an inverse relationship. For the most part, the more puzzles solved the least number of scaffolds used. This ties into experience too. For the most part, dyads with previous game experience used less digital scaffolds.

Table 5-1. Number of puzzles solved by each dyad along with total scaffolds use for each group

	Total Puzzles Solved	Total Scaffolds Used
Middle-Middle* #2	13	2
High-Low* #2	13	5
High*-Middle #1	10	14
High*-High #2	9	10
High-High #1	9	9
Low-Low* #2	8	0
Middle-Low* #1	7	9
Low-Low #1	6	0
Middle*-Middle* #1	6	13
High-Low #1	6	16
High*-Middle #2	6	55
Middle-Low #2	4	22

## Research Question 2: In What Ways Does the Ability Level of Preschool Dyads Impact How Digital Scaffolds Are Used When Playing the Problem Solving Game Rush Hour®?

### Overall

There was significant evidence to support that dyads in Class B comprised of mixed-ability dyads used digital scaffolds differently than dyads in Class A comprised of same-ability dyads ( $X^2 [df=2, n=155] = 24.22, p < .05$ ). Dyads in Class B used on average 20.2 scaffolding tools during game play, while Class A used an average of 5.7 scaffolding tools. Dyads in Class B solved on average 7.67 puzzles during ten minutes of game play utilizing 121 scaffolds as compared to an average of 8.5 puzzles utilizing a total of 34 scaffolds for Class A (Figure 5-6). Overall, Class B completed 21/46 puzzles with help tools, while Class A completed 9/51 puzzles with help.

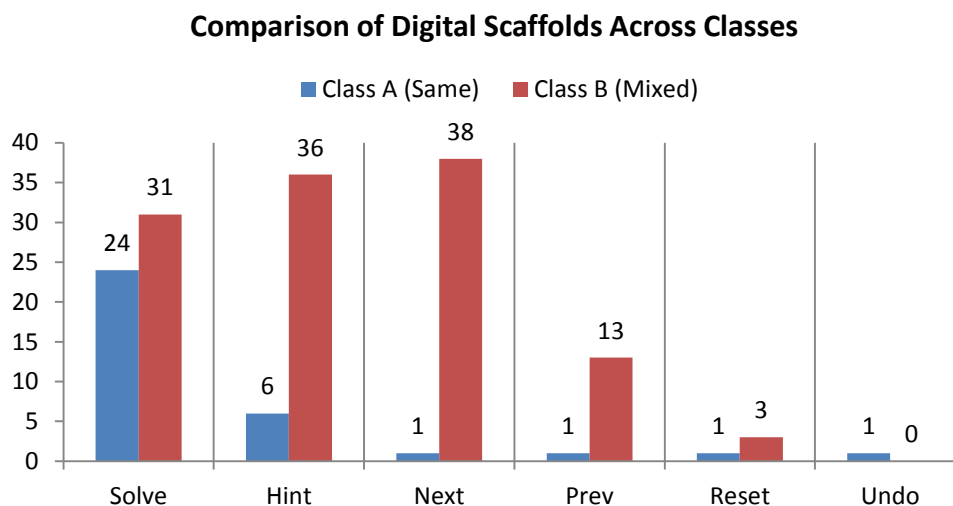


Figure 5-6. Comparison of digital scaffolds across classes

When comparing how many moves were made to complete each puzzle versus the minimum number of moves needed to complete each puzzle, dyads in Class A were found to be more efficient problem solvers. Through puzzles 4 to

16, Class A had a total problem-solving efficiency ratio of 58.16%, while Class B had a total problem-solving ratio of 54.91% (Table 5-2).

Table 5-2. Problem solving efficiency between Class A and Class B

	Class A (Same)	Class B (Mixed)
Total # of Puzzles Completed	51	46
Total # of Puzzles Completed with Help	9	21
	17.65%	45.65%
Total # of Puzzles Completed without Help	42	25
	82.35%	54.35%
Problem Solving Efficiency (Puzzles 4-7)	56.59%	55.62%
Problem Solving Efficiency (Puzzles 8-11)	51.50%	48.11%
Problem Solving Efficiency (Puzzles 12-16)	66.40%	61.00%

The top problem solving dyads (one from each class), Middle-Middle #2 and High-Low #2, both solved 13 puzzles. Dyad Middle - Middle #2 from Class A solved the most puzzles with the least amount of help from digital scaffolds (12) while dyad High – Low #2 used scaffolding tools on just two puzzles (11). Both of these dyads had one member with previous game experience. All participants with previous game experience are noted with an asterisk on Table 5-3.

Table 5-3. Total number of puzzles solved by Class including those solved with and without help

	Total Puzzles Solved	Total Puzzles with Help	Total Puzzles without Help
<b>Class A (Same)</b>			
High High #1	9	4	5
High* High #2	9	2	7
Middle* Middle* #1	6	2	4
Middle Middle* #2	13	1	12
Low Low #1	6	0	6
Low* Low #2	8	0	8
<b>Class B (Mixed)</b>			
High Low #1	6	4	2
High Low* #2	13	2	11
Middle Low* #1	7	1	6
Middle Low #2	4	4	0
High* Middle #1	10	6	4
High Middle* #2	6	4	2

## **Previous Experience with Rush Hour®**

In regards to previous experience with the game, both classes had four dyads with an experienced partner. When placing the dyads in rank order from most digital scaffolds used to least digital scaffolds use, the four top dyads had at least one member with previous experience (Class B-HM#2, Class B-HL#1, Class B-HM#1, Class A-HH#2). When placing the dyads in rank order from most puzzles solved to least, the four top dyads (Class A-MM#2, Class B-HL#2, Class B-HM#1, Class A-HH#2) also had a member with previous game experience. The one dyad where both members had previous experience (B-HM#2) ranked 11<sup>th</sup> in solving the most puzzles and first in using the most scaffolding tools.

## **Demonstration Scaffold (Solve Tool)**

The Solve tool was used by all six dyads from Class B an average of 5.17 times during game play, while only four dyads from Class A used the tool an average of 4 times per game play. Additional differences between the two groups included the verbal interactions that took place before, during, and after tool use along with how Solve was used with other tools. Class B was more verbal in its use of the tool, with partners suggesting use of the tool twice as much (Figure 5-7).

**High – Low Group #2:** C-EW(3) says to her partner, “This won’t work out.” [Rests her hand on her chin.] “I can’t.” to which C-BS(9) says to the researcher, “We cannot do this.” After a moment, C-EW(3) says, “Look, look.” and presses the Solve button. [HL#2-C-EW(3)-157]

**Middle – Low Group #2:** C-TW(1) has control of the board and says, “So, I was just thinking,” as he moves to press the Hint button. His partner, C-EH(6) stops him from pressing Hint and presses Solve instead. She says to her partner, “We need an explanation,” then presses Solve. “Did you see that?” [ML#2-C-EH(6)-430].

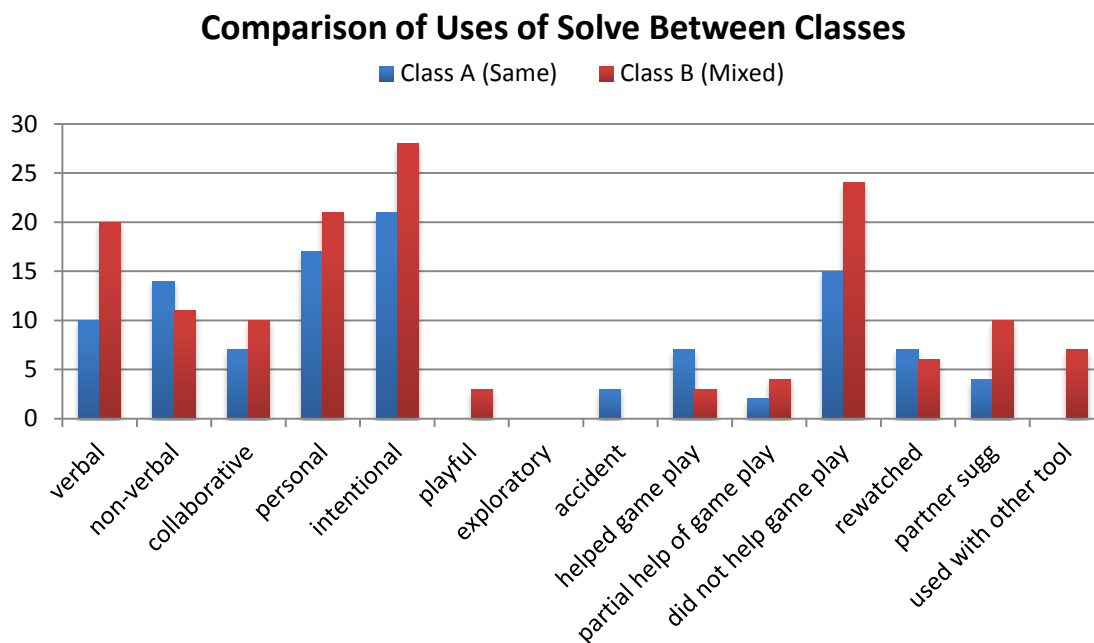


Figure 5-7. Comparison of uses of Solve between classes

Class B dyads also used the Solve tool in conjunction with other tools which did not occur at all during game play by dyads from Class A. For example,

**Middle – Low Group #2:** C-EH(6) remarks to her partner, “How do we get this guy home?” while pressing the Undo button. She then immediately says, “How do we get these guys out. We need this.” as she presses the Solve button [S-ML#2-C-EH(6)-247].

**High – Low Group #1:** C-TD(10) makes about 10 moves and then presses Hint. C-TD(10) now presses the Solve button [purple car, purple truck, pink car, light blue, yellow, red]. C-TD(10) finishes the puzzle in almost the same order as the solve movie. [HL#1-C-TD(10)-114]

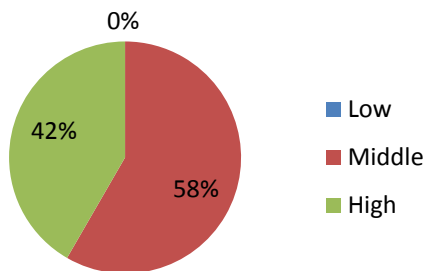
While there were differences between the two classes, several similarities also existed. First, both classes used the Solve tool with high levels of intentionality. Class A had a few incidents of accidental use (3), while Class B had a few incidents of playful use (3). Second, both groups used the tool more personally than collaboratively. Finally, both groups often used the tool in succession when it did not provide help the first time (Figure 5-7). Here are some examples of the tool being used in succession:



**Middle – Low Group #1:** C-NC(2) presses the Solve button. [He and his partner are quiet as they watch the puzzle being solved on the screen.] C-JM(8) says, “Okay” and makes to move the orange car. “Okay, this is pretty hard.” C-NC(2) says, “That’s not it. Look at what you’re supposed to do.” [Presses the Solve button again.] [ML#1-C-NC(2)-229]

**Middle – Middle Group #1:** B-AO(7) presses the Solve button. She then moves just the red car before pressing the Solve button again. B-AO(7) does not make any moves right away but rather poses her hand over the Hint button. Her partner, B-MK(8) says “You don’t need a hint.” B-AO(7) then decides to press Solve again. [MM#1-B-AO(7)-185]

Use of Solve by Class A (Same)



Use of Solve by Class B (Mixed)

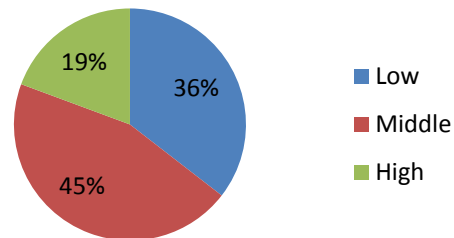


Figure 5-8. Use of Solve tool by ability level across both classes

The Solve tool was used by students of all abilities but was used most by students ranked with middle problem-solving abilities. The next highest users were high-ability students with low-ability students using the demonstration scaffold the least (Figure 5-8). Of the low-ability users, only those in Class B used the tool with one student using it seven times. In analyzing mixed-ability groups, there was no pattern in which member used the tool first. The lowest member of a dyad was the first to use the tool just as many times as the highest member of the dyad used the tool.

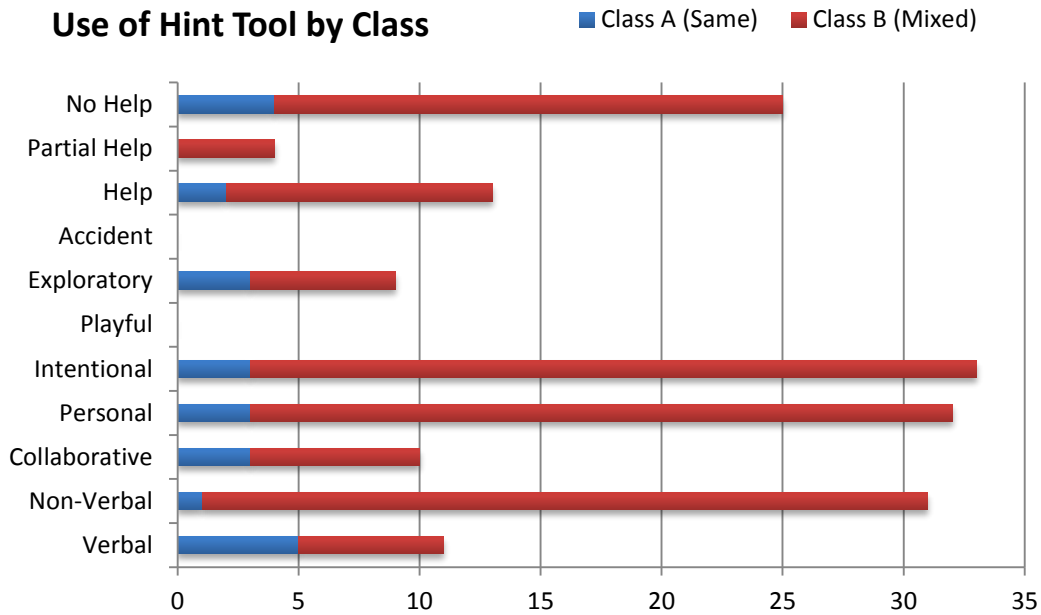


Figure 5-9. Use of Hint tool between Class A and Class B

### Reduction in Degree of Freedom Scaffold (Hint Tool)

Two dyads from Class A used the hint tool six times, while three dyads from Class B used the Hint tool a total of 36 times. Primary users of the tool from both classes were students with middle-ability and high-ability problem solving skills. Students with low-ability skills did not use the tool at all. While both classes found about the same level of success using the tool, the dyads did use the tool differently. Dyads from Class A were more verbal when using Hint, while dyads from Class B were mostly personal, non-verbal users. The most obvious difference between the two classes was how individuals from Class B would use the tool repeatedly. Of the 14 distinct uses of the tool by Class B, six of them were successive with the Hint tool being used anywhere from two to eight times in a row.

## **Frustration Control Scaffolds (Next, Prev, Reset, Undo Tools)**

Class A had four instances of using frustration control scaffolds (one each of Next, Prev, Undo, and Reset), with only one of those instances being intentional. Class B dyads, on the other hand, used the tools on 54 occasions although with a very playful attitude. One student from the Middle-High #2 dyad especially liked to use the Next and Prev tools to search for easier and harder puzzles. In fact, in just one instance of game play he used the tools together 30 times. He was very verbal during game play, making lots of jokes to his partner. The more his partner laughed, the more he got excited and pressed the buttons. Even with this playfulness, it was clear he did use the tools with purpose some of those times. Here is an excerpt from that game play:

C-LF(5) says, "What!" as he pulls the iPad closer. "But it is my turn and I would like to go to the other one." [Presses Next.] "What! Whoa, lots of cars." [He then presses Prev to go back.] He then presses the Prev button eight more times. "I'm going back to the first one – the real one. [He is now on puzzle #1.] When his partner C-SK(11) says, "That's easy, only four cars," C-LF(5) begins to press Next six times until a pop up screen comes up asking what he wants to do at the level. Then he presses the Next button 14 more times. "I want do the last one." [Trying to get to the hardest puzzle.] [MH#2-C-LF(5)-214-231]

A second dyad from Class B (Middle-High Group #1) was responsible for 13 uses of the Next and Prev buttons. While also a middle-high dyad, their use of the tools was more intentional as they tried to avoid playing the same puzzle twice.

**C-AS(12):** Had solved level #5. She presses the Try Again button before passing the iPad to her partner. She then asks, "What level is this?" Realizing that C-KD(7) is playing puzzle #5 again, she says, "Why are you doing level 5?" and then presses the Next button.

**C-KD(7):** Used the Solve button to solve puzzle #10 and then presses Try Again when the congratulatory music finishes. C-AS(12) gets the iPad and presses the Next button, which moves her to #11. She starts working on the puzzle.

### **Chapter Summary**

Chapter 5 presented both quantitative and qualitative data describing the ways preschool dyads use digital scaffolds when playing the problem solving game Rush Hour<sup>®</sup>. In addition to sharing descriptive statistics on the types of scaffolds used, the behaviors surrounding each use of a scaffold were analyzed. Specially, the researcher evaluated tool use on four factors: type of verbalization, level of collaboration, reason for tool use, and the level of help provided during game play. Data pertaining to the 12 dyads as a whole was reviewed first and then analyzed by class to determine if the ability level of preschool dyads impacts how digital scaffolds are used. Chapter 6 summarizes the findings of this study, discusses their implications for current practice in the preschool classroom, and presents avenues for continued research.

## CHAPTER 6 CONCLUSIONS

Utilizing a mixed-methods research design, this descriptive capstone project examined how preschool children use digital scaffolds built into the digital game Rush Hour® while problem solving on the iPad. Specifically, it investigated the ways student dyads used demonstration, reduction in degree of freedom, and frustration control scaffolds during game play and analyzed the role of these tools within the problem solving process. The study also examined the similarities and differences between student dyads with different problem solving abilities. The following key findings emerged from the study:

1. Preschool children understand the purpose of digital scaffolds and can use them intentionally during game play.
2. Preschool children use all three types of digital scaffolds embedded within the game Rush Hour® although differences exist by ability level.
3. The use of digital scaffolds often provides frustration support during game play.
4. The use of digital scaffolds often advances or extends game play.
5. Mixed-ability dyads use more digital scaffolds than same-ability dyads when playing the game Rush Hour® on the iPad.
6. Same-ability dyads solve more puzzles than mixed-ability dyads when playing the game Rush Hour® on the iPad.
7. Demonstration scaffolds are more helpful when they are age appropriate.

### **Preschool Students Use Digital Scaffolds**

It was evident through both verbal and non-verbal interactions between dyads and through follow-up interviews that the preschool children in this study understood the role of digital scaffolds within Rush Hour®. They often used them intentionally for help, both as a means to reduce frustration and as a way to advance game play. A total of 155 digital scaffolds were used by 10 of the 12

dyads in this study. All three types of scaffolds – demonstration, reduction in degree of freedom, and frustration control – were used, but no significant difference between the three types of scaffolds was found ( $X^2$  [df=2, n=155] = .247,  $p > .05$ ).

Students often used digital scaffolding tools personally rather than collaboratively. This high level of personal use may be attributed to the students taking turns solving puzzles, as dyads would pass the iPad back and forth after each puzzle was completed. When the iPad was stationed in front of one student, that student typically controlled what was happening on the game board, which included making the decision to use a digital scaffold. This back-and-forth game play is also a result of young children still learning how to “collaborate with others and work through ideas and solutions, as well as develop social skills such as cooperating, helping, negotiation, and talking with other people to solve problems” (Copple & Bredekamp, 2009, p. 155).

Even with this high level of personal use, there were many instances in which peers encouraged their partners to use scaffolding tools. These suggestions are consistent with previous research on peer scaffolding in various educational contexts and support Vygotsky’s sociocultural theory that more knowledgeable others can help extend student thinking during the learning process (Berk & Winsler, 1995; Vygotsky, 1978). Individuals within this study showed their partners how to complete tasks, gave direct instruction on how to play the game, explained how tools worked or why they should be used, and suggested use of the tools during game play (Ahmad & Assim, 2003; Ellis & Rogoff, 1982; Heft & Swaminathan, 2002; Hyun & Davis, 2005; Sharma &

Hannafin, 2007; Verba, 1998). This was especially the case with the Solve and Hint tools, which were viewed by most groups as ways to get help when they were stuck. The Next and Prev tools were viewed as ways to find easier puzzles or avoid repeating already completed puzzles.

When looking specifically at the ability level of individuals, students identified as mid-level problem solvers used scaffoldings tools the most (94) followed by high-level problem solvers (49). Low-ability students used digital scaffolds least (12). This last finding confirms previous research that says children with low prior knowledge or novice learners struggle to use built-in help and supports the need for classroom teachers to explicitly model how to use tools (Clarebout & Ellen, 2009; Gall, 1981; Gall, 1985; Harskamp & Suhre, 2007).

### **Digital Scaffolds as Frustration Support**

Preschool dyads used the digital scaffolds embedded in the puzzle game Rush Hour<sup>®</sup> as a way to reduce frustration during game play and to extend time spent problem solving. This is in line with the findings of Sun et al. (2011) and Hung et al. (2012) who also found demonstration, reduction in degree of freedom and frustration control scaffolds helpful when students are stuck or 'bogged-down' on problem solving tasks. By reducing frustration through the use of scaffolds, dyads can increase their chances of success, spend more time problem solving, and solve more puzzles (Sun et al., 2011).

Both Sun et al. (2011) and Hung et al. (2012) caution that digital scaffolds can have a negative effect when they are overused as increased reliance reduces learning opportunities. While there were occasions in which scaffolds were used repeatedly, overuse in the early childhood context seems less

important as children are participating in more playful, exploratory experiences and are at the beginning stages of problem solving and learning how to seek help. Young children need to know that it is okay to explore and should be encouraged to use digital scaffolds. While students may not understand that they are developing problem solving strategies that can be transferred to other contexts when they use digital scaffolds, they need to know that it is okay to use these digital scaffolds and that their use is not negative or bad. Teachers need to understand that these explorations are the beginning stages of children seeking help and critical to cognitive development (Gall, 1981; Gall, 1985; Puustinen et al., 2009).

### **Same-Ability vs. Mixed-Ability Dyads**

While no significant difference was found between the three scaffold function types for the data set as a whole, there was a significant difference ( $X^2$  [df=2, n=155] = 24.22,  $p < .05$ ) in how students from Class A (same-ability dyads) used the tools as compared to students from Class B (mixed-ability dyads). The following differences emerged between the groups:

- Class B used digital scaffolds built into the game Rush Hour® four times more often than Class A.
- Class B dyads were more verbal when using digital tools.
- Class B dyads suggested tool use more often to their partner than dyads in Class A.
- Class B dyads used the Solve tool back to back with other digital tools.
- Class B dyads used the Next/Prev tools to move between puzzles.
- Low-low ability dyads in Class A did not use any tools during game play.



### **Level of Help Provided**

Both classes received approximately the same amount of help using digital scaffolding tools during game play. Of the 34 times dyads from Class A used digital scaffolds, help was provided at a rate of 35%. Of the 121 times dyads in Class B used digital scaffolds, help was provided at a rate of 34%. There were, however, differences between individual tools. Same-ability dyads found Solve as a more effective help tool (37.5% vs. 22%) while mixed-ability dyads found the Hint (41% vs. 33%) and Next/Prev tools (35% vs. 25%) as providing more help. The type of dyad configuration did have an impact on the number of tools used but did not impact the amount of help provided by digital scaffolds during game play.

### **Level of Collaboration**

Same-ability dyads appeared to work better together than mixed-ability dyads. Their behaviors were more cooperative, and they stayed on task for longer periods of time. There were few confrontations or arguments between the dyads and none of the same-ability dyads required redirection from the researcher. Within the mixed-ability dyads, there were several instances in which the higher ability student 'took over' game play from the lower ability student. In three of the mixed-ability dyads, the higher ability student controlled the game for longer periods of time, were quick to redirect their partners, and on some occasions would take the iPad away citing they knew how to solve the puzzle even at the protest of their partner. Researchers studying dyads from the elementary context also noted these controlling behaviors. They found same-ability partners are better at taking turns and less dominant over their partners

during collaborative problem solving activities (Light et al., 1994; King et al., 1998; Shih et al., 2010).

### **Level of Problem Solving**

Dyad configuration also played a role in both the amount of total puzzles solved by dyads as well as the efficiency of game play. Same-ability dyads solved more puzzles than their counterparts in mixed-ability dyads. This is in line with those of Ramani (2005), who found same-ability partners working in playful, natural contexts able to complete more builds. Same-ability partnerships also proved to be slightly more efficient problem solvers, as the overall ratio between the number of total moves made to complete a puzzle compared to the minimum number of moves needed to complete a puzzle was lower.

Even though there is evidence to support same-ability partnerships as an effective strategy for partnering preschool students during problem solving tasks on digital games, caution is needed when interpreting the findings. First, as noted in the Limitations section of Chapter 4, no valid developmental measure was used to rank the children. While the basic demographics regarding mean age as well as age range were essentially the same between the two groups, it became clear in observing the students that there were some differences in the overall social-emotional competencies of the groups. Students in Class B needed more direction to stay focused during game play, required more intervention by the researcher, and were found to be more playful, even silly at times. The teachers and the Early Childhood Director also confirmed that students in Class B were less socially competent than their counterparts in Class A. In fact, one of the students from Class B who was ranked as having middle

problem-solving abilities is repeating Junior Kindergarten during the 2013-2014 school year. This same child was one of the outliers in this study who used tools in a playful manner; especially the Next and Prev buttons find other puzzles. The fact that “social development underlies and affects all other areas of learning and development” was quite evident (Epstein, 2007, p. 69).

### **Need for Age Appropriate Digital Scaffolds**

Many researchers have cataloged essential features of good games for young children (An & Bonk, 2009; Chiasson & Gutwin, 2005; Hong et al., 2009; Shute & Miksad, 1997). Games should be easy to use and responsive to a child’s input. They should have sequential levels that encourage critical thinking and provide a variety of ‘just in time’ scaffolds. Feedback and hints should be extensive, and full and partial demonstration scaffolds are especially important (Fisch, 2005; Shute & Miksad, 1997). According to Shute and Miksad (1997), high-level scaffolds, like the Solve tool built into the game Rush Hour<sup>®</sup>, are the most beneficial kind of scaffold for young children. Yet, despite the perceived appropriateness of the sliding puzzle game for preschool children (rated 4+), the demonstration scaffold built within the game would probably not be considered developmentally appropriate for the age group of this study.

The Solve tool did provide a demonstration scaffold considered important for facilitating problem solving with young children. And while it did give help 29% of the time, the speed of the demonstration itself was just too fast-paced for most of the students. Despite the warning sign ‘Pay Attention’ that appears just before the movie begins, many students were not prepared to watch the movie for a variety of reasons such as being distracted by one’s partner. An additional

issue with the tool was related to the length of the movie and the number of moves demonstrated. Depending on how far along the dyad was in the problem solving process, Solve movies could have vehicles move three or four times or could last much longer with ten or more moves.

Using the Solve tool requires children to tap into their short-term memory and then freely recall or retrieve what they see in order to replicate the movement of the vehicles to complete the puzzle. Research on memory in preschool children shows free recall is limited to three or four successive presentations or chunks of information with more chunks being recalled as children get older (Perlmutter & Ricks, 1979). Recall is dependent on type of task, condition in which students are working, the amount of effort put forth as well as the organizational strategies used to organize information such as sorting, grouping and rehearsing (Chi, 1976; Sodian, Schneider, & Perlmutter, 1986; Wellman, Collins, & Gliberman, 1981). Therefore, there are many factors that need to be considered when designing scaffolding tools for young children.

Makers of the game Rush Hour<sup>®</sup>, along with other game designers, can make games more developmentally appropriate for young children by adding features within settings that would allow adults to customize the scaffolding experience based on the individual user. The recommendation to “design different levels of scaffolds that instructors can control” was also supported by the work of Sun et al. (2011, p. 2125). These types of settings would further support how apps could be used to individualize the learning experience, especially since individualization is a key component of developmentally appropriate practice in early childhood settings (NAEYC, 2009). Early childhood

educators need to complete a deep exploration of digital games before they use them in the classroom to make sure all features of the game are appropriate, and they also need to develop a plan on how they will support students in the use of these games.

### **Implications for Educators**

Games played on touch tablets such as the iPad provide opportunities for students to explore mathematical concepts, engage in problem solving activities, and work on visual discrimination skills. They also provide opportunities for preschooler's to engage in collaborative play rich in social interactions. Digital scaffolds built in to these games can provide help, can reduce frustration during game play, and have the potential to extend time spent problem solving. Also of importance is the fact that games with digital scaffolds give children the chance to practice help seeking strategies.

### **Ensuring Developmentally Appropriate Apps**

In order for digital problem solving games to be used in developmentally appropriate ways in the preschool classroom, teachers need to carefully examine apps and scaffolding tools to ensure they are appropriate for their students and verify the tools will not introduce additional frustration into game play. Utilizing app evaluation rubrics, like the ones developed by Harry Walker, a doctoral student at John Hopkins studying the impact of iPod Touch on student achievement or Kathy Schrock, a distinguished educational technologist, can be beneficial, especially for the technology-shy teacher (Schrock, 2011; Walker, 2011). While neither Walker nor Schrock touch specifically on digital scaffolds within their rubrics, their work, when combined with the design principles of

Chiasson and Gutwin (2005) along with insights garnered through this study, provides a strong foundation for early childhood educators to evaluate digital games for young children.

### **Intentional Planning**

Children, especially young children, need overt instruction on how to use tools during game play. This suggestion ties in to findings related to help seeking behaviors and the need for young children to be explicitly taught how to seek help (Aleven et al., 2003; Bartholomé et al., 2006; Gall, 1981; Gall, 1985). Young children need to learn how to use help constructively, and it is the role of the classroom teacher to facilitate experiences where this instruction can take place. Prior to allowing children to play problem-solving games such as Rush Hour® on their own, teachers need to spend time modeling how to use the tools during game play. It is important for teachers to encourage students to try on their own, but at the same time, if a “teacher waits too long or never offers help, children can become anxious or discouraged” (Epstein, 2007, p. 18).

Teachers need to actively model and assist students to ensure they know not just how digital scaffolds work but when and how they should be used. They need to coach by providing direct instruction during game play, and they need to provide varied opportunities for practice (Epstein, 2007). Luckin et al. (2003) found that giving direct instruction before game play is not enough. Children still need prompts on how to use tools, and they also need opportunities to ask how to use tools (Roberts et al., 2008). Therefore, based on the findings of this study as well as documentation within the literature, best practices for early childhood educators is to have young children use digital games in the presence of a

teacher or adult so that implicit instruction on help tools is available throughout all phases of the problem solving process (Gail & Glor-Schieb, 1985; Roberts et al., 2008).

### **Process vs. Product**

As for the best way to partner students, the results of this study are mixed and dependent on the goal for problem solving. If the goal for collaborative problem solving with digital games on the iPad is for dyads to be efficient problem solvers who solve the most number of puzzles, then same-ability dyads would be the preferred way to group students. However, if the goal for collaborative problem solving is the process of learning how to effectively use digital scaffolds and broaden help seeking behaviors then mixed-ability groupings allow for this construction of knowledge. While the levels of help provided by digital tools was the same between same-ability and mixed ability-dyads, mixed dyads spent more time exploring and learning how to use digital tools. What should be remembered when using either of these grouping configurations is that children with low problem solving ability require significant guidance and support and should not be left on their own. Of course teachers need to consider not only the problem solving ability of the students they are pairing together but also other developmental factors that might impact how children collaborate with each other, such as a child's social-emotional competence.

### **Future Research**

Replication of this study with a larger number of students in different types of preschool environments such as voluntary Pre-K or Head Start programs is needed to validate the results across settings. Additionally, due to the

convenience sample used, along with the subjective nature by which problem solving ability was assigned, employing a standardized assessment focused on “basic cognitive function and visual problem solving” such as Raven’s Progressive Matrices Test would provide a more objective way to create dyads thus lending more dependability to the study (Raven, 2000, p. 1). Additionally, there are several other interesting avenues of research that can build on these initial findings.

First, due to the personal nature of how scaffolding tools were used by young children, it would be interesting to watch students working independently to further observe differences in how tools are used by low, middle, and high ability students. Would these differences mirror how the tools were used by ability dyads in this study? Does the dynamic of the dyad impact how scaffolds are used? Also, could this avenue shed light on how children with low-problem solving ability develop their help seeking skills after being given explicit instruction and modeling?

Second, it would be worth looking more closely at the help aspect behind using digital scaffolds to further examine their impact on learning. This study did not deeply capture the actual learning that took place and how that learning might extend to other problem solving experiences in different settings. Observing students playing a variety of problem-solving digital games with built-in scaffolds would help present a more comprehensive view. It would also be valuable to observe digital game play longitudinally across a school year to capture how students can extend scaffolding experiences from one gaming experience to another. Modifying the research design to include a pre-test and



post-test would allow researchers to see if there is growth in problem solving ability.

A third avenue of research would be to examine gender groupings as some differences emerged during game play. Boys, overall, used digital scaffolds more than girls, but girls used the Solve tool more. Boys were also more playful or sillier than the girls. Examining a variety of dyad compositions ties in to the work of Johnson-Pynn and Nisbet (2002) who found the creation of dyads should be dependent on the age, experiences, and settings in which the collaborative learning takes place and should not follow any one methodology or formula.

Fourth, replicating this study with an added control group that does not have access to digital scaffolds during game play would further demonstrate the role scaffolds play within the problem solving process. While there is no doubt that exposing young children to problem solving experiences is critical to the development of mathematical concepts, it is unclear if the use of digital scaffolds in the early childhood context increases learning. A control group would help examine if the use of digital scaffolds increases cognition, and if they are found to do so, is it significant.

Finally, researchers should delve deeper into how digital scaffolds can extend time young children spend problem solving. This study capped the time each dyad played the game at 10 minutes. This time period was selected because it mirrored the time students typically spend at a center during daily rotations; however, many of the dyads were disappointed when the timer rang as they wanted to continue playing the game. Conversely, there were students who

were less engaged during game play and would have left the table had they been given the choice. Observing dyads play for a longer period of time when they could choose when to stop playing would certainly capture more deeply the extent by which digital scaffolds can extend time spent playing.

### **Summary**

Preschool children intentionally used the demonstration, reduction in degree of freedom, and frustration control scaffolds built in to the problem solving game Rush Hour® to reduce frustration and extend time spent playing. Use of digital scaffolding tools was more personal than collaborative, but there were many examples of partners suggesting tool use to help advance game play. Factors such as individual problem solving ability level, type of dyad configuration (same ability vs. mixed ability) and the level of social development of individuals within those dyads appear to impact the ways digital scaffolds are used by preschool children. This study found children with mid-level problem solving ability use digital scaffolds the most followed by children with high-level problem solving ability. This study also found mixed-ability dyads use more digital scaffolds than same-ability dyads and that low-low dyads did not use scaffolds at all. Finally, students with lower social-emotional competencies use tools more playfully than their more mature peers. When looking specifically at tools, Solve (demonstration tool) provided some help to students, but overall was not found to be developmentally appropriate for young children as it moves too quickly and does not match free recall skills of young children.

While this study was an important step in examining the use of technology tools and games in the preschool setting, it was a small one. The small sample

size makes it difficult to generalize its findings beyond the walls of the two classes from the private Early Childhood Center in this study, but it does contribute to the call by NAEYC for evidence-based practice exemplifying “effective and appropriate use of technology and interactive media as tools for learning and development in early childhood settings” (NAEYC, 2012, p. 12). This study is still significant in that it provides insight into how early childhood educators can use gaming applications with built-in digital scaffolds within developmentally appropriate practice to promote problem solving. It confirms the important role teachers play in partnering students during collaborative work and affirms the need for teachers to explicitly teach students how to use help tools. Finally, it reminds teachers that they must critically examine all aspects of digital games including built-in help tools before integrating them into their curriculum.

Several factors set this study apart from much of the research concerning collaborative problem solving with young children. First, this study took place within the natural classroom environment rather than an experimental setting. Second, the research focused on the use of scaffolds in a technological play environment. Finally, it utilized the iPad, a technology tool that is of great interest to early childhood educators for its potential to expand social play opportunities. There is no doubt that the unique developmental needs of young children, coupled with the proliferation of gaming into their lives, warrants continued research in this field.

## APPENDIX A STUDY INTRODUCTION LETTER

School of Teaching and Learning  
University of Florida  
2403 Norman Hall, PO Box 117048  
Gainesville, FL 32611-7058

March 2013

Dear Parent/Guardian,

My name is Anna Baralt, and I am a doctoral student in the School of Teaching and Learning at the University of Florida as well as a member of the Shorecrest faculty. I am currently conducting research on how preschool children use help tools built into digital games under the supervision of Dr. Kara Dawson. The purpose of this study is to examine the ways preschool children use digital scaffolds or tools built-in to the problem solving game Rush Hour in their natural classroom environment when working with a partner. This study will also explore how the ability level of preschool partnerships impacts how digitals scaffolds are used. My hope is that this research will help educators better understand how to use new tablet technologies such as the iPad to enhance children's cognitive and social development as well as problem solving skills in the preschool environment.

The study will be conducted during school hours within the regular classroom and will utilize the application, Rush Hour, a sliding block puzzle game. Your child's teacher will introduce the game and how to play it during instructional circle time. Students will then work with partners to play the game during their morning center rotations. The study will take place from March 2013 to June 2013.

With your permission, your child will be videotaped during game play. Additionally, I will be present to observe your child. Finally, your child will be interviewed informally about their experiences while playing the game. These interviews will also be recorded. All video and audio recordings will be accessible only to me for the purposes of this study as well as to my committee during the doctoral process. Video and audio recordings will be used only for educational purposes.

The identity of students will be kept confidential when reporting results. Code numbers will be used to identify individual participants. Non-participating students will still have the opportunity to engage in the learning experience without being videotaped, observed, or interviewed.

You and your child have the right to withdraw consent for your child's participation at any time without consequence. There are no known risks or immediate benefits to the participants, and no compensation is offered for participation. Group results of this study will be available in December 2013 upon request. If you have any questions about this research protocol, please contact me at (727) 580-8042 or my faculty supervisor, Dr. Dawson, at (352) 273-4177. Questions or concerns about your child's rights as research participant may be directed to the IRB02 Office, University of Florida, Box 11250, Gainesville, FL 32611, (352) 392-0433.

  
Anna Baralt, Ed.S.

Approved by  
University of Florida  
Institutional Review Board 02  
Protocol # 2013-U-0447  
For Use Through 04/4/2014

# APPENDIX B PARTICIPANT CONSENT FORM

School of Teaching and Learning  
University of Florida  
2403 Norman Hall, PO Box 117048  
Gainesville, FL 32611-7058

## Parental Consent Form

**Protocol Title:**

The Effect of Digital Scaffolds on Collaborative Problem Solving in the Preschool Classroom

**Purpose of the Research Study:**

The purpose of this study is to examine the ways preschool children use digital scaffolds or tools built-in to the problem solving game Rush Hour in their natural classroom environment. This study will also explore how the ability level of preschool dyads impacts how digitals scaffolds are used.

**Description of the Study:**

The study will be conducting during school hours within the regular classroom and will utilize the application, Rush Hour, a sliding block puzzle game. Your child's teacher will introduce the game and how to play it during instructional circle time. Students will then work with partners to play the game during their morning center rotations. The study will take place from March to June 2013.

Participants will be videotaped during game play. Additionally, observations and informal interviews will be conducted. Interviews will also be recorded. All video and audio recordings will be accessible only to the researcher for the purposes of this study as well as to her committee during the doctoral process. Video and audio recordings will be used only for educational purposes and will be destroyed upon completion of the doctoral degree.

**Confidentiality:**

The identity of your child will be kept confidential to the extent provided by law. Code numbers will be used to identify individual participants when reporting results.

---

I have read the procedure described above. I voluntarily give my consent for my child,  
\_\_\_\_\_, to participate in Anna Baralt's study,  
*The Effect of Digital Scaffolds on Collaborative Problem Solving in the Preschool Classroom*. I have  
received a copy of the study's purpose and description. I understand that I may withdraw my child  
from the study at any time without consequence.

---

Parent/Guardian

---

Date

---

2<sup>nd</sup> Parent/Guardian

---

Date

Approved by  
University of Florida  
Institutional Review Board 02  
Protocol # 2013-U-0447  
For Use Through 04/4/2014

APPENDIX C  
CHECKLIST FOR GAME INTRODUCTION

- Gather students from both classes in shared space within Exploratorium.
- Introduce Rush Hour® application while connected to projector. Explain to students that they will play the game during centers over the next few weeks.
- Show how vehicles move. Explain that some vehicles move up and down while other vehicles move side to side. Further explain that vehicles can only move one way.
- Discuss the objective of the game, which is to move the vehicles in the parking garage out of the way so that the Red Car can exit.
- Play puzzle #1.
- Discuss options available after completing a puzzle: Next Puzzle or Replay Challenge.
- Introduce the Previous and Next buttons. Demonstrate how they can help move between puzzles.
- Introduce the Reset and Undo buttons while playing puzzle #2.
- Solicit help from students to solve puzzle #2.
- Review options available after completing a puzzle as in step 6.
- Begin play on puzzle #3. Ask students about what they could do if they get stuck while playing the game.
- Introduce the Hint and Solve buttons as tools.
- Complete play of puzzle #3 while demonstrating how the Hint and Solve buttons work.
- Review rules for how to properly handle the iPad.
- Remind students they will be playing Rush Hour® with a partner.

## APPENDIX D INDIVIDUAL DYAD OBSERVATION FORM

Date:

Class:

Dyad Name:

Total # of Levels Completed in 10 Minutes:

Total # of Levels Completed with Hint(s):

Total # of Levels Completed with Help:

Total # of Levels Completed without Help:

	#4	#5	#6	#7	#8	#9	#10	#11	#12
Minimum # of Moves Needed to Complete Level	12	13	21	24	18	21	19	18	20
Total # of Moves Used to Complete Level									
Total # of HINT used within Level									
Total # of SOLVE used within Level									
Total # of RESET used within Level									
Total # of UNDO used within Level									
Total # of NEXT used within Level									
Total # of PREVIOUS used within Level									
Total # of scaffolding tools used within Level									

Notes

APPENDIX E  
SUMMARY FORM



	Total # of Levels Completed	Total # of Levels Completed Without Help	Total # of Levels Completed With Help	Puzzle Completion Ratio without Help (Minimum Moves/Total Moves)	Puzzle Completion Ratio With Help (Minimum Moves/Total Moves)	Total Puzzle Completion Ratio (Minimum Moves/Total Moves)	Total # of HINTS (Reduction in degrees of freedom)	Total # of SOLVE (Demonstration)	Total # of RESET (Frustration control)	Total # of UNDO (Frustration control)	Total # of NEXT (Frustration control)	Total # of PREV (Frustration control)	Total # of Scaffolding Tools Used	Total Demonstration	Total Reduction of Degrees of Freedom	Total Frustration Control
High-High #1	9	5	4	0.58	0.51	0.55	0	8	0	0	0	1	9	8	0	1
High-High #2	9	7	2	0.63	0.25	0.55	3	7	0	0	0	0	10	7	3	0
Middle-Middle #1	6	4	2	0.60	0.61	0.61	3	7	1	1	1	0	13	7	3	3
Middle-Middle #2	13	12	1	0.66	0.25	0.63	0	2	0	0	0	0	2	2	0	0
Low-Low #1	6	0	6	0.41	-	0.41	0	0	0	0	0	0	0	0	0	0
Low-Low #2	8	0	8	0.53	-	0.53	0	0	0	0	0	0	0	0	0	0
High-Low #1	6	2	4	0.36	0.60	0.44	11	4	0	0	1	0	16	4	11	1
High-Low #2	13	11	2	0.66	0.34	0.61	0	5	0	0	0	0	5	5	0	0
Middle-Low #1	7	6	1	0.57	0.47	0.48	0	8	0	0	1	0	9	8	0	1
Middle-Low #2	4	0	4	0.53	-	0.53	8	11	3	0	0	0	22	11	8	3
High-Middle #1	10	4	6	0.72	0.59	0.64	0	1	0	0	11	2	14	1	0	13
High-Middle #2	6	2	4	0.25	0.58	0.47	17	2	0	0	25	11	55	2	17	26
						<b>TOTALS</b>	42	55	4	1	39	14	155	55	42	58
Average	8.08	4.42	3.67	0.54	0.58	0.54	3.50	4.58	0.33	0.08	3.25	1.17	12.92	4.58	3.50	4.00
Standard Deviation	2.84	4.06	2.19	0.14	0.15	0.08	5.60	3.63	0.89	0.29	7.52	3.16	14.83	3.63	5.60	7.83
Variance	8.08	16.45	4.79	0.02	0.02	0.01	31.36	13.17	0.79	0.08	56.57	9.97	219.90	13.17	31.36	61.27

APPENDIX F  
FINAL DATA REPORT

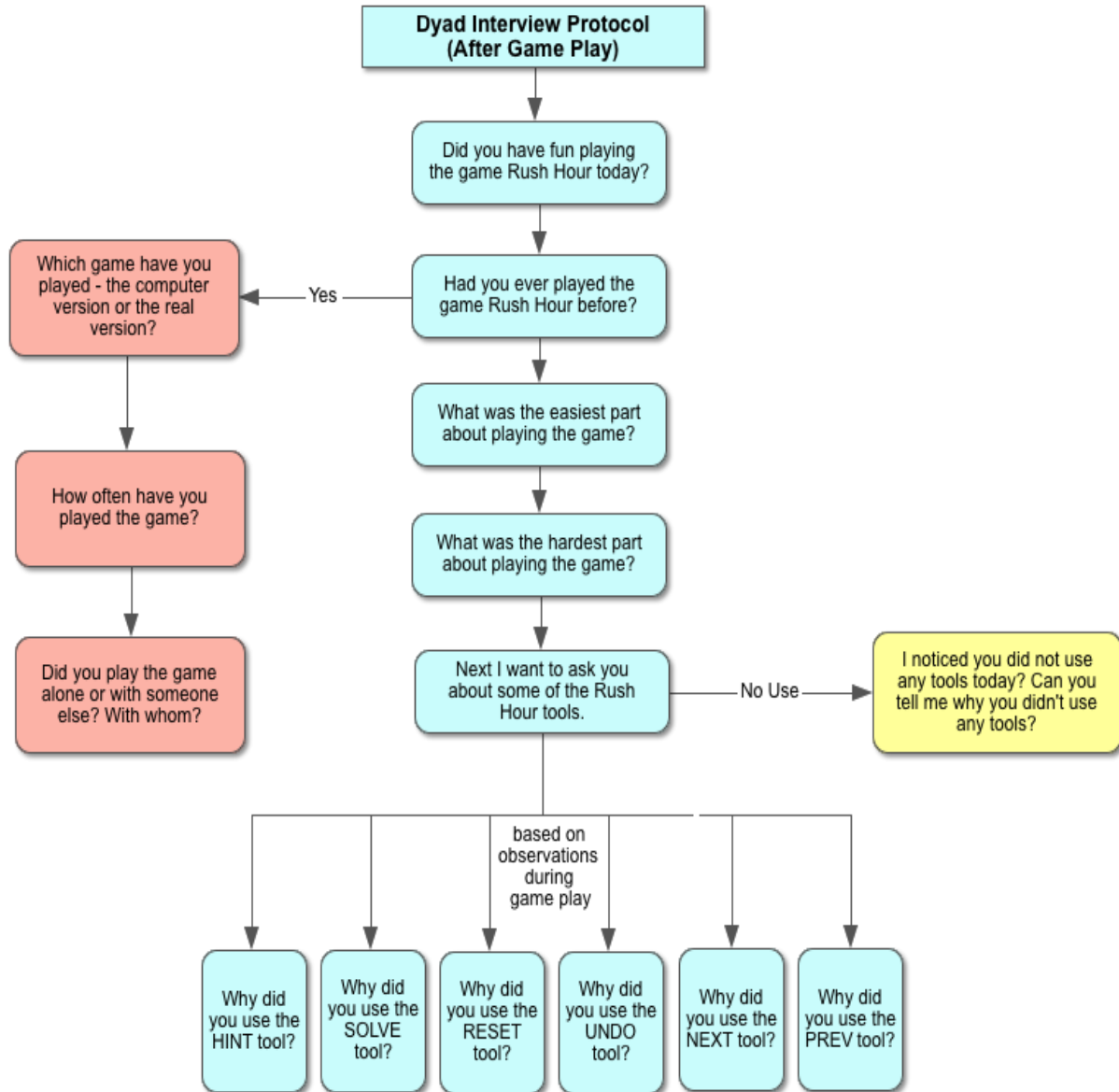
		Not Attempted				Skipped				Not Completed				Level Completed Multiple Times (1st Attempt Recorded)									
		Total # of Levels Completed in 10 minutes	Total # of Levels Completed using Scaffolding Total	Total # of Levels Completed without Help	Total # of Scaffolding Tools Used on Completed Levels	PUZZLE 4					PUZZLE 5					PUZZLE 6							
						Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Use to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used
Class A																							
Same-Ability Dyads																							
High-High #1		9	4	5	9	12	18	67%	0	0	1	13	59	22%	3	0	0	21	36	58%	1	0	0
High-High #2		9	2	7	10	12	14	86%	0	0	0	13	19	68%	0	0	0	21	26	81%	0	0	0
Middle-Middle #1*		6	2	4	13	12	58	21%	0	0	0						1	21	24	88%	0	0	0
Middle-Middle #2		13	1	12	2	12	16	75%	0	0	0	13	53	25%	0	2	0	21	26	81%	0	0	0
Low-Low #1		6	0	6	0	12	110	11%	0	0	0	13	55	24%	0	0	0	21	44	48%	0	0	0
Low-Low #2*		8	0	8	0	12	50	24%	0	0	0	13	57	23%	0	0	0	21	26	81%	0	0	0
Class B																							
Mixed-Ability Dyads																							
High-Low #1		6	4	2	12	12	52	23%	1	6	0	13	29	45%	0	0	0	21	28	75%	0	0	0
High-Low #2		13	2	11	3	12	42	29%	0	0	0	13	21	62%	0	0	0	21	22	95%	0	0	0
Middle - Low #1		7	1	6	8	12	16	75%	0	0	0	13	39	33%	0	0	0	21	38	55%	0	0	0
Middle - Low #2		4	4	0	22	12	16	75%	0	1	0	13	118	11%	6	4	3	21	38	55%	4	3	0
High - Middle #1		10	6	4	14	12	14	86%	0	0	0	13	33	39%	0	0	1	21	30	70%	0	0	0
High - Middle #2		6	4	2	35	12	36	33%	0	0	0	13	81	16%	0	0	0	21	25	84%	0	9	0

		PUZZLE 7					PUZZLE 8					PUZZLE 9					PUZZLE 10										
		Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used		
Class A Same-Ability Dyads																											
High-High #1		24	30	80%	0	0	0	18	31	58%	4	0	0	21	23	91%	0	0	0	19	34	56%	0	0	0		
High-High #2		24	34	71%	0	0	0	18	77	23%	3	1	0	21	33	64%	0	0	0	19	54	35%	0	0	0		
Middle-Middle #1*		24	28	86%	0	0	0	18	39	46%	0	0	0	21	33	64%	3	0	1	19	33	58%	3	0	0		
Middle-Middle #2		24	42	57%	0	0	0	18	45	40%	0	0	0	21	25	84%	0	0	0	19	36	53%	0	0	0		
Low-Low #1		24	38	63%	0	0	0	18	121	15%	0	0	0	21	25	84%	0	0	0								
Low-Low #2*		24	28	86%	0	0	0	18	33	55%	0	0	0	21	35	60%	0	0	0	19	30	63%	0	0	0		
Class B Mixed-Ability Dyads																											
High-Low #1		24	74	32%	1	2	0	18	29	62%	1	3	0	21	77	27%	1	0	0						1		
High-Low #2		24	28	86%	0	0	0	18	49	37%	2	0	0	21	25	84%	0	0	0	19	34	56%	0	0	0		
Middle - Low #1		24	38	63%	0	0	0				7		1	21	37	57%	1	0	0	19	60	31%	0	0	0		
Middle - Low #2		24	34	71%	1	0	0																				
High - Middle #1		24	44	55%	0	0	1	18	35	51%	0	0	0						2	19	24	79%	0	0	1		
High - Middle #2		24	36	67%	0	8	0	18	94	19%	0	1	1	21	34	62%	1	0	30						5		

		Not Attempted Skipped Not Completed Level Completed Multiple Times (1st Attempt Recorded)																								
		PUZZLE 11						PUZZLE 12						PUZZLE 13						PUZZLE 14						
		Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	Minimum # of Moves Used to Complete Level	Total # of Moves Used to Complete Level	Problem Solving Ratio	Total # of Demonstration Scaffolds Used	Total # of Reduction in Degree of Freedom Scaffolds Used	Total # of Frustration Control Scaffolds Used	
Class A Same-Ability Dyads																										
High-High #1		18	49	37%	0	0	0	20	76	26%	0	0	0													
High-High #2		18	49	37%	0	0	0	20	76	26%	4	2	0													
Middle-Middle #1*					1	3	1																			
Middle-Middle #2		18	38	47%	0	0	0	20	32	63%	0	0	0	19	23	83%	0	0	0	17	28	61%	0	0	0	
Low-Low #1																										
Low-Low #2*		18	52	35%	0	0	0																			
Class B Mixed-Ability Dyads																										
High-Low #1																										
High-Low #2		18	37	49%	2	0	0	20	64	31%	1	0	0	19	35	54%	0	0	0	17	26	65%	0	0	0	
Middle - Low #1		18	75	24%	0	0	0																			
Middle - Low #2																										
High - Middle #1		18	48	38%	1	0	2						1							1	17	28	61%	0	0	1
High - Middle #2																										



# APPENDIX G INTERVIEW PROTOCOL



APPENDIX H  
SAMPLE OF CODED TRANSCRIPT

**Carson-EH(6), TW(1)**  
**Low-Middle Dyad**

Game Play

**Mrs. Baralt**

You are going to play the game for 10 minutes. I'm going to set a time on my phone. Do you want to see it."

**C-EH(6)**

"My mom has a timer."

**Mrs. Baralt**

"Do you want to press the start button for me?" [EH starts the timer.] "Great, go ahead and start playing."

**C-EH(6)**

EH makes the first move. It is very slow and deliberate. She then pauses with her hand poised just above the board.

**C-TW(1)**

"You want me to help?"

**C-EH(6)**

EH does not respond to TW. Instead she presses the HINT button one time and then says, "I needed a hint."

**C-EH(6)**

EH ends up moving the hint car back to the position she had it before the hint (which essentially undid the hint).

**C-EH(6)**

EH continues to make moves while TW watches. After a few move moves she solves the puzzle. [Puzzle #4, 16 Moves]

**C-TW(1)**

After the music plays, TW takes his hands and slides the iPad closer to him. "Now it's my turn."



### **C-TW(1)**

TW made no move to try and play the game after his first effort to help.

### **C-EH(6)**

"Then it is my turn."

### **Mrs. Baralt**

I help TW by pointing to the Next Puzzle button after the game is over because he seemed unsure of what to do when the finished games screen came up.

### **C-TW(1)**

TW does not make a move right away.

### **C-EH(6)**

"Come on TW." [with an exasperated voice].

### **C-TW(1)**

TW make three moves. He does not speak while he is working.

### **C-EH(6)**

"TW, you can't move that one." She watches TW for a few seconds as he decides what to do next. "You need a hint."

### **C-TW(1)**

TW lifts his hand so that EH can press the button.

### **C-EH(6)**

EH presses the HINT button.

### **C-TW(1)**

TW then moves a car into the space where the hint car just resided. [Not sure if this is what he would have done on his own.]

### **C-TW(1)**

TW makes about five more moves but gets into a gridlock. "How do you move these cars out?"

### **C-EH(6)**

"Here let me help you." as she nudges TW's hand.

### **C-EH(6)**

EH tries moving the same cars that TW was trying to move when she offered help. She is trying to move a vertical car horizontally.

### C-EH(6)

"We need a hint." She poses her hand over the help tools but does not select one right away. "Uhh." She presses the RESET button.

### C-EH(6)

She tries to move a car that is gridlocked. Then softly whispers, "You need a hint." {Even though she is the one currently in control of the board.} She does not press the hint button but then says, "You need to reset." She does not reset though.

### C-EH(6)

EH presses the SOLVE button. [It seems that she understand that the Hints will help her solve the puzzle but I'm not sure what button she was actually trying to press since her actions and words did not match.]

### C-EH(6)

"See." As she watches the board. "There we go." [The car order for the first four cards was yellow, blue, purple, red.]

### C-EH(6)

EH again tries to move the purple car that his gridlocked and that she has been trying to move since the beginning of the level.

### C-EH(6)

EH is beginning to show frustration. She grunts and sighs then says, "You really..." (all while still trying to move the same car).

### C-EH(6)

She presses the HINT button again. [Does not say anything.] After a few seconds she presses the RESET but nothing happens because the last hint she used actually set her back to the beginning.

### Mrs. Baralt

TW has stayed completely quiet so far. While he seems to be interested in the game he is content to let others do the work.

### C-TW(1)

[Finally.] Pointing to the purple car that is gridlocked in the middle "How do you get that car out of the way."

### C-EH(6)

Another sigh, "Ugh." "How do you get these cars to move." [Referencing the gridlocked line.] She keeps trying to move the purple car horizontally even though it is positioned vertically.

### C-TW(1)

TW also looks up to me.

### C-EH(6)

"We are having a hard time." Puts her hands up in the air and looks up to me.

### Mrs. Baralt

I finally decide to intervene as they have spent almost 2:30 minutes on this puzzle. I move the yellow car up and tell them to look at the blue car. [This appears at this time to help them get on track.] EH is still the main player of the game. TW is watching.

### Mrs. Baralt

EH is stuck on the game. When she finally moves the red car (which is very much needed), I tell her "That is a good idea."

### C-EH(6)

"This level is kind of hard. I have to get out of here." She moves the yellow car up and down over and over. "It is blocking the cars."

### C-EH(6)

"This car is blocking the way." [Has not made in progress in the last 45 seconds.]  
"These guys are blocking the way." Starts moving the red car back and forth but the yellow car is blocking. "It has to get out of here." Makes a fist with her hand in frustration.

### C-EH(6)

"What do we do." Looks over to TW. "TW, you know what, I have an idea. We need a hint."

### C-EH(6)

EH presses the HINT button. [As before, she ends up moving the hint car back into the same exact spot where it just was undoing the hint.]

### C-EH(6)

EH then presses the SOLVE button. [Cars are moved in this order red, yellow, blue, purple.]

### C-EH(6)

EH moves the yellow car first [which is the same thing she did the last time she pressed the solve button.]

### C-EH(6)

"This is only what we can do." as she moves the yellow car up and down.

### C-TW(1)

"Yes, the car is not playing very nice."

**C-EH(6)**

"Yeah." "It can only go that way." "He needs to go sideways."

**Mrs. Baralt**

"He can't go sideways."

**C-EH(6)**

EH tries again moving the red car back and forth. She puts her hands up in the air and says with frustration "It can't get out."

**C-EH(6)**

"Hmmm." EH then presses the SOLVE button again.

**Mrs. Baralt**

"Watch carefully." [The red card is moved first, then yellow, blue, purple.]

**C-EH(6)**

EH tries to move the blue car that is gridlocked first.

**C-EH(6)**

"Hmmm"

**C-TW(1)**

TW remains quiet.

**C-EH(6)**

EH keeps trying for another 15 seconds, "Hhhh. How do we get this out." "I don't know how."

**C-TW(1)**

TW points to the Next button. "How about we press that."

**C-EH(6)**

To me, "Do we have to try this?"

**Mrs. Baralt**

"Want do you want to do?"

**C-EH(6)**

EH presses the SOLVE button.

**C-EH(6)**

EH works on puzzle. This time she starts with the blue then the yellow but again misses

that the solve said to move the red car first.

**C-TW(1)**

Is learning over the iPad watching but is not talking or making moves.

**C-EH(6)**

EH bangs her elbows down on the table in frustration. "I don't know what is missing."

**Mrs. Baralt**

"Well, what happens if you can't solve a puzzle. What can you do?"

**C-EH(6)**

EH keeps trying.

**C-TW(1)**

"I don't know." His hands are resting under his chin. Again he is just watching.

**C-EH(6)**

[As if answering my previous question] "Get help." "I need help." "TW can you help me."

**C-TW(1)**

"No," whispered softly.

**C-EH(6)**

"We need a hint."

**C-EH(6)**

After the HINT moves car up and then back to its same position as before the hint.

**C-EH(6)**

"How do we get this guy home."

**C-EH(6)**

EH presses the UNDO button. Then makes two moves.

**C-EH(6)**

"How do we get these guys out." "We need this." EH again presses the SOLVE button.

**C-EH(6)**

She does not move the red car as indicated by the solve and again goes back to the immovable car. "How did it do that."

**C-EH(6)**

EH presses the SOLVE button. [For the first time watches intently blue, yellow, blue,

purple, yellow, red.]

### C-EH(6)

She moves the blue and yellow cars as in the solve. [The first time she actually copied the moves.]

### C-TW(1)

TW is still watching although he will also look away to see what others around the Exploratorium are doing.

### C-EH(6)

"How did we get it."

### Mrs. Baralt

I finally chime in, "Move the red car. Move the red car." "Okay, now move the purple car."

### C-EH(6)

EH makes the moves I tell her to. Then she removes her hands and places them on her hips. "Now what."

### Mrs. Baralt

"Move the blue car."

### C-TW(1)

TW goes to move the blue car with EH.

### C-EH(6)

EH then moves the yellow and finally solves the puzzle. [Puzzle #5, 118 Moves] ALMOST SIX MINUTES TO COMPLETE THIS PUZZLE!!!

### C-EH(6)

"Okay, next level." Presses the button to advance to puzzle #6. "Whoa, that's a hard one."

### C-TW(1)

"Oh, oh." TW does not make any effort to move the cars. He just leans up on his elbows to watch over the iPad screen.

### C-TW(1)

EH makes one move then TW says, "That's a hard one."

### C-EH(6)

"Yeah, this is really hard." EH keeps moving the green car back and forth.

**C-TW(1)**

Excitedly, "There's the red car. There's the red car." As he points to the iPad screen.

**C-EH(6)**

EH then moves the red car back and forth. "How do I get through."

**C-EH(6)**

Moving the green car back and forth. "Oh, oh, we're trapped."

**C-TW(1)**

"We are. You're trapped." "I don't know." TW is moving back and forth in his chair but not touching the board.

**C-EH(6)**

"Sigh," with hands on her hips.

**C-EH(6)**

"How do we get this out."

**C-TW(1)**

"Hmm. It is hard."

**C-EH(6)**

"This is the really hard one."

**C-TW(1)**

TW moves the pink car.

**C-EH(6)**

When EH tries to move the car back, I say "That was good move. That was a good move." After a few more moves.

**C-TW(1)**

"Give me a hint." TW goes to make a hint but EH pushes his hand up and he doesn't the chance.

**C-EH(6)**

EH ends up solving the puzzle on her own. "Ooooh, next puzzle."

**C-EH(6)**

"Oh, my gosh." As she begins to work on the puzzle.

**C-TW(1)**

"Let me see." TW goes to move a car. When EH tries to move a car he says to her, "This one is mine" and moves her hand aside.

**C-EH(6)**

"Okay, and then mine." After a few moves, "TW it's now blocking the way."

**C-TW(1)**

TW makes several moves.

**C-EH(6)**

"Here, let me do it." as she pushes his hand up. She looks at the board then presses HINT.

**C-TW(1)**

TW then begins to make moves. EH tries to take over again but TW says, "No."

**C-EH(6)**

"We need this," She presses the SOLVE button but it does not work because TW has his finger on a car.

**C-TW(1)**

"No" as he nudges EH. "No." TW makes two more moves.

**C-EH(6)**

Nudges TW's hand away. "We need this." EH presses the SOLVE button. [Pink, yellow, dark purple, light purple.]

**C-EH(6)**

Even though EH did not make the same exact moves, she is now able to solve the puzzle in five more moves.

**C-EH(6)**

"Whoa, next level." As she presses the next level button.

**C-TW(1)**

"Uh, oh."

**C-EH(6)**

EH starts working on the puzzle. She goes to press the solve button but instead presses HINT. Then she just keeps on working. After another move she presses SOLVE.

**C-TW(1)**

"Just move the truck."



**C-EH(6)**

EH watches the solve (the first four moves were red, dark purple, light purple, blue0. When it is over she says, "Ohhh."

**C-EH(6)**

EH does not end up moving any of the cars that were just moved in the solve.

**C-TW(1)**

TW is leaning over on his arms watching EH move the cars. "This one has lots of cars. They have to right over."

**C-EH(6)**

EH moves a few cars then presses the SOLVE button. [red, pink, yellow, dark purple, light purple]

**C-EH(6)**

EH does not move the cars like in the puzzle. "How do I do this."

**C-TW(1)**

"The truck is blocking the way. That's how."

**C-EH(6)**

EH then moves the truck.

**C-TW(1)**

"It is blocking the exit" (referring to the yellow truck.0

**C-EH(6)**

"The truck is blocking the exit. We need help."

**C-TW(1)**

"Push the hint."

**C-EH(6)**

"Yeah, we need a hint." She pushes the button, HINT, then just looks at the screen.

**C-TW(1)**

"No, that's not a hint." [Probably said that because the truck was still blocking the exit.]

**C-EH(6)**

EH moves a car.

**C-TW(1)**

"So I was just thinking," as he moves to press the hint button.

**C-EH(6)**

EH stops him from pressing Hint and presses SOLVE instead. "We needed an explanation." The movie plays. "Did you see that?"

**C-EH(6)**

"How do we move the green car?" EH nor TW made any of the movie moves.

**Mrs. Baralt**

The alarm goes off. "Oh, guess what, time's up.

**C-EH(6)**

"But we have to solve the missing problem. Can we do some more later?"

APPENDIX I  
DESCRIPTIVE STATISTICS FOR CLASS A (SAME ABILITY DYADS)

	Total # of Levels Completed	Total # of Levels Completed Without Help	Total # of Levels Completed With Help	Puzzle Completion Ratio without Help (Minimum Moves/Total Moves)	Puzzle Completion Ratio With Help (Minimum Moves/Total Moves)	Total Puzzle Completion Ratio (Minimum Moves/Total Moves)	Total # of HINTS (Reduction in degrees of freedom)	Total # of SOLVE (Demonstration)	Total # of RESET (Frustration control)	Total # of UNDO (Frustration control)	Total # of NEXT (Frustration control)	Total # of PREV (Frustration control)	Total # of Scaffolding Tools Used	Total Demonstration (SOLVE)	Total Reduction of Degrees of Freedom (HINT)	Total Frustration Control
Class A Same-Ability Dyads	BOWEN															
High-High #1	9	5	4	0.58	0.51	0.55	0	8	0	0	0	1	9	8	0	1
High-High #2	9	7	2	0.63	0.25	0.55	3	7	0	0	0	0	10	7	3	0
Middle-Middle #1	6	4	2	0.60	0.61	0.61	3	7	1	1	1	0	13	7	3	3
Middle-Middle #2	13	12	1	0.66	0.25	0.63	0	2	0	0	0	0	2	2	0	0
Low-Low #1	6	0	6	0.41	-	0.41	0	0	0	0	0	0	0	0	0	0
Low-Low #2	8	0	8	0.53	-	0.53	0	0	0	0	0	0	0	0	0	0
							6	24	1	1	1	1	34	24	6	4
Class A Mean	8.50	4.67	3.83	0.57	0.40	0.55	1.0	4.0	0.17	0.2	0.2	0.2	5.7	4.00	1.00	0.67
Class A Range	7.00	12.00	7	0.25	0.36	0.22	3	8	0	1	1	1	10	8	3	2
Class A Stand Dev	2.59	4.55	2.71416	0.09	0.19	0.08	1.55	3.74	0.41	0.41	0.41	0.41	5.68	3.74	1.55	1.21
Class A Variance	6.70	20.67	7.36667	0.01	0.03	0.01	2.40	14.00	0.17	0.17	0.17	0.17	32.27	14.00	2.70	1.47

APPENDIX J  
DESCRIPTIVE STATISTICS FOR CLASS B (MIXED ABILITY DYADS

	Total # of Levels Completed	Total # of Levels Completed Without Help	Total # of Levels Completed With Help	Puzzle Completion Ratio without Help (Minimum Moves/Total Moves)	Puzzle Completion Ratio With Help (Minimum Moves/Total Moves)	Total Puzzle Completion Ratio (Minimum Moves/Total Moves)	Total # of HINTS (Reduction in degrees of freedom)	Total # of SOLVE (Demonstration)	Total # of RESET (Frustration control)	Total # of UNDO (Frustration control)	Total # of NEXT (Frustration control)	Total # of PREV (Frustration control)	Total # of Scaffolding Tools Used	Total Demonstration (SOLVE)	Total Reduction of Degrees of Freedom (HINT)	Total Frustration Control
Class B Mixed-Ability Dyads	CARSON															
High-Low #1	6	2	4	0.36	0.60	0.44	11	4	0	0	1	0	16	4	11	1
High-Low #2	13	11	2	0.66	0.34	0.61	0	5	0	0	0	0	5	5	0	0
Middle-Low #1	7	6	1	0.57	0.47	0.48	0	8	0	0	1	0	9	8	0	1
Middle-Low #2	4	0	4	0.53		0.53	8	11	3	0	0	0	22	11	8	3
High-Middle #1	10	4	6	0.72	0.59	0.64	0	1	0	0	11	2	14	1	0	13
High-Middle #2	6	2	4	0.25	0.58	0.47	17	2	0	0	25	11	55	2	17	36
							36	31	3	0	38	13	121	31	36	54
Class B Averages	7.67	4.17	3.5	0.52	0.52	0.53	6	5.166667	0.5	0.00	6.3	2.2	20.2	5.17	6.00	9.00
Class B Range	9.00	11.00	5	0.47	0.26	0.20	9	9	3	0	4	7	25	10.00	17.00	11.00
Class B Sdev	3.27	3.92	1.76068	0.18	0.11	0.08	7.18	3.76	1.22	0.00	10.07	4.40	18.04	3.76	7.18	14.07
Class B Variance	10.67	15.37	3.10	0.03	0.01	0.01	51.6	14.16667	1.5	0.00	101.47	19.37	325.37	14.17	51.60	198.00

APPENDIX K  
PERMISSION TO USE IMAGES



October 23, 2013

Anna Baralt, EdS  
University of Florida, Doctoral Candidate  
Director of Educational Technology  
Shorecrest Preparatory School  
(727) 522-2111 x218

Dear Anna,

We are responding to your request to obtain permission to use the attached screen shots as figures within your dissertation.

We are flattered by the request and pleased to inform you that we are granting permission for you to use the screen shots of the Rush Hour® iPad app as part of your dissertation.

The Rush Hour® app is the intellectual property of ThinkFun, and we are sure that you will understand our need to protect the use of it. As such, we would like to receive acceptance to the following requirements:

1. The permission is granted only to the request of using the images as part of your dissertation.
2. It is understood that there will be no charge for distribution of the images.
3. We would like the following acknowledgement:
  - a. The intellectual property belongs to ThinkFun Inc, a leading creator of mind challenging games, as well as mention of the company's website: [www.ThinkFun.com](http://www.ThinkFun.com).
  - b. Mention of the inventor, Nob Yoshigahara, who created the Rush Hour® game.

At ThinkFun, one of our core beliefs is that learning and stretching your brain can be fun! Over 25 years ago our company was founded with the dream of changing the world through play; and whether you're 5 years old or 90 years old, we are firm believers that games can sharpen your mind and build life-long skills. We are excited that you have chosen to include ThinkFun in your dissertation and we hope it is a success!

Please sign the letter below and either email ([kbloxom@thinkfun.com](mailto:kbloxom@thinkfun.com)) or fax (703-549-6210) it back to us. Let me know if you have any questions. I look forward to hearing back from you.

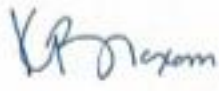
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Best regards,

Kirsten Bloxom  
ThinkFun Inc.

 10/23/13

ThinkFun Signature, Date

 10/26/13

Anna Baralt, Date

Attachment 1:



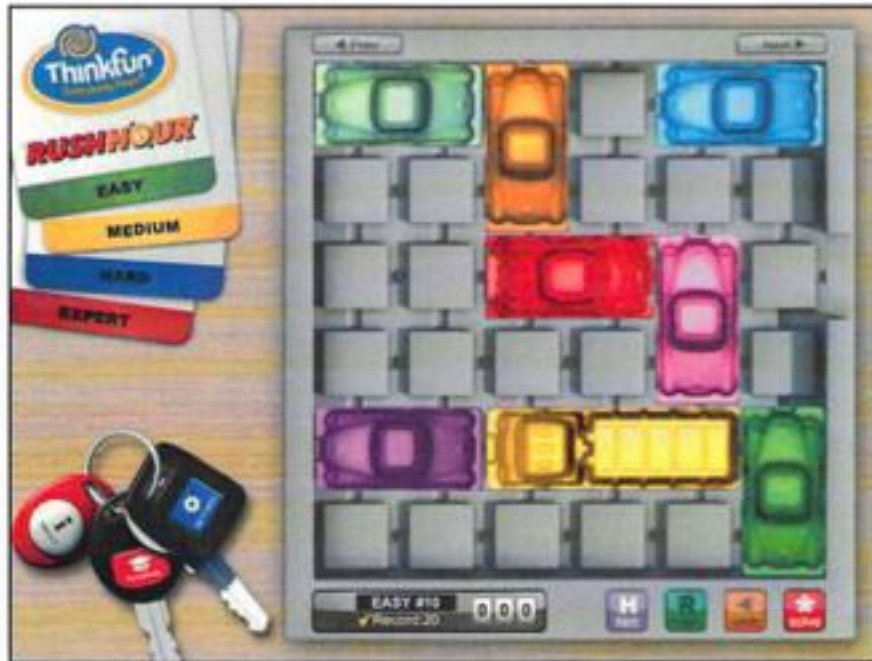
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## BIOGRAPHICAL SKETCH

Anna Baralt has taught preschool and elementary students at a private school in the United States for eighteen years. She joined the school's administrative team as Director of Educational Technology in 2013. Anna was recognized as a Teacher of the Future by the National Association of Independent Schools in 2008 and as a Superpower Educator in 2009. She has presented at numerous state and national conferences. In addition to researching how touch technologies can be used in the preschool classroom in developmentally appropriate ways, Anna is passionate about integrating technology into project work, fostering digital citizenship, 1:1 learning environments, and using technology to facilitate professional learning communities. She received her Ed.D. from the University of Florida in the fall of 2013.