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Programming in a Robotics Context in the Kindergarten Classroom: The Impact on Sequencing Skills

ELIZABETH KAZAKOFF AND MARINA BERS
Tufts University, USA
elizabeth.kazakoff@tufts.edu
marina.bers@tufts.edu

This paper examines the impact of programming of robots on sequencing ability in early childhood and the relationship between sequencing skills, class size, and teachers' comfort level and experience with technology. Fifty-eight children participated in the study; 54 children were included in data analysis. This study was conducted in two different school environments, where class size and teachers' experiences with the technology use varied – one teacher had used the technology in the prior year; the other teacher had not. School environments were further subdivided into control and experimental groups. Children in the experimental group were exposed to the TangibleK program for a period of 20 hours, taught by their classroom teacher. Children participated in computer programming activities using a developmentally appropriate tangible programming language, specifically designed to program a robot's behavior. All 54 participants' sequencing skills were assessed before and after the intervention using a picture story sequencing task and analyzed using a repeated measures, 2x2x2 design ANOVA. A significant interaction was found between group assignment and test results. No significant interactions were found for school assignment. Results are discussed taking into account class size, teacher experience, and teacher comfort level with technology.

Keywords: computer programming, early childhood, robotics, sequencing, STEM

INTRODUCTION

Despite the pervasive nature of digital technologies in the United States, American children are lagging far behind other countries in STEM education (Science, Technology, Engineering, and Math) (Kuenzi, 2008). The National Science Board urged the Obama administration to make STEM education a priority in early childhood education, stating, "the earlier children are exposed to STEM concepts, the more likely they are to be comfortable with them later in life." The current presidential administration has pledged to do so (National Science Board, 2009) and has identified STEM in grades K-12 as a high priority for education and is supporting programs such as Education to Innovate (US DOE, 2010a) and the National Technology Education plan (US DOE, 2010b).

In order to address the goal of promoting STEM education, the study outlined in this paper explores a computer programming and robotics program which engages young children in learning a critical skill in the digital age: computer programming. Computer programming "is a creative endeavor requiring planning, precision in the use of language, the generation and testing of hypotheses, the ability to identify action sequences…and a variety of other skills that seem to reflect what thinking is all about" (Nickerson, 1982, p. 42).

Computer programming is the foundation of all digital technologies and an important skill for 21st Century literacy (Rushkoff, 2010; Jenkins, 2009). Computer programming, at its core, involves the use of symbolic commands arranged in an appropriate sequence to create a series of actions in order to instruct a computer's behavior (Pea & Kurland, 1984). In order to create a successful program, children (and adult programmers alike) must use procedural thinking and understand the logic of instructions. When creating a program, children are thinking in terms of *next, before,* and *until* which are all components of sequencing, in particular, temporal sequencing (Pea & Kurland, 1984). Thus, the research question at the core of this paper is: does computer programming have an impact on kindergartners' sequencing skills?

In this study, engaging kindergarten children in computer programming activities is done in the context of programming the behaviors of robotic artifacts. Robotics was chosen as a domain because it can support the making of abstract ideas more concrete, as the child can directly view the impact of his or her programming commands on the robot's actions, and because it extends a tradition of learning with manipulatives (in this case, using digital manipulatives) that is well explored with young children (Bers, 2008; Resnick, Martin, Berg, Borovoy, Colella, Kramer, & Silverman, 1998).

This paper focuses on the impact of programming robotic artifacts in sequencing skills in kindergarten classrooms, replicating a prior laboratory-based study (Kazakoff & Bers, 2010, 2011) that showed improvements on sequencing skills in a more controlled lab-based environment. However, STEM education primarily takes place in classrooms, not in research labs, thus, it is important to understand if educational interventions, such as the one outlined in this study, may have an impact on young children's sequencing abilities when implemented in real-world classrooms settings.

Classroom-based settings add a myriad of variables and levels of complexity to understanding how children learn with and through digital technologies. This study will focus on two key areas: the diversity in the teachers' previous experiences with digital technologies and the size of the classrooms. Previous work demonstrated that, when children participated in the TangibleK program on a one-to-one basis in a laboratory setting, there were significant improvements in their sequencing skills (Kazakoff & Bers, 2010, 2011). The primary focus of this paper is to explore if the significant result may be replicated when children are working in classroom settings with different teachers and varying class sizes.

Teaching Technology in the Early Childhood Classroom

The ubiquitous nature of technology in today's world combined with increased pressure for STEM education yields an even greater interest in integrating technological tools into early childhood classrooms. The children entering preschools today are a generation of so-called digital natives, meaning they were born into a world filled with technological artifacts – they do not know a world before iPads and cell phones (Zevenbergen, 2007; Prensky, 2001). Children today are using computers before they even step foot inside of school – a recent report states 53% of 2 - 4 year olds and 90% of 5 - 8 year olds have used a computer and a quarter of children go online daily by the age of three, with half of children going online daily by the age of five (Rideout, 2011).

Despite decades of research attempting to demonstrate the positive impact technology can have in the classroom, teachers and schools have been slow to universally integrate digital technologies into classrooms because of lack of experiences with the new technology, lack of on-site tech support, lack of availability, and lack of financial support (Mumtaz, 2000). Though by 2001, 99% of public schools had Internet access (Judge, Puckett, & Cabuk, 2004), by 2010 only 59% of K-3 classroom teachers reported having a computer in their classroom (Wartella, et al., 2010).

In 2010, 92% of K-3 teachers surveyed stated they could successfully navigate the Internet and 80% reported going online daily, most commonly to check email (82%), search for work-related websites (79%), and look for classroom activities (67%) (Wartella, et. al., 2010). Thirty-eight percent of K-3 teachers surveyed used their classroom computer daily, 23% sometimes used it and 35% never did (Wartella, et. al., 2010).

What happens when classrooms vary so dramatically in technology use? There has been concern for the equity between children, especially those children with lower SES who tend to only have access to technology in schools (Zevenbergen, 2007). It is becoming increasingly important for all children to have technological knowledge and schools are a key area for bridging this digital divide and ensure there are no gaps in technological learning (Zevenbergen, 2007).

Teachers and Technology in Classrooms

Since before the very first computer even entered the classroom, there has been much debate about the appropriateness and usefulness of technological tools in early childhood education. These debates typically centered on the question of "are computers wonderful tools or simply high-tech worksheets?" Teachers' positions traditionally depend on the types of computer programs used in their classrooms, their training experiences, and their own personal attitudes towards technology (Hermans, Tondeur, van Braak, & Valcke, 2008; Davidson & Wright, 1994; Bredekamp & Rosegrant, 1994). Educators debate if computer technology enhances the classroom with constructivist practices and curriculum or if they are just expensive replacements for more productive classroom activities. This concern is compounded by teachers who have not grown up with these technologies and therefore do not feel confident in teaching with or about them (Davidson & Wright, 1994). One early study found 26% of teachers who were classified as exemplary users of computers in their classrooms had used the technology for over five years compared to just 10% of typical-users (Becker, 1994; 2000).

Prior research demonstrates teachers' beliefs about technology highly influenced their use of computers in their classrooms. Teachers who hold constructivist beliefs tend to use digital technology with a more open-ended, child-centered approach over a drill and practice approach (Hermans, Tondeur, van Braak, & Valcke, 2008, Haugland, 1992; 1999). Research shows technology that is fully integrated into the curriculum has the most positive impact (Judge, 2002). Just putting a computer in a classroom does not necessarily mean it is used effectively (Zevenbergen, 2007). Teachers who use digital technologies effectively tend to set up their classrooms so that the computer is used in a social, child-directed, and exploratory way to engage children in a variety of learning opportunities as just one of many classroom materials (Davidson & Wright, 1994; Bers et. al., 2002).

Computer Programming in the Classroom

Historically, a popular and frequently researched technological tool for children in the classroom was Logo: a constructionist programming environment for children (Papert, 1980). Constructionist programming environments are tools for engaging children in thinking about their own thinking; a place where abstract ideas can become more concrete and thereby subject to reflection (Papert, 1980). Children who used Logo in kindergarten were found to have sustained attention, self-direction, and took pleasure in discovery (Clements, 1987). A large scale study of children using the Logo programming language, demonstrated that children in grades K –6 scored significantly higher on tests of mathematics, reasoning, and problem-solving (Clements, et al., 2001). A proposed explanation for the difference in scores is that when children engage in computer programming, and thereby create a sequence of commands for the computer to read, the child may be better able to externalize his or her inner thought process. This externalization of inner thoughts makes the child's thought process more available for reflection and understanding. Young children who used Logo also transferred their knowledge to map reading and interpreting the rotation of objects, and demonstrated understanding of a wide variety of logical and math knowledge. Furthermore, computer programming has been found to positively impact creativity and emotional response in children with learning difficulties (Clements & Swaminathan, 1995) and has been linked to development of domain knowledge as well as cognitive and social-emotional skills (Clements, 1999; Liao & Bright, 1991).

Research on innovative, developmentally appropriate, computer programming supports the argument that children's programming of animations, graphical models, games, and robots with age appropriate materials allows them to learn and apply core computational thinking concepts such as abstraction, automation, analysis, decomposition, modularization, and iterative design (e.g. Lee, et al., 2011; Bers & Horn, 2010; Mioduser, Levy & Talis, 2009; Mioduser & Levy 2010; Resnick, 2006; Resnick et al., 2009) and cognitive skills, such as problem solving (Haugland, 1992; Clements & Sarama, 2002; Wang & Ching, 2003). Prior research has shown the benefits of integrating robotic technologies into the early childhood classroom in developmentally appropriate ways (Bers, 2010; Bers, 2008; Rogers & Portsmore, 2004; Bers, Ponte, Juelich, Viera, & Schenker, 2002). Children may become producers, not just consumers, of digital technologies (Bers & Horn, 2010; Bers, 2008; Bers et. al., 2006; Berson, 2003; Johnson, 2003).

New digital technologies can make learning more social, collaborative, and networked (Gee, 2010; Jenkins, 2006). Researchers have found when children work at a computer, they speak twice as many words per minute than when engaged in other non-technology related play activities such as play dough and building blocks (New & Cochran, 2007). Children, when working on computers, are also more likely to ask other children for advice and help, even if an adult is present, thus increasing child-child socialization (Wartella & Jennings, 2000). Even in situations where each child has an individual computer, or their own piece of digital equipment to work with, children still tend to choose to form groups while working with technological tools (Druin, 1998).

From both an economic and a developmental standpoint, educational interventions that begin in early childhood are associated with lower costs and longer-lasting effects than interventions that begin later in childhood (Reynolds, et al., 2011; Cuhna & Heckman, 2007). In addition, preliminary research suggests that children who are exposed to STEM curriculum and computer programming at an early age demonstrate fewer gender-based stereotypes regarding STEM careers (Metz, 2007; Steele, 1997) and fewer obstacles entering these fields (Madill, et al., 2007; Markert, 1996).

Class Size

One of the largest and most widely analyzed studies on class size was Project Star (Mosteller, 1995). Eighty schools in Tennessee participated in this project where children and teachers were both randomly assigned to one of three groups: regular classrooms (22 - 25 students), regular classrooms with aides, or small classrooms (13 - 17) to examine the effect of classroom size on learning (Konstantopoulous, 2011; Mosteller, 1995). This study demonstrated there was a significant positive impact on reading and mathematics scores for kindergarten children in the smaller (13 - 17 student) classrooms than the larger classrooms, with or without aides.

Additional studies found teachers who were the most effective at using computers were found in small classrooms (Becker, 1994; 2000). A regression analysis of 20 variables indicated that class size was the largest predictor of exemplar use of computers in the classroom (Becker, 1994; 2000). Additional research from the Early Childhood Longitudinal Study (ECLS-K) found a similar pattern to Project STAR – a positive relationship between small class sizes and reading and math skills. The effect was particularly apparent for children from lower SES and minority backgrounds (Yan & Lin, 2005).

Sequencing

Computer programming, the technological skill students in kindergarten classrooms were exposed to in this study, is defined as "using…a sequence of instructions, variables, recursion, etc. to write solutions to problems… (Liao & Bright, 1991, p. 253)." If sequencing is at the core of one's ability to understand and create computer programs (Pea & Kurland, 1984) and computer programming is linked to improvement in cognitive skills (Clements, 1999; Liao & Bright, 1991), can computer programming positively impact sequencing skills in early childhood?

Sequencing is a component of planning and involves putting objects or actions in the correct order (Zelazo, Carter, Reznick, & Frye, 1997). Sequencing is an important skill for early childhood and is found repeatedly in both curricular frameworks and learning assessments. For example, retelling a story in a logical sequence, ordering numbers in the correct sequence, and understanding the sequence of a day's activities are all common components of curriculum frameworks for children in kindergarten in both language arts and mathematics (MA DOE, 2008).

In addition, a 1998 US Department of Education study assessed approximately 19,000 kindergarten students to collect a baseline of what children this age know, called the Early Childhood Longitudinal Study (US DOE NCES, 2001). This assessment included "recognizing a sequence of patterns" as a mathematics assessment measure (US DOE NCES, 2001). This study found 58% of kindergarteners are proficient in recognizing patterns of sequence, and 20% are proficient in ordinal sequencing (first, second, third, etc.). Twenty percent of kindergartners could determine the next number in a sequence, with the older children more likely to achieve these skills than the younger children (US DOE NCES, 2001).

Since sequencing is an important component of both early mathematics and early literacy learning, it is a common theme in early childhood classrooms. Sequencing, along with sorting, measurement, and pattern recognition are a child's mathematical building blocks; starting with these foundational skills, children begin to think of the world mathematically (Sarama and Clements, 2003). In terms of literacy, both the code-related skills (letter-sound correspondence, phonemic and phonological awareness, and letter naming abilities) and oral language skills (vocabulary, story schemas, conceptual knowledge, and narrative comprehension skills) are important in early and later literacy development (Whitehurst & Lonigan, 1998). The use of sequencing is apparent in a variety of these skills – understanding story schemas, narrative comprehension, letter order for phonemic and phonological awareness and word recognition. These all require the appropriate ordering of letters, words, or ideas. Constructing narratives scripts or sequences of daily routines are a common part of early childhood, both in and out of the classroom (Paris & Paris, 2003). Sequencing problems are a contributing factor to poor reading in kindergarten as they impact understanding and prediction of themes, patterns, and storylines (Kamps, et. al., 2008).

Piaget believed children in the preoperational stage could not sequence, due to their inability to reason about more than one object or action at a time. He believed the ability to reason about multiple objects simultaneously, and thus be able to reverse them, was key to understanding sequencing (Piaget, 1969). In his studies, Piaget found children younger than 6 or 7 were unable to successfully complete a story sequencing task (Piaget, 1969) however, since then, studies have shown that children as young as two can begin to understand, and imitate, short (2-3 action), highly familiar sequences (O'Connell & Gerard, 1985). Other studies found children in kindergarten can construct sequences, but not necessarily discuss logic or cause and effect related to those sequenced stories (Brown & French, 1976). During this transitional period between preoperational and concrete operational periods, the child lacks the ability to understand any series of events in any order and display logic which only works in one direction (Brown & French, 1976).

Criticism of Piaget's work in this area comes also in the form of his sequencing assessment themselves, which some claim were arbitrary and not grounded in meaning for the child (Brown & Murphy, 1975). However, when a sequencing task is presented in a meaningful context, such as a narrative, the kindergarten child is able to sequence (Brown & Murphy, 1975). Furthermore, with simple two-step, cause-effect patterns, studies indicate that children as young as two can sequence a familiar event in a forward direction (Fivush & Mandler, 1985).

Overall, research shows that children in the preoperational period may be able to sequence in a forward direction without the needing to understand reversibility (Fivush & Mandler, 1985). The kindergarten child has the easiest time with a familiar sequence in the forward order, but a more difficult time, even in the forward order, for events the child has not experienced. The child, in this case, would have to rely on understanding and inferring logical connections between events, rather than his/her own experiences, which is difficult for the young child in the preoperational period (Fivush & Mandler, 1985; Brown & French, 1976).

In both literacy and mathematics, sequencing is essential for putting words, letters, and formulas in the appropriate order and the sequencing of letters and phonemes is a key component to building early literacy skills (Neuman & Dickinson, 2002). Story sequencing skills, along with vocabulary knowledge and story comprehension in kindergarten are strongly linked to success in literacy later in life (Snow, Tabors, Nicholson, & Kurland, 1994). Using pictorial stories is common in early childhood because they require narrative thinking and understanding of sequences without relying on words (Paris & Paris, 2003).

Computer programming with a developmentally appropriate tool can be seen as a version of story sequencing. The developmentally appropriate computer programming tool, CHERP (Creative Hybrid Environment for Robotic Programming), which was used in this study, utilizes 2 inch x 2 inch cubes of wood that are covered with pictures depicting units of code, for example, forward, backwards, right turn, left turn, light on, light off, spin, shake, sing, and beep. Children use these cubes to create a program or story for a robot to act out. The child translates his or her idea for the robot's behaviors (its story) into a sequence of commands. Both the program and the robot can be held and physically manipulated. This is a power tool for visualizing and reflecting on the sequence of a program. The next section will describe the technology in more detail.

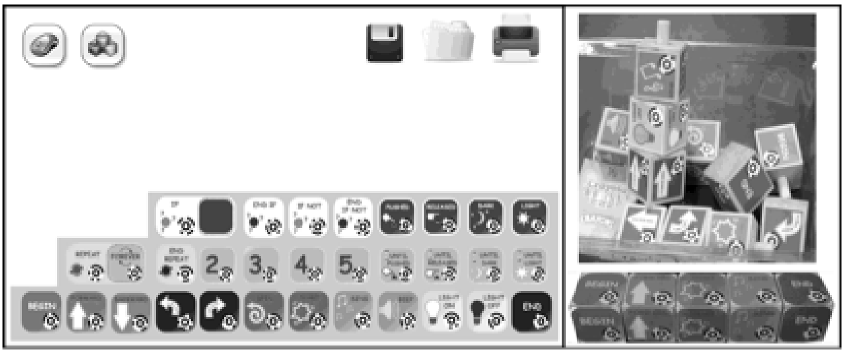

Figure 1. Two Interfaces of CHERP.

Children may choose their method of programming with the tangible-graphical programming language CHERP. The photo on the left is a screen shot of the graphical programming language. The photo on the right shows a sample of the tangible wooden blocks.

CHERP

The Creative Hybrid Environment for Robotic Programming system allows young children to program with interlocking wooden blocks or corresponding on-screen blocks (Figure 1 above) and to transition back and forth between the two interfaces. The tangible block-based and graphical on-screen icons represent the same actions for the robot to perform in either case. This hybrid approach caters to individual preferences in interface and allows children to work with multiple representations of the same concepts (Horn, Crouser, & Bers, 2011).

In a prior study, after piloting CHERP in several classrooms and summer camp settings to inform the interface design (Horn, Crouser, & Bers, 2011), a controlled laboratory study was conducted to closely examine aspects of programming with CHERP in a one-on-one setting to assess possible learning outcomes, such as understanding of sequencing (Kazakoff & Bers, 2010, 2011).

PRIOR LABORATORY RESULTS ON SEQUENCING

In the laboratory study, 34 children (ages 4.5 – 6.5) participated in robotic-based computer programming activities with CHERP during three sessions of 1.5 hours in duration. The participants' sequencing skills were assessed before and after the intervention using a picture story sequencing task, the same one used in this study. Pre-test and post-test scores for sequencing were compared. The mean pre-test score was 7.06 (SD = 2.45) and the mean post-test score was 8.44 (SD = 1.76) on a 10-point scale, a 19.5% increase in average test score. A paired t-test found the increase in test scores was significant, $t(33) = 2.71$, $p < .01$. This study demonstrated children as young as 4.5 could learn to program robotic artifacts using the programming language, CHERP, and test results indicated improvement in their sequencing scores over the short (average 17.8 days) duration of the study.

After finding a significant impact on sequencing skills in the prior laboratory study, the current study is, in part, an attempt to replicate those results in a real-world classroom setting. Thus, the goal of this study is to assess the impact of the same programming and robotics intervention, in a larger-scale setting – kindergarten classrooms – taking into consideration class size and teacher experience and comfort level with technology.

In the current study, the hypothesis is that young children who program robots with a developmentally-appropriate computer programming interface, CHERP, will see an increase in post-test picture sequencing scores compared to their baseline pre-test scores and that these increases will not be present in the control groups. In addition to testing this hypothesis, two other questions are explored: (1) Will differences in effect size emerge between groups based on classroom size? Will differences in effect size emerge between groups based on teachers' previous experience and comfort level with technology?

Each classroom had a different number of students (e.g., one group had 11 students being taught simultaneously, and others had 19 students being taught simultaneously). Different teachers had very different levels of previous experience with the technology used in this study – one teacher had previously taught using the curriculum, and one had not.

The prior laboratory study demonstrated results with 1:1 instruction conducted by research assistants who were experts with the technology and curriculum being used. Therefore, it was important to take class size and teachers' prior experience and self-rated comfort level with the technology into consideration when replicating this study.

METHOD

Participants

A total of 58 kindergarten students participated in this study, 54 of whom are included in data analysis. Four children were not included in data analysis based on incomplete data sets due to excessive absences from activities. The children are divided by school: 22 from a private elementary school and 32 from a public elementary school. These groups were further subdivided into an experimental and control group within each school. Details of the groups are further outlined below.

Group One

Group one is comprised of a private kindergarten at an independent, K-8, private school in a suburb of Boston, MA. This sample has 22 children whom completed the robotics pre-post tests and are included in data analysis. Of these children, 64% are male and 36% are female with an average age of 5.65 years, $SD = .39$. This is the only kindergarten classroom located within this school and is taught by a male teacher with seven years of teaching experience and considerable comfort with technology. On a scale of 1 (none) to 5 (expert), he self-rated his computer experience as a 5, programming experience as a 3, and robotics experience as a 1. This teacher spent a year prior to this study teaching with the robotics technology and curriculum in his classroom.

For this study, this classroom was randomly divided into two groups, intervention and control, with a gender balance, based on the gender distribution in the classroom. The control group ($N = 11$) is 64% male, 36% female with an average age of 5.70, $SD = .34$. The intervention group ($N = 11$) is 64% male, 36% female with an average age of 5.65, SD = .42.

Group Two

Group Two is comprised of two kindergarten classrooms from an underperforming K-8 public school (NCLB Level 3) located in a suburb of Boston, MA. The makeup of this school for the 2010 – 2011 school year is 38.9% White, 36.3% Hispanic, 16.2% African American, 7.0% Asian American, and 1.7% multi-race. The school is comprised of 41.1% English-Language Learners and 64.4% of students are classified as low income (MA DOE, 2011).

Group two was divided into an intervention and control group by classroom. The intervention group was taught by a female teacher with six years of teaching experience. She self-rated her computer experience as a 4, robotics experience as a 2, and programming experience as a 2. This teacher had no prior experience with the technology or curriculum. She was provided training sessions before the start of her teaching.

This classroom had 19 children who participated in the educational program, 15 of whom are included in the data analysis. Due to movement in and out of the classrooms, 15 students completed both the pre-test and post-test for sequencing. Of the 15 participants included in data analysis, 60% are male and 40% are female. Average age of these student is 5.54 years, *SD* = .33.

The control group is comprised of 17 children who completed both the sequencing pre-test and post-test. These 17 children are 59% males and 41% females with an average age of 6.00 years, *SD* = .27.

Recruitment

Each of the teachers involved in this study volunteered to participate following notification of the opportunity via email to their respective principals. Emails were sent to schools throughout the Greater Boston Area. Consent forms were sent home to each kindergarten family from the school, allowing each family to decide whether or not to allow data to be collected on their child's work during the project. If permission for data collection was not granted, this did not prevent the child from participating in the curriculum unit. Consent forms were translated into Portuguese and Spanish for parents who needed these translations.

Procedure

Group One's teacher had previously taught with the TangibleK program during a pilot study the year prior. This was his second year using the hardware and software. Group Two's teacher was teaching with the program for the first time and enrolled in training sessions prior to the start of teaching the curriculum units. All classrooms were staffed with research assistants for technological support and data collection purposes only, not as curriculum teachers.

Children in Group One were divided into an intervention and a control group during the fall of kindergarten. Children from both groups were administered the sequencing assessment pre-test during the same week. Children from the intervention group then participated in twice-weekly curriculum lessons from the TangibleK program, taught by the kindergarten teacher, for approximately 60 to 90 minutes at a time while children from the control group participated in art activities. When the children were finished with the program both groups were administered the sequencing post-test assessment.

Children in Group Two were divided based on classrooms. The intervention group participated in the program first while the control group continued with their typical curriculum in the fall. Children from both classrooms were pre-tested before the intervention group began the program and post-tested after the intervention group completed the program. All of the children who participated as controls in both school settings had opportunities to participate in computer programming and robotics lessons after post-testing.

Sequencing Assessment

A picture sequencing task was chosen because of the similarities between programming a robot and telling a story (i.e., putting the beginning, middle, and end of a story together). Picture story sequencing assessments are common for assessing sequencing in early childhood (e.g. Linebarger & Piotrowski, 2009; Meadowcroft & Reeves, 1989; Brown & French, 1976; Brown, 1975). The sequencing assessment used in this study was derived from the picture sequencing cards created by Baron-Cohen and colleagues (Baron-Cohen, S., Leslie, A.M. & Frith, U., 1986). Baron-Cohen, et. al. created a battery of 15 picture stories. Each story contained four picture cards that fit one order to make a correct story. The stories are broken down into five different categories. The stories of each category were correlated. For the purposes of this study, one story from each category for the pre-test and one story from each category for the post- test was used to ensure a test of equal difficulty for both the pre-testing and post-testing tasks. This particular set of picture cards were chosen because of they were designed for use with pre-school and kindergarten children, and they can also be used to assess the concept of theory of mind in young children, a direction that was ultimately not to pursued in this study.

For each picture sequencing trial, the cards were presented according to the standardized procedure. The assessment was standardized using children in a similar age range to the participants in the current study. Baron-Cohen, et. al. (1986) created this procedure to correct for spontaneously placing cards in the correct location (by asking the child to tell the story made by the cards) and ensuring the child understands the pictures presented.

During pre-testing and post-testing, participants were presented with the first picture in the story sequence. The other three pictures were placed in a random order above the first card. All cards were placed on the table facing the participant. The participant was told “this is the first picture (pointing at first card) of the story. Look at the other pictures and see if you can make a story with them." If the participant did not respond right away, the researcher named all the objects in the first picture to make sure the participant understood the drawings. The researcher then asked the participant to continue with the next picture. After all cards were in place, the researcher asked the participant to "tell me about the story you made" and recorded the participant's response. A score of 2 was awarded for a correct sequence, a score of 1 was awarded for the correct beginning and ending card, and a score of 0 was used for an incorrect sequence. For both the pre-testing and post-testing a participant could earn a total of 10 points

RESULTS

A repeated measures 2x2x2 ANOVA was conducted with School Assignment (private/classroom one vs. public/classroom two) and Group Assignment (experimental vs. control) as the between-subjects factors and the Test Score (Pre-Test vs. Post-Test) as the within-subjects, repeated measure. As previously mentioned, significant results were found in the prior laboratory study using a t-test (Kazakoff & Bers, 2011). In this study, an ANOVA was used since multiple t-tests increase the chances of Type I error.

A significant interaction effect was found between Test Score and Group Assignment, $F(1,50) = 5.642$, $p < .02$, meaning there was a relationship between the change in Pre-Test and Post-Test scores and whether the participant was assigned to the experimental or control group. The interaction effect for Test Score and School Assignment was not significant, meaning there was not a significant interaction between the classroom the participant was enrolled in and their Pre-Test and Post-Test scores. However, based on class averages alone, a difference between groups was seen. Group One had a 16.8% change in Pre-Test to Post-Test score compared to Group Two, which only had a 2.7% increase. Results are summarized in Table 1.

Table 1

Intervention and Control Group Sequencing Pre-Test and Post-Test Scores

Classroom	Type	N	Average Pre-Test Score	Average Post-Test Score	Change	% Change
1A	Private Intervention	11	7.55	8.82	1.27	17%
1B	Private Control	11	7.82	6.91	(0.91)	-12%
2	Public Intervention	15	7.40	7.60	0.20	3%
3	Public Control	17	8.53	7.59	(0.94)	-11%

DISCUSSION

The significant ANOVA result between Pre-Test and Post-Test scores and Experimental/Control group indicates there is a connection in score based on the group to which the child was assigned, with the children who participated in the intervention groups improving their scores on the sequencing assessment compared to the control groups. This is consistent with the laboratory-based study and a promising replication of the prior results. Contrary to expectations, the results did not show a significant effect for specific classroom assignment. Teacher experience with robotics, computer programming, technology, or even the specific curriculum did not appear to have a significant effect on the outcome.

Based on the pre-test and post-test score averages, there is some indication the impact of the programming intervention on sequencing tasks may be more effective in smaller group instruction, since there did seem to be variation in the degree of score change between the smaller intervention group and larger intervention group, though this difference was not significant. However, this could also be based on the type of measurement used or the school environment (the small classroom was also within a private school while the larger classroom was part of a public school). In future studies additional measures of sequencing ability will be used.

Though the overall intervention versus control group effect does not seem to be impacted, the average change in scores may have also been impacted by teacher experience and comfort level with technology. The laboratory study was instructed by a research assistant who had helped created the curriculum and software and thus had the most directly-related computer experience and most confidence with the program. Group One was taught by a teacher who was working with the program for his second year, and Group Two's teacher was new to the program (she did, however, go through several hours of training before teaching the program).

The teacher of Group One also self-rated himself a five in computer experience and three in programming experience compared to the Group Two teacher who rated herself a four in computer experience and two in programming experience. While these teachers rated themselves similarly, the teacher for Group One had experience teaching with the program and the teacher for Group Two did not. A future direction of this study may be to follow-up with this teacher for her second year of teaching the program and see if this would yield similar results to the laboratory study and Group One in regards to the degree of score change.

The decrease in scores for both controls group is particularly interesting, especially since it is consistent phenomena for both groups. A potential hypothesis for this effect could be due to the natural fluctuation between pre-operational and concrete thinking of children in this age range (Feldman

& Benjamin, 2004), and perhaps children who participated in computer programming were able to transition more solidly into the concrete operational phase while the children who did not participate continue to struggle with sequencing concepts. Further study with more simultaneous classrooms and control groups should be conducted to see if the phenomenon persists.

CONCLUSION

Overall, this study demonstrated the positive impact a computer programming intervention in kindergarten may have on sequencing skills, consistent with the prior study. The classroom studies showed a significant increase in sequencing scores for the experimental groups versus the control groups.

Differences in teacher experiences with technology are important to consider with our current and expanding digital world. This study may indicate the need for teacher training and professional developmental programs that focus on engaging teachers in using technology in their classrooms. Furthermore, the results are consistent with previous studies that show greater impact on academic skills for children in smaller classrooms.

Though there is still much to learn about the impact of individual digital technologies on the development of young children, this work demonstrates that it is possible to teach young children to program a robot with developmentally appropriate tools, and, in the process, children may not only learn about technology and engineering, but also increased their sequencing abilities, a skill applicable to multiple domains in early childhood

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