Ready for Robotics:
Bringing Together the T and E of STEM in Early Childhood Teacher Education

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Prior work has shown that early childhood educators demonstrate a lack of knowledge and understanding about technology and engineering, and about developmentally appropriate pedagogical approaches to bring those disciplines into the classrooms. This paper reports a study in which 32 early childhood educators participated in an intensive three-day professional development workshop with the goals of: increasing teachers' knowledge about robotics, engineering and programming, and pedagogies for teaching them in the early childhood classroom. Results show a statistically significant increase in the level of knowledge in all the three areas of technology in general, pedagogy, and robotics content knowledge after participation in the institute. Additionally, results show significant increases in several aspects of technology self-efficacy and attitudes toward technology. Implications for designing effective technology focused professional development are discussed.

INTRODUCTION

There is a growing interest in the field of robotics as an educational tool. However, little interest is focused on the foundational schooling years.

We know, however, both from an economic and a developmental standpoint, that educational interventions that begin in early childhood are associated with lower costs and more durable effects than interventions that begin later on (e.g., Cunha & Heckman, 2006). Two National Research Council reports—*Eager to Learn* (2001) and *From Neurons to Neighborhoods* (2002) document the significance of early experiences for later school achievement. The National Science Board urged the Obama administration to make STEM education a priority in early childhood education, writing that, "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). Along with the goal to increase comfort levels, these reports reflect a belief that early experiences are critical. Research also shows that introducing STEM in early childhood might help to avoid stereotypes and other impediments to entering the innovation pipeline later on (Markert, 1996).

However, there are two major impediments for bringing technology and engineering into early childhood education. First, among early childhood educators there is a lack of knowledge and understanding about technology and engineering, and about developmentally appropriate pedagogical approaches to bring those disciplines into the classrooms (Bers, 2008). New professional development models and strategies are needed to prepare early childhood teachers for this task. Second, there is a need of new technologies with design affordances and interfaces specifically developed for young learners. Without these, the results of the investment on professional development will not scale, as it will be difficult for teachers to integrate the use of technology into their classrooms. The work presented in this paper is driven by all of these needs.

The paper reports a study in which 32 early childhood educators participated in an intensive three-day professional development workshop with the goals of increasing teachers' knowledge about robotics, engineering and programming, as well as pedagogies for teaching those content areas in the early childhood classroom. Participating teachers worked with KIWI (Kids Invent with Imagination) robotics construction kits, a robotic prototype specifically designed to address developmental needs in early childhood education. During the workshop, teachers spent three days learning how new robotics technologies can be used with young children and integrated with content areas that are fundamental to early childhood education. The institute's curriculum focused on two central themes in early childhood: *Sensing as Tools for Observation* and *How Things Move,* with a culminating project curriculum called *Dances from Around the Around*. Upon completion of the

institute, participating teachers designed their own robotics-based curricular unit to later implement in their classrooms. Pre and post assessments were conducted before and after the institute assessing teachers' sense of technology self-efficacy, attitudes towards teaching with technologies, and pedagogical and robotic content knowledge. Results from this experience are presented.

Robotics in Early Childhood Education: Bringing together the "T" and the "E"

We are surrounded by technology. From pens and pencils to cell phones and digital cameras, technology permeates our existence. Yet, in the early grades, children learn very little about this. For decades early childhood curriculum has focused on literacy and numeracy, with some attention paid to science, in particular to the natural world. While understanding the natural world is important, developing children's knowledge of the human-made world is also needed (Bers, 2008). This is the realm of technology and engineering, which focus on the development and application of tools, machines, materials, and processes to solve human problems. Just as it is important to begin science instruction in the early years by building on children's curiosity about the natural world, it is as important to begin engineering instruction and the development of technological literacy by building on children's natural inclination to design and build things, and to take things apart to see how they work (Resnick, 2007).

Early childhood education has not ignored this; it is common to see young children using recycled materials to build cities and bridges. However, what is unique to our human-made world today is the fusion of electronics with mechanical structures. We go to the bathroom to wash our hands, and the faucets "know" when to start dispensing water. The elevator "knows" when someone's little hands are in between the doors and they should not close. Our cell phones "know" how to take pictures, send emails, and behave as alarm clocks (Bers & Horn, 2010). We live in a world in which bits and atoms are increasingly integrated (Gershenfeld, 2000); however, we do not teach our young children about this. In the early schooling experiences, we teach children about polar bears and cacti, which are probably more remote from their everyday experience than smart faucets and cellular phones (Bers, 2008).

Recent work has addressed this challenge by studying how the field of robotics offers a type of educational technology that holds special potential for early childhood classrooms (Bers & Horn, 2010; Bers, 2008b; Kazakoff

& Bers, 2012). Robotics facilitates cognitive as well as motor and social skills development, which are all important for young children. Given the increasing mandate to make early childhood education more academically challenging, while honoring the importance of play in the developmental trajectory, robotics can provide a playful bridge to integrate academic content with meaningful projects. Furthermore, in early childhood content areas tend not to be isolated, but integrated more broadly into classroom curriculum that encompasses different content and skills; thus robotics can serve as integrator of curricular content (Bers, Ponte, Juelich, Viera, & Schenker, 2002). Young children can become engineers by playing with gears, levers, motors, sensors, and programming loops, as well as storytellers by creating their own meaningful projects that react in response to their environment (Bers, 2008a). Robotics can also be a gateway for children to learn about applied mathematical concepts, the scientific method of inquiry, and problem solving (Rogers & Portsmore, 2004). Moreover, robotic manipulatives invite children to participate in social interactions and negotiations while playing to learn and learning to play in a creative context (Resnick, 2003). However, in order for robotics to be successfully used in the classroom, teachers need to understand its potential benefits and the best pedagogical approaches to implement integrated curriculum. Thus, professional development is a key element. The next section will explore this.

Professional Development: Early Childhood Teachers as Innovators

Although developmentally appropriate robotic kits such as KIWI are needed, that is not enough. We need research to understand how they can be successfully used and integrated into the early childhood classroom. The study described in this paper seeks to investigate this in the context of professional development for teachers. Research shows that successful professional development must include both content knowledge and pedagogical knowledge (Shulman, 1986, 1987). Furthermore, in a nationally representative study of 1,027 mathematics and science teachers, Garet et al. (2001) identified three core features of professional development activities that have significant impact on teachers' knowledge and change in classroom practice: (a) focus on content knowledge; (b) opportunities for active learning; and (c) coherence with other content knowledge.

Building on Shulman's work (1986, 1987), Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPCK*)* framework studies the various elements of the art and science of teaching with

and about new technologies. Central to this framework is the understanding that the use of technology in the classroom depends greatly on three interacting factors: teachers' familiarity with the chosen technology, with the particular content knowledge, and with the pedagogical knowledge. The resulting technological pedagogical content knowledge (TPCK) emerges out of the interrelations of these three factors, and is situated within a particular classroom culture exposed to a particular curricular content using a particular technology. Effective professional development, thus, must take into account these factors. This study contextualizes the different elements of Mishra and Koehler's TCPK framework for early childhood educators by focusing on robotics as a domain that integrates technology and engineering:

- Content knowledge (CK): robotics as a subject matter, the engineering aspects of building an autonomous artifact that can move and can sense its environment; and the programming aspects that determine the sequence of its behaviors.
- Pedagogical knowledge (PK): knowledge about the processes and practices, strategies and methods of teaching engineering and technology content with developmentally appropriate pedagogies that take into account cognitive, social, emotional and other developmental aspects of learning in early childhood. For example, robotic competitions are a common pedagogical approach with children in the older grades (Sadler et al, 2000); however some argue that it is not good practice in early childhood, a period when children are learning to collaborate and cooperate (Bers, 2008).
- Technology knowledge (TK): understanding the affordances and constraints of robotics as an educational technology and the transferable skills and concepts. This is crucial for sustained technology integration in the classroom. Platforms change rapidly, but there are certain ways of thinking about and working with technology in the classroom that will not. For example, regardless of the specific robotic kit used, children need to know how to problem solve and debug.

At the intersection of CK, PK and TK emerges TPCK to describe the interactions of content knowledge, pedagogy and technology. Teachers must be able to adapt their teaching practices and how they use particular educational technologies to address specific content areas given the unique characteristics of their classrooms and students. This, in essence, is the ability to assess the goodness-of-fit among the three domains. Professional develop-

ment must equip teachers with knowledge about existing educational technologies to meet their pedagogical needs but also with a framework for understanding and examining the relationship between technology and content knowledge. This understanding will help them choose "the right tools for the right content with the right pedagogy" amongst an increasingly confusing technological landscape that is sometimes driven by commercial goals rather than educational ones.

The goal of the work reported in this paper seeks to determine if early childhood teachers participating in a professional development institute using the KIWI robotics kit make gains in TPCK. Specifically, our research questions were:

1. To what extent did participating teachers gain knowledge about robotics, engineering, programming, and pedagogies for teaching that content knowledge in the early childhood classroom?

2. To what extent have they increased their familiarity with, comfort with, and understanding of the use of robotics in early childhood?

After the institute, we expected to see (a) an increase in positive attitudes toward teaching technology and engineering, (b) a desire to spend more time on technology and engineering content, and (c) higher levels of teachers' sense of self-efficacy.

METHOD

Study Design

The study used a combination of qualitative and quantitative data collection. Participating teachers completed a series of pre and post questionnaires in order to measure changes in their knowledge, attitudes, and sense of self-efficacy after participating in the three-day professional development institute. Additionally, teachers' interviews were used to collect qualitative data during and after the institute. It is beyond the scope of this paper to present full analysis of these interviews. Here, excerpts are taken to illustrate quantitative findings only.

All surveys were conducted online and implemented before and after the workshop. Those who had not completed all pre-surveys prior to attending the institute were asked to fill them out on the first day of the institute (before any activities had started) using computers provided on site. At

the end of the third and final day of the institute, all the teachers were also asked to complete and submit post-surveys on site. A 5-point Likert scale was used for answering the questions in all three surveys (pre and post). For all questions, teachers could choose to: Strongly Disagree, Disagree, Neither Agree/Nor Disagree, Agree, or Strongly Agree with the statements in all of the surveys.

Teachers' Knowledge Survey

In order to measure teacher's knowledge in the different areas of TPCK (Technology, Pedagogies, and Content Knowledge), the DevTech Research Group designed a survey derived from the technical knowledge surveys and instruments currently used in the field (i.e. Schmidt et al., 2009; Sullivan & Moriarty, 2009). The 28 survey items used the Likert scale described above and contained questions in all three domains of Technology, Pedagogy, and Content.

Teachers' Sense of Technology Self-Efficacy Survey

To measure changes in teachers' sense of technology self-efficacy, a widely used and cited survey called the "Computer Technology Integration Survey (CTIS) was used (Wang, Ertmer, and Newby, 2004). The CTIS survey contains 21 items that assess different aspects of technology self-efficacy with regard to the integration of technology in their classrooms, using the Likert scale previously described.

Teachers' Attitudes Towards Teaching Technology Survey

Finally, to measure teachers' attitudes towards teaching technology and engineering, the widely used "Attitudes towards Computer Technology (ACT) instrument" was used (Kinzie, Delcourt, & Powers, 1994). This 17-item assessment targets teachers' level of comfort and confidence towards technology, with regard to more general usage of computer technologies.

Interviews

Semi-structured interviews were conducted with teachers throughout the institute and on the last day, a semi-structured group interview was conducted and recorded to get a sense of teachers' perceived efficacy of the institute. The interview was led by the head researcher with a set of guiding questions, but was flexible in order to change with what the teachers had to

say. Analyses of these interviews are beyond the scope of this paper; however, quotes from teachers are provided in the results section to help illustrate trends found in the survey data only.

Sample

A self-selected sample of early childhood educators (N=32) from across the United States participated in this study. Participants responded to online advertisement for a free three-day professional development institute and completed a screening application to ensure they met the criteria for participation (i.e. they were actively teaching in a Pre-K- 2nd grade classroom and could be present for the full duration of the institute. No previous technology expertise was required). Applicants who met the criteria were accepted on a first-come first-serve basis. Participants varied widely in their experience teaching ranging from 4 to 38 years of experience (mean=15.12, SD=8.2). The majority of teachers (73%) were attending with a colleague from their school or district and all teachers (100%) said that were planning to collaborate with a colleague on implementing their robotics curriculum upon returning to their school. Teachers represented 7 different states and several geographic regions of the US; however more than half (56%) were local to Massachusetts. Almost all participants were female, with only one male participant. Prior to the institute, the majority of teachers (58%) considered themselves average users of technology, while 39% considered themselves expert users and only 4% considered themselves novices. In terms of *teaching* with technology, only 39% of teachers considered themselves experts, while 30% considered themselves average and another 31% considered themselves novices.

Of the 32 participants in the study, data are presented for a final sample of N=25 teachers. Criteria for inclusion in the final data set was completion of all pre and post surveys on time.

The Robotics Institute

In order to develop the curriculum for the summer institute reported in this paper, the DevTech Research Group first conducted a pilot experience with 21 early childhood teachers participating in an intensive robotics institute followed up by classroom implementation. Teachers entered the summer institute with no previous knowledge about robotics, and left

with a ready-to-implement robotics curricular unit that they had designed and tested to bring back to their classrooms during the upcoming fall semester. Results from this pilot showed that the institute was successful in increasing TPCK for participating teachers. However, teachers also reported back that they decided to pre-build the robotics artifacts for their children to use because the Mindstorms LEGO® kit available at the time was not developmentally appropriate for young children. This needed change to make the project feasible because it interfered with the curricular goal of having students explore engineering concepts by building the artifacts themselves. Therefore, for the research study reported in this paper, it was decided to use the KIWI robotics kit, specifically designed to be developmentally appropriate, in order to address some of these challenges.

This pilot experience, informed the development of the institute described in this paper. The institute described here consisted of three days of robotics and programming (a total of 18 hours) focused professional development activities for 32 early childhood educators, for which these teachers had the opportunity to earn professional development points. All participants were new to the institute and had not been involved with the pilot. The overarching goal of the three days was to show teachers how new robotics technologies can be used with young children and integrated with content areas that are fundamental to early childhood education. A combination of lecture, large and small group discussions, and hands-on work with the KIWI robotics construction sets and CHERP programming software were used. A later section describes both of these. Teachers were also introduced to LEGO® WeDo™ robotics construction sets to serve as a comparison to KIWI in terms of the appropriateness of each to an early childhood setting. A pedagogical overview was given on the first day of the institute and pedagogical tools and strategies were modeled and demonstrated throughout all aspects of the hands-on work.

Each day of the institute was primarily spent with hands-on work completing curricular activities with the technology, both individually and in small groups. The institute's curriculum focused on two central themes in early childhood: *Sensing as tools for observation* (including human and animal sensory systems, technology that extends human senses, and engineering robots that can "see"), and *How Things Move* (locomotion of humans and other animals; exploring physics and engineering with rolling, sliding, and ramps; engineering transportation robots; comparing and contrasting human, animal, and robot parts and movement). Teachers also completed a culminating project curriculum called *Dances from Around the World,* which integrates foundational social studies, culture, and history subject

matter with designing and programming robots to perform a dance using advanced programming instructions. These modules address content and skills mandated by the state of Massachusetts. After experiencing these curricular units and gaining skills and pedagogical knowledge about using KIWI and LEGO® WeDo™ during the first day and a half of the institute, the teachers spent the last day and a half working on designing their own robotics curricular units to be implemented in their classrooms during the upcoming academic year. Additionally, teachers shared and learned ideas about the types of teaching tools and strategies, as well as assessment techniques that might be effective when implementing their curriculum with young children. During this time, teachers collaborated with other participants, tested out their activities, and received feedback on their curriculum and teaching tools. By the end of day 3, all teachers left with a plan for the robotics curriculum they wanted to implement.

The KIWI Technology

During the institute teachers utilized the KIWI (Kids Invent with Imagination) robotics prototype developed by the DevTech Research Group, in collaboration with Modkit with funding from the National Science Foundation. The KIWI construction set enables young children (5-7) to engage in robotics activities in a developmentally appropriate way. The KIWI set contains different elements including two motors, a sound sensor, a distance sensor, a light sensor, a light output, and a USB cable (see Figure 1). There are three different spots for the motors to attach to the robot body. Two are on the side of the robot, one on the top. The robot can be mobile or stationary. If the motors get attached to the sides and attached to wheels, the robot will be mobile. If one motor gets attached to the top spot, the robot will be stationary. KIWI includes three different types of sensors: a sound sensor (with the shape of an ear), light sensor (with the shape of an eye), and distance sensor (with the shape of an arrow). The sound sensor is used to differentiate the two concepts of "Loud" and "Quiet". Using the Sound Sensor, the robot can be programmed to do something when it is loud, and do something else when it gets quiet, or vice versa. The light sensor is used to differentiate the two concepts of "Dark" and "Light". The robot can be programmed to do some thing when it is light out, and do something else when it gets dark, or vice versa. Finally, the distance sensor is used to detect whether the robot is getting near or far from something. The robot can be programmed to do something when it gets near something, and do some-

thing else when it gets far from it. The light output is shaped with the form of a sun and is made of a different color plastic than the sensors, so children do not get confused between the concepts of inputs and outputs.

KIWI was developed to address the lack of developmentally appropriate tools for young children. Very few commercially available robotic kits have been explicitly designed for young children. For example, the Bee-Bot (http://www.terrapinlogo.com/bee-botmain.php) is a small plastic robot with a shape of a bee that has directional keys on its back that are used to enter up to 40 commands which send Bee-Bot forward, back, left, and right. However, although this product is reminiscent of the first Logo floor turtle developed by Seymour Papert in the 60's (Papert, 1980), children do not have opportunities to engage in the building of the robotic artifact and thus explore engineering ideas; neither can they explore programming concepts beyond sequencing.

Taking this into consideration, several research labs have developed robotic kits for STEM education. In some cases, these tools became the seeds for commercial products. However, none of these robotic kits have been explicitly designed to meet the developmental needs of young children and the classroom challenges of early childhood education. Although they could be adapted to be used in pilot work, they do require major technical expertise and lots of support in the classroom (Beals & Bers, 2006). Thus, the development of the KIWI technology, that involves hardware (the robot itself) and the software used to program KIWI, called CHERP (Creative Hybrid Environment for Computer Programming).

Figure 1. The KIWI Robot and CHERP Tangible-Graphical Programming Interface.

The CHERP Programming Language

Robotics involves making physical artifacts that come to "life" by programming their behaviors. KIWI utilizes a software called CHERP that allows young children to program it. Previous research has shown that children as young as four years old can understand the basic concepts of computer programming and can build and program simple robotics projects (Bers, 2008; Cejka, Rogers, & Portsmore, 2006). Furthermore, early studies with the text-based language Logo, have shown that computer programming, when introduced in a structured way, can help young children with variety of cognitive skills, including number sense, language skills, and visual memory (Clements, 1999). Nonetheless, computer programming is difficult for novices of any age due to syntax and conceptual hurdles (Kelleher & Pausch, 2005). In addition to these challenges faced by all novice programmers, we must also consider the developmental needs and capabilities of young children (Beals & Bers, 2006).

Based on these considerations, CHERP provides a system that allows children to *construct* physical computer programs by connecting interlocking wooden blocks (see Figure 1). CHERP's wooden blocks contain no embedded electronics or power supplies. Instead, children use CHERP's blocks to create the program for their robot and then take a picture of it using a standard webcam connected to a computer. The picture is converted into digital code using the TopCodes computer vision library and downloaded to LEGO®'s RCX robotic hardware through infrared (Bers & Horn, 2010).

CHERP is inspired by early ideas from tangible programming (Perlman, 1976) that were revived nearly two decades later (Suzuki & Kato, 1995). Since then, a variety of tangible languages for children have been created in a number of different research labs around the world (e.g., Wyeth, 2008). Instead of relying on pictures and words on a computer screen, tangible programming uses physical objects to represent aspects of computer programming. They exploit the physical properties of objects, such as size and shape, to express and enforce syntax. For example, the interlocking wooden blocks shown in Figure 1 describe the CHERP's language syntax (i.e. a sequential connection of blocks). In fact, with this language, while it is possible to make mistakes in program logic, it is impossible to produce a syntax error. The process of constructing programs is now situated in the classroom at large—on children's desks or on the floor— thus children's code can be open and visible and they can engage in discussing ideas for debugging and literally "sharing" the code.

RESULTS

Of the 32 teachers participating in the summer professional development institute, data was included in analysis for a final sample of N=25 teachers who completed and submitted all pre and post survey responses. In order to determine changes in teachers' knowledge and attitudes as a result of participation in the institute, pre and post comparisons using two-tailed T-tests were used. Prior to this, preliminary analyses were performed to ensure no violation of the assumptions of normality and linearity of all data sets. Results show statistically significant increases in the level of knowledge in all the three areas of technology, pedagogy, and content knowledge after participation in the institute. Additionally, results show significant increases in several aspects of technology self-efficacy and attitudes toward technology. Analysis of the teacher interviews are not presented in this paper; however, quotes from teachers are included to illustrate trends found in the quantitative data.

Technology, Pedagogy, and Content Knowledge

Questions from the 28-item TPCK survey were used to determine whether or not teachers made significant gains in their knowledge of technology, pedagogies for teaching with technology, and/or knowledge of robotic content. On average, participating teachers had significantly more knowledge in the three areas of Technology, Pedagogy, and Robotics Content after participating in the summer robotics institute. Teachers' average level of knowledge was significantly higher *after* participating in the summer robotics institute (M= 4.2, SD=0.4) compared to *before* the institute (M=2.1, SD = 0.6); $t(24)= 2.06$, $p<0.05$). For each of the 28 questions in the Teacher Knowledge survey, two tailed T-tests were used to compare teachers' pre and post responses. The average scores given to all of the 28 questions were significantly higher after participating in the institute (See Table 1 for complete list of questions). The areas in which the largest increases in knowledge were found were from the Technology section of the TPCK survey (KIWI/CHERP). However, there were also significant differences in teachers' pedagogical knowledge of *teaching* robotics and programming.

In interviews, the teachers often related their gains in knowledge to the amount of time devoted to each curricular activity and the hands-on nature of the institute. One teacher explained that:

> It was great to touch and manipulate things, explore, make mistakes, and take the time to do all these. As teachers, we are not always given the resources we need, including time, to prepare to engage our students in learning adventures such as robotics.

Several teachers also related their gains in knowledge to the collabora-
tive nature of the activities. For example, one teacher stated that, "I think I
learned most from talking with my group members". Interactions amongst
teachers were particularly rewarding since we had a heterogeneous group
with teachers coming from both private and public institutions, urban and
suburban locations and across 7 states in the US.

Table 1

Significant Increases I n Knowledge after Participation in the Institute

Knowledge Survey Items	Mean Pre	Mean Post	Mean Difference	t
Knowledge of what makes a device a robot.	3.0 (1.0)	4.6 (1.0)	1.6***	-7.9
Knowledge of the main components of a robot.	2.6 (1.0)	4.5 (1.0)	1.9***	-9.3
How a robot is given instructions.	2.8 (0.9)	4.6 (0.9)	1.8***	-10.7
Stages of the Engineering Design Process.	2.4 (1.4)	4.4 (1.4)	2.0***	-7.8
How to apply the Engineering Design Process in activities.	2.2 (1.2)	4.2 (1.2)	2.0***	-9.8
Knowledge of effective teaching approaches to guide students' thinking and learning in robotics.	2.6 (1.3)	4.2 (1.3)	1.6***	-6.4
How to teach the construction aspects of robotics.	2.2 (1.0)	4.2 (1.0)	2.0***	-9.6
How to teach the programming aspects of robotics.	2.4 (1.2)	4.3 (1.2)	1.9***	-9.6
How to teach robotics in a developmentally appropri-ate way	2.4 (0.9)	4.3 (0.9)	1.9***	-9.8
How to integrate robotics into other traditional content areas	2.5 (1.0)	4.5 (1.0)	2.0***	-8.2
How to use robotics to enhance students' problem solving skills.	3.5 (1.4)	4.5 (1.4)	1.0***	-4.3
How to use Engineering Design Process to teach robotics.	2.3 (1.2)	4.3 (1.2)	2.0***	-7.5
How to use robotics to enhance students' collaboration skills.	3.4 (1.4)	4.6 (1.4)	1.2***	-4.2

Table 1 Continued

How to plan student-centered robotics projects	2.9 (1.2)	4.5 (1.2)	1.6***	-7.7
How to implement student-centered robotics projects in the	2.9 (1.2)	4.2 (1.2)	1.3***	-5.4
How to assess students' learning in robotics.	2.6 (1.2)	4.0 (1.2)	1.4***	-6.3
How to assess students' learning when integrating robotics with other traditional content areas	2.7 (1.2)	4.0 (1.2)	1.3***	-5.3
Have used CHERP in the past.	1.4 (0.8)	1.6 (0.8)	0.2	-0.74
How to program a robot using CHERP	1.4 (1.0)	4.2 (1.0)	2.8***	-12.3
How to program with CHERP, using both the tangible and graphical versions.	1.3 (0.6)	4.4 (0.6)	3.1***	-17.9
Understanding of the different messages (including the error messages) given by CHERP.	1.2 (0.5)	4.1 (0.5)	2.9***	-13.8
How to access all rows of programming blocks (to use Repeats, Sensors, etc.) in the graphical version of CHERP.	1.2 (0.5)	4.2 (0.5)	3.0***	-14.6
Able to construct a sturdy KIWI robot.	1.2 (0.6)	4.3 (0.6)	3.1***	-12.6
Knowledge of the power source of KIWI is.	1.2 (0.5)	4.5 (0.5)	3.3***	-17.6
How to program KIWI using CHERP.	1.2 (0.5)	4.5 (0.5)	3.3***	-20.7
How the CHERP program gets transferred to the KIWI robot.	1.1 (0.4)	4.4 (0.4)	3.3***	-18.4
How to build a moving robot using KIWI and CHERP.	1.2 (0.6)	4.5 (0.6)	3.3***	-16.8
How to build a sensing robot using KIWI and CHERP.	1.0 (0.2)	3.9 (0.2)	2.9***	-13.8

Note. *** = $p < .001$. N=25 and *df*=24 for all analyses. Standard Deviations appear in parentheses below means

Technology Self-Efficacy

To measure changes in teachers' sense of technology self-efficacy, teachers' responses to the 21-item "Computer Technology Integration Survey" (CTIS) were examined. Results show that, although their level of technology self-efficacy has improved in general (increases in scores given to most of the survey questions were found), the level of improvement was only statistically significant on 5 of the questions.

Two tailed T-tests were used to assess the significance of teachers' increases on all 21 items from pre to post. The five areas that demonstrated significantly higher scores after the institute were: confidence in understanding computer capabilities well enough to maximize in the classroom ($t(24)$ = 2.06, p < .05), confidence in ability to use correct computer terminology when directing students' computer use ($t(24)$ = 2.06, p < .05), confidence in ability to motivate students to participate in technology-based projects ($t(24)$ = 2.06, p < .05), confidence in ability to mentor students in appropriate uses of technology (t(24) = 2.06, p < .03), and confidence that ability to address students' technology needs will continue to improve (t(24) = 2.06, p < .02).

Attitudes towards Teaching Technology

To measure teachers' attitudes towards teaching technology and engineering, pre and post comparisons were made using two-tailed T-tests for each of the 17 questions on the "Attitudes towards Computer Technology" (ACT) instrument. Increases were significant in five areas: teachers' attitudes regarding the necessity of using computers on a daily basis (t(24) = 2.06, p < .08), attitudes regarding using computers to communicate with others and to be effective at work (t(24) = 2.06, p < .07), attitudes regarding use of computers to create materials that can enhance job performance (t(24) = 2.06, p < .08), and finally, attitudes regarding the use of word processing software to be more productive (t(24) = 2.06, p < .08).

Relationships between Variables

In addition to looking at the changes in the level of knowledge, self-efficacy, and attitudes, relationships between these variables as well as relationships between these variables and teachers' background information were investigated using the Pearson-product-moment correlation coefficient. Results show a moderate positive correlation between teachers' personal experience with Technology and teachers' pre-test level of technology self-efficacy (r = 0.36; n = 25; p<0.005). Additionally, a moderate positive

correlation was detected between the teachers' experience teaching with technology and pre-test levels of technology self-efficacy (r = 0.37; n = 25; p<0.005). However, teachers who had less knowledge in different areas of TPCK before starting the institute gained more knowledge after completion of the workshop, compared to the ones who started their experience with more knowledge. A strong negative correlation was detected between the teachers' pre level of knowledge and the difference in the level of knowledge (r = -0.75; n = 25; p<0.05)

Teachers who started the institute with a lower level of self-efficacy, experienced more improvement in their level of self-efficacy after the institute, compared to the ones who began the workshop with a higher level of self-efficacy. A strong negative correlation was detected between the teachers' pre level of self-efficacy and the difference in the level of technology self-efficacy (r = -0.82; n = 25; p<0.005)

Finally, teachers who began the institute with more negative attitudes towards computer technologies, improved their attitudes more so than teachers who started with highly positive attitudes towards technology. A strong negative correlation was detected between the teachers' attitude levels before the workshop and the difference in their level of attitude from pre to post (r = -0.69; n = 25; p<0.05)

Discussion

This study contextualizes the different elements of Mishra and Koehler's TCPK framework for early childhood educators by focusing on robotics as a domain that integrates technology and engineering. The goal of the work reported here was to evaluate if the early childhood teachers participating in the professional development institute would gain TPCK. Results highlight the general efficacy of a three-day professional development institute in increasing teachers' technology, pedagogy, and robotic content knowledge as well as several aspects of teachers' technology self-efficacy and attitudes toward technology. Mean scores on all 28 items on the survey developed to assess teachers' Technology, Pedagogy, and Content knowledge improved statistically significantly. This may be due to the amount of time devoted to each of these areas over the course of the 3-day institute. It may also be due to the structure of workshop and the materials that were introduced to the teachers throughout the course of the institute. In their interviews and blogs, many teachers commented on the hands-on and collaborative nature of the institute helping them learn particular concepts.

In examining teachers' technology self-efficacy, the widely used and cited survey called "Computer Technology Integration Survey" (CTIS) was used. This survey contains 21 questions that assess different aspects of teachers' technology self-efficacy in regards to the integration of technology in their classrooms. Results from this survey show a general increase in self-efficacy after participating in the workshop. However, of the 21 questions in this survey, statistically significant increases were found for only five of the questions in the survey. This may be because teachers were asked to complete this survey directly after the workshop and prior to having a chance to actually integrate the new content knowledge they have acquired in their own classrooms.

Finally, in looking at teachers' attitudes towards teaching technology, results show that on approximately 76% of the items (13 out of 17), there was an increase in mean scores from before the institute to after the institute. However, increases were only statistically significant in five areas. This 17-question survey was designed to target teachers' level of comfort and confidence towards technology, meaning a more general usage of computer technologies, not robotics specifically. It was hoped that participating in the summer institute would result in a more positive attitude towards technology in general for all or some of the teachers. Our results indicate that while attitudes improved a little overall, there were specific areas in which this institute was able to change the way teachers feel about teaching with technology. Once again, it is important to note that teachers answered these questions directly after participation in the institute and before they have had the opportunity to actually teach technology in their own classrooms. It is possible that after actually implementing the curriculum in their classrooms, their responses to these 17 questions will change.

One of the most interesting findings was that institute was more beneficial for teachers who started the institute with *lower* levels of knowledge and self-efficacy, and more negative attitudes toward technologies than teachers who began with higher levels of each of these. This might be due to the fact that these levels were measured on a 5-point Likert scale. Therefore, teachers who started out lower on this scale had more room to grow than those who began the institute at a 4 or 5. This may also be because teachers were provided with many opportunities to play with materials, ask questions, and collaborate with peers. Teachers with less experience and confidence could learn from those who began the institute with a greater experience. Finally, in their interviews several teachers mentioned that the activities in the institute were fun and/or that they could see that robotics would be fun to bring into the classroom. Given that playfulness is an important aspect of early childhood curriculum, these remarks are positive in-

dicators. After the first day of the institute, one teacher stated that she had a "fun day" and she was now "excited to use [robotics] with [her] students and her children at home". Meanwhile, another teacher mentioned that they were having a fantastic time at the institute. By having fun using technology (perhaps for the first time), novice teachers may have changed some of their preconceived attitudes and conceptions about technology.

Additionally, there were some negative changes in the level of technology self-efficacy and attitude for some of the participants. This could be due to a new level of understanding in regards to the self-efficacy and attitude towards technology that teachers achieve after participating in a robotics institute. After completion of the workshop, teachers might have a better understanding of the challenges and the requirements of a successful integration of technology into their classrooms (especially after they know more about the technology, the content, and the necessary pedagogies), that they might answer the questions with lower scores when answering the technology self-efficacy and attitude surveys. Although this gets observed through negative numbers, it can be interpreted as a positive accomplishment of the robotics summer institute. Teachers understood how much they did not know before and how much they still need to learn.

Limitations and Future Research

The study presented in this paper looks only at short-term results assessed directly after teachers had participated in the three-day institute. These results cannot be generalized to assume that teachers maintain the new knowledge they have gained or retain the same attitudes towards teaching technology and levels of technology self-efficacy. In fact, it is very likely that depending on their experience implementing these technologies into their own classrooms that these scores will change. Longitudinal research that follows up with teachers throughout the school year are necessary to truly determine how effective this institute was. Our research study will explore this in the upcoming iterations and will also take into consideration teachers' individual classroom practices. Additionally, this study focuses solely on self-report from teachers. It does not look at data from the children in their classrooms. Without classroom data, it is difficult to determine how effective the pedagogies and strategies taught during the workshop are for teachers in real school settings. Once teachers begin to implement robotics into their classrooms, they may feel like they were strongly prepared in some areas but lacking in others. Again, our future research will focus on this.

In future iterations of the study, the instruments used for the measurement of teachers' knowledge, self-efficacy, and attitudes may be re-examined. The surveys used in the present study refer to technologies in general, rather than technologies specifically related to robotics and engineering. Although questions specific to robotics were addressed in our knowledge survey, future research may wish to expand these specifically tailored robotics questions with regard to attitudes and self-efficacy as well. Finally, it is important to note that due to conducting the interviews prior to distributing the post-surveys, it is possible that teachers may have been biased by the discussion when completing these surveys. However, because the survey targeted different questions than the interview, it is unlikely that this occurred.

The study described in this paper is only the beginning of a three-year research grant. In the next phase of the NSF funded *Ready for Robotics* project, the participating teachers described in this paper will implement the robotics-based curricular units that they developed during the institute in their own classrooms. Research assistants will keep in close contact with these teachers throughout the year and a combination of qualitative and quantitative data will be collected and analyzed from the teachers and from the children in their classrooms. After all the teachers have completed their work in the classrooms, there will be an open house for teachers to share their robotics units, student's experience, and implementation strategies.

Conclusion

Despite the growing interest in the field of robotics as an educational tool, little effort is focused on the foundational schooling years. For decades, early childhood curricula have focused primarily on literacy and math, especially with the educational reforms of No Child Left Behind (Zigler & Bishop-Josef, 2006). Only recently has educational reform across organizations begun to address technology learning standards and best practices for integrating technology into early childhood education (International Society for Technology in Education (ISTE), 2007; National Association for the Education of Young Children (NAEYC) & Fred Rogers Center, 2012; United States Department of Education (U.S. DOE), 2010). Considering this, it is not surprising that early childhood educators generally demonstrate a lack of knowledge and understanding about technology and engineering, and about developmentally appropriate pedagogical approaches to bring those disciplines into the classrooms (Bers, 2008). New professional development models and strategies, such as the institute described in this

paper, are needed to prepare early childhood teachers for the task of implementing best practices for integrating technology into their classrooms.

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