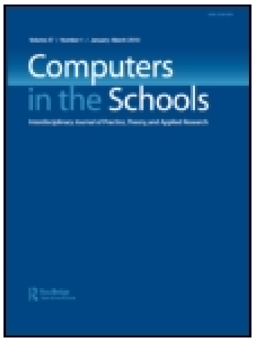

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Kenneth T. H. Lee, Amanda Sullivan & Marina U. Bers

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Collaboration by Design: Using Robotics to Foster Social Interaction in Kindergarten

KENNETH T. H. LEE
University of California, Irvine, Irvine, California, USA
AMANDA SULLIVAN and MARINA U. BERS
Tufts University, Medford, Massachusetts, USA

Research shows the importance of social interaction between peers in child development. Although technology can foster peer interactions, teachers often struggle with teaching with technology. This study examined a sample of (n = 19) children participating in a kindergarten robotics summer workshop to determine the effect of teaching using a structured versus unstructured robotics curriculum on fostering peer-to-peer collaborative interactions. Results indicated that using a structured curriculum was associated with significantly less collaboration than an unstructured curriculum. Findings from this study indicated that to foster peer collaboration, a less structured learn-by-doing approach might be useful for teachers when integrating technology.

KEYWORDS *robotics, social interaction, collaboration, constructionism*

Early childhood is a critical developmental period for learning necessary social skills through peer-to-peer interactions that help develop social knowledge of the peer group and differentiate friends from playmates (Hartup, 1983; Howes, 1987). Deficiencies in peer relations are often associated with behavioral problems and have long-term developmental implications, such as loneliness and social dissatisfaction (Parker & Asher, 1987). Incorporating new technologies in early childhood curricular activities can offer a unique way to foster positive peer-to-peer interactions and social development by encouraging teamwork and collaboration. As we transform into an increasingly digital society, new technological tools now play a significant role

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Address correspondence to Kenneth T. H. Lee, School of Education, University of California, Irvine, 3200 Education, Irvine, CA 92697-5500, USA. E-mail: ktlee2@uci.edu

in the social development of young children (Bers 2010; Clements, 1999). While much research highlights the negative impact of technology in education (Cordes & Miller, 2000), our work focuses on how the ever-growing field of digital technologies can positively impact the development of children.

For young children who are in a developmental process of learning how to work with others, the design features of certain types of technology can promote social and pro-social development (Bers, 2012). Early work with technology and young children has shown that computers can serve as catalysts for social interaction in early childhood education classrooms (Clements, 1999), and that children have twice as many social interactions in front of the computer than when they are doing other activities (Svensson, 2000). More recently, research has continued to support this claim, finding that children speak twice as many words per minute when playing together at a computer than they do during non-technology related activities (New & Cochran, 2007). Children are also more likely to ask their peers for help when using the computer, even when an adult is present, thereby increasing the amount of peer collaboration in the classroom (Wartella & Jennings, 2000).

Furthermore, research suggests that teaching children about the human-made world, such as the realm of engineering, technology, and computers, is as much needed as teaching them about the natural world, math, and literacy (Bers & Horn, 2010; Bers, Ponte, Juelich, Viera, & Schenker, 2002). One of the most fascinating aspects of the human-made world today may be the fusion of electronics and software with mechanical structures (Bers, 2008), an integration that is captured by the discipline of robotics (Craig, 2005). Previous research has shown that robotics activities can promote social and pro-social development among children in early childhood (Bers, 2012).

Although there is significant research regarding technology in education, relatively little is focused on the foundational early childhood years (Bers, 2008; Bers & Horn, 2010; Martin, Mikhak, Resnick, Silverman, & Berg, 2000; Rogers & Portsmore, 2004; Rogers, Wendell, & Foster, 2010; Rusk, Resnick, Berg, & Pezalla-Granlund, 2008). However, technology is such an integral part of a child's daily life that many educators and researchers claim that learning environments without technology are out of touch with a child's reality (Berson & Berson, 2010).

More importantly, there is a debate regarding the pedagogy or level of structure educators should adopt when incorporating technology in curricular activities. When deciding how to integrate technology into the classroom, Papert's (1980) constructionist framework stated that children learn better when engaging in building their own meaningful projects without top-down instruction. Papert's (1980) constructionism is rooted in Piaget's (1952) constructivism and belief in the learn-by-doing approach to education. While Piaget's (1952) theory was developed to explain how knowledge is constructed in an individual's mind, Papert (1980) expanded this to focus on the ways that internal constructions are supported by constructions in the world, for example, through the use of computers and robotics. A constructionist teaching approach allows children the freedom to explore their own interests through technologies (Bers, 2008). This type of hands-on, interactive approach to learning is not new (Dewey, 1916; Vygotsky, 1978) and is, in fact, one of the principles of child development and learning that inform developmentally appropriate practice.

In contrast to the constructionist teaching approach (in which the role of the teacher is to provide an environment where children explore personally meaningful interests and gain knowledge through designing their own technology-based projects), in an instructionist approach, it is the teacher's role to transfer or provide information to the students (Bers, Ponte, Juelich, Viera, & Schenker, 2002). In an instructionist classroom, the teacher designs learning tasks and children have less freedom to explore their own ideas. An instructionist curriculum is typically much more structured than the constructionist one. However, it is uncertain that when introducing new technologies in early childhood curricular activities to encourage peer-to-peer interactions and social development, which of the two teaching pedagogies or levels of structure educators should adopt.

As such, technology can foster peer interactions; and in previous studies we have created, implemented, and evaluated developmentally appropriate robotics curricula for the kindergarten classroom (Bers, 2010). How to best use this curriculum and subsequent other curricular activities using technology to foster social interaction and collaboration is still in question. This study examined how the pedagogy or level of structure plays a key role in either promoting or hindering peer-to-peer social interactions when incorporating technology into early childhood education classrooms.

HYPOTHESIS

This study explores the relationship between the kind of structure provided by a robotics curriculum in a kindergarten setting and the amount of peer collaboration that is then observed. It is hypothesized that by designing a constructionist or open-ended learning environment that incorporates technology and by providing children with the time to explore tools and ideas on their own, there would be an observable increase in the amount of peer collaboration.

THE ROBOTICS PROGRAM

While there are many different types of technology that can be used in early childhood, this study looks specifically at a robotics and programming curriculum for kindergarten students. Previous research has shown that children as young as 4 years of age can build and program simple robotics projects (Bers, 2012; Bers & Horn, 2010, Bers et al., 2002; Cejka, Rogers, & Portsmore, 2006). Additionally, the use of robotic manipulatives are particularly appropriate for kindergarten students because they allow children to develop fine motor skills and hand-eye coordination while also practicing social skills like collaboration and teamwork (Bers, 2008).

Data were collected from two kindergarten classrooms participating in a robotics summer program run by the DevTech Research Group at a northeastern U.S. university. Both classrooms were introduced to the Creative Hybrid Environment for Robotic Programming (CHERP). CHERP is a hybrid tangible/graphical computer language designed to provide young children with an engaging introduction to computer programming. It allows users to create both physical and graphical programs to control their robots (Bers & Horn, 2010). Children can create physical (tangible) programs using interlocking wooden blocks, or onscreen (graphical) programs using the same icons that represent actions for their robot to perform. With CHERP there is no such thing as a syntax error because the shape of the interlocking blocks and icons creates a physical syntax that prevents the creation of invalid programs. CHERP programs are compiled quickly with the press of a button (Bers & Horn, 2010; Horn, Crouser, & Bers, 2012).

Along with CHERP, children used specialized LEGO® bricks (manufactured by the LEGO Group) from the LEGO MINDSTORMS™kit to construct their robots. In particular, children used a LEGO Robotic Command eXplorers (RCX) brick that served as an embedded microcomputer (or "robot brain") and contained special ports where robotic parts could be connected to the internal micro-computer via wires with LEGO-compatible connectors (Bers, 2010). The RCX also has an infrared (IR) receiving port that must face the IR tower connected to the computer in order to receive a program. Additional robotic parts (motors, sensors, and wires) as well as standard LEGO bricks and crafts materials were also used to build the robots. After completing a 17.5-hour curriculum program in which children were introduced to a variety of building and programming concepts, they were invited to work on a robotics final project to show to their parents.

METHOD

Participants

The sample included 19 children (mean age = 5.68 years, 5 female and 14 male) from the greater Boston area participating in a 5-day robotics summer workshop conducted by the DevTech Research Group in the Department of Child Development at a university. Rising and recently graduated kindergarten children were allowed to participate in the study. The 19 children were randomly divided into the treatment ($n = 9$) and control ($n = 10$) groups.

Each child was randomly placed in one of two groups: (a) In the first classroom, children were part of an instructionist environment in which they learned how to program their robot by participating in pre-designed teacher-guided challenges (labeled the *structured curriculum group*); or (b) in the second classroom, a constructionist approach was followed. Children did not have structured experiences, and instead were given free time to explore interesting ideas and concepts on their own (labeled the *unstructured curriculum group*).

Procedure

Participants in both groups were shown the basics of the CHERP interface, how to program using tangible programming blocks, and how to build a sturdy robot. From days 1–3, both groups were taught a specific aspect of programming, such as how to make a robot move, how to use a repeat parameter, and how to use a touch sensor. After being taught a concept, the structured curriculum group was asked to solve a specific challenge regarding the concept to which they had just been introduced. For example, after being introduced to the notion of sequencing, children were presented with the challenge of programming their robots to dance the hokey-pokey (a dance that requires a specific sequence of actions). The unstructured curriculum group was not presented with any of these challenges. After being introduced to a new concept, they were given free time to explore on their own. Both groups had three trained instructors (one male and two female for the structured curriculum; two male and one female for the unstructured curriculum). On the latter part of day 3, both groups were introduced to their final projects: creating a robotic animal that could live in a robotic zoo. Children were allowed to work in pairs, groups, or alone for the final project. Days 4 and 5 were allocated for work on the zoo and the robotic animals.

Twice a day, children were each given a *collaboration web*, a sheet of paper with a picture of the child in the middle. The child's picture is surrounded by a circle composed of pictures of everyone else in the class. Children used these webs to draw arrows in two ways: (a) arrow(s) from their own picture to the pictures of children that they helped during the given time period or, (b) an arrow from the picture of classmates who helped them to their own picture, indicating that students provided them with help during the given time period. The first collaboration web session took place 1 hour and 50 minutes after the program started. The second session took place an hour after the first instance. During the second instance, children were instructed to draw arrows and lines to indicate interactions since the last time that they filled out their webs. Children were asked to fill out their webs alone and in secret. They were also allowed to abstain from filling out their webs if they did not wish to at the time of data collection. These interactions were triangulated with video recordings taken throughout the camp and spurious interactions were not used in the analysis.

Measurement

For the duration of the program, the collaboration web was given to all 19 children twice a day for 5 days, totaling 190 data points. Out of the 190 data points collected during the program, 176 were included in this study. Some children fell ill and were absent, while some children refused to fill out their webs at the correct time intervals. To measure the amount of social interaction, the arrows drawn on each web were counted. Children were instructed to draw a maximum of two lines between their photo and the photo of each student in the class. Thus, children in the structured curriculum group could draw a maximum of 18 lines per web, and children in the unstructured curriculum group could draw a maximum of 20 lines per web. Children were not given a minimum number of lines to draw. Each interaction in every web was validated with video that monitored the groups and all imaginary or false interactions were not taken into account for this study.

A total of six video cameras (three per group) recorded the entirety of the camp at different angles. The number of participant self-reported interactions was triangulated with the number of interactions observed across the three videos taken per group. Any interactions that were self-reported but not observed in the video were taken out of the analysis.

RESULTS

General Trends

The unstructured curriculum group had a higher average number of interactions for all but two data collection points over the duration of the study. For both groups, the last data collection point reflected the lowest mean number of interactions (unstructured group, $M = 1.22$; structured group, $M = 1.00$), possibly due to the fact that the students' projects were nearly complete by this point.

As such, we examined the average number of interactions per day for both the structured and unstructured group to see if there were differences between the two groups. The unstructured group reflected higher mean numbers of interactions (see Table 1).

TABLE 1 Descriptive Statistics of Interactions Between Groups

			95% Confidence Interval	
	Observation	*M (SD)*	Lower Limit	Upper Limit
Structured	99	1.86 (1.51)	1.56	2.16
Unstructured	77	2.57 (2.75)	1.95	3.20
Combined	176	2.17 (2.17)	1.85	2.49

Significant Relationships

An independent sample t test was conducted to compare mean collaboration scores between the structured and unstructured curriculum groups. Results from the t test indicated that the unstructured curriculum group ($M = 2.57$, $SD = 2.75$) had a statistically significant higher mean number of collaborative interactions than the structured group ($M = 1.86$, $SD = 1.51$); $t(174) = 2.19$, $p = 0.03$, $d = 0.32$. These results suggest that an open-ended class had more social interaction and collaboration between their students than a structured class. Further, Cohen's effect size value ($d = 0.32$) suggested a small to medium effect size.

DISCUSSION

Overview

Results from this study show a significant difference in the amount of collaborative interactions reported by children in the unstructured versus structured curriculum group. Children who participated in the open-ended, constructionist (unstructured) robotics class engaged in a significantly higher number of collaborations than children who followed a standard curriculum with structured activities.

This may be due to several factors. Children in the unstructured group had more time at their disposal because they were not trying to complete specific activities, tasks, or challenges each day. Additionally, the lack of structured guidance they received from teachers in the unstructured class may have pushed these children to get help from their peers instead. These findings may have significance for teachers and curriculum developers who hope to foster a collaborative and social environment around new technologies in early childhood.

Significance of Findings

Research shows the importance of developing social competence in young children, and new technologies, like robotics, offer unique ways of fostering this. However, teachers often experience difficulties when attempting to teach with new technologies in the classroom. This could be due to lack of experience and confidence regarding teaching with tools they may just be mastering themselves. Whatever the reason, many teachers who generally follow a less-structured constructivist teaching philosophy in other early childhood domains often use a structured and instructionist method of teaching when it comes to technology. However, the effect of this pedagogical choice on social interaction among children has not been thoroughly explored in previous research on technology in early education.

Results from this pilot study support the hypothesis that, when giving children the opportunity to play and learn with technology in a constructionist learning environment, children will engage in more positive social interactions than when given structured challenges in a similar learning environment. This may be due to the possibility that structured challenges may provide a small, albeit significant incentive for a child—being the first in his or her group to complete the challenge presented in front of them. As such, having challenges might turn learning into a form of competition and thus motivate a child to work independently rather than collaboratively. Or, the difficulty of the structured challenges might have left less time for social interaction among peers (i.e., children might feel they do not have time to talk or help one another if they are going to complete the challenges on time).

Without any structured challenges, the competitive environment and time constraints of completing a challenge is nonexistent. As such, children in the unstructured curriculum group had more free time to explore and could readily share what they learned or figured out with their peers—leading to a greater amount of social interaction. It is important to note that both groups ended up with a similar quality of final robotic projects, thus the type of curriculum did not have an impact on the robotics concepts and skills learned.

Limitations and Future Research

This study was limited by the small sample of 19 children and 176 data points. A small sample size was necessary to avoid conducting this research in a laboratory setting. We wanted to examine this question in a more natural educational setting, such as a summer camp, in order to have a more classroom-like setting rather than a laboratory, which required a certain number of staff and technology. To include more children in the study would have overburdened the available staff, who were responsible for overseeing the well-being of the children, educating them, and providing technology support. Furthermore, we were limited by the number of LEGO RCX bricks and components. We wanted to ensure that each child had his or her own LEGO RCX brick and components should he or she choose to work alone. Had we increased the number of children, we would have forced children into collaborating and working together, which would have skewed and biased the results of this study.

These points also represent cross-sectional data from single time points over the course of only 5 days. Without longitudinal data, we cannot assess the long-term effects of having a structured curriculum on social interaction (or lack thereof).

Additionally, this study only looked at one specific type of social interaction: collaboration. This study did not examine whether children in the two groups differed in the amount of general conversation, fighting, joking, or playing experienced by the children. In future studies, different types of social interaction, both positive and negative, should be measured in order to make a statement about the overall benefit of a constructionist approach. Furthermore, the temperament and behavioral characteristics of participating children were not assessed before enrolling in the program. The amount of observed social interaction could have been affected by the placement of particularly introverted or extroverted children in either the control or experimental group.

It is important to note that this study did not look at whether children participating in the unstructured or structured curriculum group had an individual better understanding of the robotics and programming concepts taught, as the primary focus of this study was only on social interactions. However, it did look at the quality of the final projects produced by each group. Further research should examine curriculum design and an individual's concept mastery with regard to robotics and programming. It is possible that, while the structured group had less instances of collaboration, the structured challenges they undertook may have induced a better understanding of the concepts. If this is the case, teachers might consider designing a curriculum with a combination of unstructured and structured activities.

Furthermore, due to the small sample size and the nature of the pilot study, we did not look into potential gender effects within the different groups. Although we had a similar split of males and females between the groups, examining gender splits was beyond the scope of this pilot study. Future research with a larger sample should examine how gender of the children may affect the amount of peer collaboration.

Finally, this study focused on robotics and programming among kindergarten students in a summer workshop setting. The camp setting may yield different types of social interaction from a traditional classroom setting even though formal classes were taught. Future research must be done if we wish to generalize these findings to other types of technology and early childhood settings.

CONCLUSION

The struggle with how to best integrate technology into the classroom is an ongoing one. While many teachers are followers of Piaget's (1952) constructivist learn-by-doing philosophy of education, when it comes to technology many seem to do just the opposite. The present pilot study indicates that the pedagogical approach to technology curriculum design can have significant impact on the social atmosphere of the classroom. Kindergarten is a pivotal time for developing skills in collaboration and communication, and teachers must take this into consideration when developing curriculum in all domains, including using new technologies.

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