Innovative Session: Early Childhood Robotics for Learning

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Abstract: Robotics is a powerful learning manipulative for young children (four through seven years) as it enables the early introduction of engineering and programming. This session begins with a theoretical introduction to the robotic technology of programmable LEGO® bricks and its relationship to developmentally appropriate practice. This will be followed by an interactive poster and demonstration session where participants can learn about and discuss different research projects using robotics in early childhood education, including: fostering interactions between parents and children; promoting problem-solving skills; engaging teachers with different teaching styles; innovative partnerships between pre-service teachers, in-service teachers, and engineers; innovative curriculum projects using this technology; and the use of robotics with special needs students. A table with LEGO bricks and computers with ROBOLAB™ software will be available so participants can explore the materials in a hands-on workshop environment. After the presentations, the session organizer will lead an open discussion.

Objectives of the Session

This session aims to introduce a research program that uses an educational technology that has a broad range of applications for early childhood in classrooms as well as in after-school settings and programs. The technology, programmable robotic LEGO bricks, is comprised of two parts: (1) physical robotic LEGO pieces, and (2) ROBOLAB programming software. The robotics pieces include traditional LEGO pieces, a microcomputer (called an RCX), motors, lamps, light sensors, touch sensors, wires, axles, and gears. ROBOLAB is a drag-and-drop graphical interface that has several levels of difficulty, so the user can tailor the functions that are available to their personal skills and developmental stage (Resnick, et al, 1996; Portsmore, 1999). Research methodologies used with this technology and research findings about this technology will be presented via the posters, and the open-ended discussion that concludes the session. The open-ended discussion will include implications for classroom practice, pre-service and in-service teacher education, home-school connections, curriculum development, integration of new technologies in the classroom, and new methods of data collection.

Session Format

For this interactive session, a set of posters highlighting research projects using robotics in early childhood will be provided along with demonstrations of the technology and videos of the technology being used. To open the session, however, the session organizer will give a short introduction to the technology and area of research (as summarized below), then there will be time for people to circulate the room—viewing the six posters (as described below) and asking questions—followed by an open discussion moderated by the session organizer. The LEGO brick materials and the ROBOLAB programming software will be available on a table so that participants in the session will have an opportunity to explore and gain a better understanding of the technology used in all of these research projects. Resources for additional learning will be provided at the end of the session.

Introduction: Early childhood and robotics

The use of technology as an educational tool is becoming widespread. The use of traditional manipulatives as a teaching aid is evident at the youngest ages—most early childhood settings have building bricks, Pattern Blocks, Cuisenaire Rods, etc. in order to allow students to build, design, experiment, and be creative (Brosterman, 1997). "Digital manipulatives" are now supplementing traditional hands-on materials, but they also afford students the opportunity to explore ideas and concepts beyond what traditional manipulatives can provide (Resnick, 1998).

The use of robotic manipulatives can serve as an ideal hands-on tool for children to learn about science, technology, engineering, and math (STEM) concepts. Children can explore traditionally abstract concepts such as gears, levers, joints, motors, and sensors in a concrete manner. While using robotic materials, children can learn STEM concepts—which are traditionally taught through boring and uninspired means—in a fun and creative way by engaging in their own design projects. This type of work with the robotic LEGO bricks is done in the sprit of "constructionism," which conceives the computer as a material to build and design with (Papert, 1980). Bers identified four pillars of educational experiences designed within a constructionist framework: (1) the potential of technological environments to help learners learn by doing, by actively inquiring, and by playing, (2) the importance of objects for supporting the development of concrete ways of thinking and learning about abstract phenomena, (3) the need for powerful ideas that span across different areas of the curriculum, and (4) the premium of self-reflection which engages learners in meta-cognition (Bers, Ponte, Juelich, Vera, & Schenker, 2002). These four pillars are consistent with developmentally-appropriate practice in early childhood settings (Bredekamp, 1997). The introduction to the session will present this theoretical work and implications for classroom practice, teacher education, home-school connection, curriculum development, integration of new technologies in the classroom, and research methods.

Poster 1: Fostering a Home-School Connection Through Robotics

New technologies are slowly making it into the early childhood classroom; however, many families expose their children to these technologies before they encounter them in the formal school setting. Thus many parents serve as the first teachers of technological literacy to their children. Or, as is more frequent, parents and children learn together new computational skills. What are the complexities hidden behind this learning process in which both adults and children are learning at the same time?

In response to these questions, Project Inter-Actions was designed (Bers, New, & Boudreau 2004). The study was developed to examine: (a) the interactions between children and parents as they both learn a new technology and as they work together to create personally meaningful projects; (b) the interactions between an abstract technology, such as a computer program, and a concrete technology, such as LEGO bricks; (c) the interactions between the technological ability of young children and the developmental appropriateness of technology for young children; and (d) the interactions between technology, art, and culture. This, study, called "Project Inter-Actions" was also developed with three major educational philosophies and concepts in mind: (a) the philosophy of constructionsim (Papert, 1993), (b) the concept of the zone of proximal development (Vygostky, 1978), and (c) the concept of peer learning environments (Blumenfeld, Marx, Soloway, & Krajcik, 1996).

For this study, 17 parent-child dyads and 20 first and second grade children were taught, during five weekend sessions, to use robotic programmable LEGO bricks to create their own meaningful final projects involving both programming and building components. The programmable LEGO kits are especially ideal as support for constructionism because students can explore abstract thoughts, ideas, and designs with concrete materials. Based on the four pillars of constructionism (Bers, et al., 2002), Project Inter-Actions workshops were designed to allow participants to learn with hands-on, fun activities with concrete materials, to explore powerful ideas, and to allow participants opportunities for self-reflection upon their projects.

In order to analyze Project Inter-Actions, four main data sources were used: (1) videotapes of the workshops, (2) "memos" that were written by every instructor at the end of each session, (3) photographs and descriptions of the final projects written by the participants and posted on the project website, and (4) pre- and post-questionnaires that were completed by all participants (and the parents of participants in the children-only sessions). Using these data sources, final projects were evaluated by the teachers/researchers by developing a scoring system which evaluated building and programming skills displayed by the projects.

A significant difference was found between building and programming aspects of final projects between the children-only projects and the parent-child projects (Beals & Bers, in press). This suggests that Vygotzky's zone of proximal development played an important role, but it is argued that the children in the parent-child groups did not learn as much as the children in the children-only groups, as the parents were too involved in their own learning and did not tailor their instruction to their children at a level appropriate for the children to understand. The findings from this study will shed light over different ways in which parents and children can spend time together learning something new—learning about a new technology is part of a larger picture of collaborative family learning, Children's fascination with new technologies provide a unique opportunity to engage families in learning together. However, just as teachers go through years of school to learn how to teach, the more opportunities parents have to learn with their children, the better their collaboration will become.

Poster 2: Exploring the impact of an engineering design curriculum on first grade students' problem solving strategies

This presentation describes a newly developed research project that focuses on exploring how engineering design activities impact students' problem-solving abilities. The presentation will identify the need for engineering education in early elementary education and explore the toolset that Tufts University's Center for Engineering Educational Outreach (CEEO) has selected for bringing engineering activities to young children. The methods of data collection that have been piloted in the research project will be described, preliminary conclusions will be presented, and issues and difficulties will be discussed.

While it is clear that successfully completing engineering projects requires problem-solving skills, it is not obvious whether students develop those problem-solving skills through their participation in open-ended design challenges. This presentation reports on a pilot study conducted with five first-grade classrooms in a suburban Boston school district (approximately 40 students) to implement 12 weeks of a curriculum entitled *Engineering by Design*. *Engineering by Design* is a sequence of activities that introduces mechanical concepts like structures, gears, and pulleys as well as engineering design ideas, such as constraints, testing, and redesign, to young children through open ended LEGO-based challenges. Projects range from constructing a chair for a stuffed animal to building a motorized snowplow. The goal of the activities is to increase students' exposure to engineering concepts and integrate key math and science concepts. In addition, *Engineering by Design* seeks to enhance their competence and confidence in problem solving. However, to date there are no developed assessment methods that aim to evaluate if the curriculum impacts students' problem solving.

Two of the classrooms serve as intervention classrooms by participating in *Engineering by Design* for the first few weeks of school while the remaining classrooms serve as the control (and will complete the activities later in the year). The pre- and post-testing is conducted during one-on-one interviews during which the student is asked to perform an engineering problem solving task (rescue a toy from an enclosure, retrieve keys from a box). These interviews are video-taped and coded for strategies used, number of attempts, response to success or failure, and persistence. In addition, the interactions in the intervention classroom are also video-taped and students' classroom work (journals, creations) is collected. Parents also complete a survey on their child's interests, experiences, and choices in play. Finally, teachers assess each student's competence with respect to grade level for major subject areas (reading, mathematics). Results from these assessments (which are only in their pilot stage) will be presented as well as the issues of reliability and validity that have arisen.

Poster 3: Simple Machines, Complex Style—Teaching Methodology in a ROBOLAB Environment

Even though ROBOLAB technology is being integrated into educational settings, teachers have received little training on how to effectively teach with this technology. The objective of this research project was to determine the instructional benefits and challenges associated with the interaction between teaching style and an early-childhood robotics curriculum. A group of first- and second-grade children participated in one of two week-long ROBOLAB workshops. The curriculum used in these workshop introduced children to the building and programming components of the LEGO robotic and ROBOLAB technologies and the concept of simple machines. One session of the workshop was taught with an emphasis on a child-centered, constructionist philosophy of teaching, while a teacher-directed, didactic philosophy was emphasized in the second session of the workshop. Otherwise, the curriculum covered the same materials and ideas in each workshop. Data presenting differences both within and between the two workshop groups will be presented as well as the innovative method for data collection.

Poster 4: Innovative Teaching Partnerships: Bringing engineering into elementary school classrooms through collaboration

Bringing robotics into elementary classrooms (PreK–4) places new demands on teachers regarding content knowledge, teaching style, pedagogical beliefs, and general classroom management. Engaging 25 young children in hands-on design challenges that interface with battery-powered microprocessors that can be programmed on a computer is a daunting challenge for any educator. This project describes innovative partnerships between engineering students and members of industry with pre-service and in-service teachers to provide these educators with the support and resources they need to engage in meaningful, open-ended projects.

STOMP and I-STOMP

STOMP (Student Teacher Outreach Mentorship Program) was developed at Tufts University to leverage the resources of engineering students to aid teachers in bringing engineering activities to their classrooms. STOMP uses the model of a two-way mentorship—where engineering students are helping teachers to learn about engineering content and the teachers are helping the engineering students learn about education and how to interact with young students. The outcome of this two-way mentorship is a teacher who is more knowledgeable and confident about using engineering activities in his or her classroom and an engineering student who is aware of the educational and societal issues in engineering and the need for early engineering education. The program does not seek to transform engineers into educators but to help them understand the issues in education so that as future leaders of industry and as voting citizens they can make informed decisions to support education. To date, the STOMP program has had over 60 engineering students supporting 40 K–12 teachers and an estimated 1800 K–12 students. The STOMP model is being used to create similar outreach programs at other universities and modified for use in high school as well.

Industrial STOMP (I-STOMP) works with engineering and technology companies to encourage, train, and support employee classroom volunteers. The employee volunteers—majority of whom are engineers—help teachers bring hands-on LEGO robotics activities that focus on developing math, science, technology, and engineering skills into the classroom. Currently, the program includes two major engineering companies with volunteers in central Texas elementary schools and British primary schools. In addition to supporting the teachers, the industry volunteers serve as mentors for the elementary students and bring real-world engineering experience into the classrooms.

Collaborative Classes: Pre-Service Elementary School Teachers and First Year Engineering Students

Pre-service elementary school teachers at Tufts, in one of their courses, focus on developing innovative curriculum in math and science and tackle the question of how to integrate new technologies in their classrooms. Typically, this course can be frustrating because the pre-service teachers need a great deal of support at the university and in the classroom environment. The instructor of the course generally has limited resources to help each student work on a meaningful project that allows them to grapple with the issues of math, science and technology. Meanwhile across campus, a class offered through the College of Engineering teaches first-year engineering students basic robotics and the engineering design process. Here the instructor grapples with providing the students with an authentic design process that allows them to create something for a "real" client.

A solution to both instructors' dilemmas is pairing pre-service teachers and first-year engineering students together to work on developing a robotic technology-based lesson. The pre-service teachers focus on the educational content and how to engage the students in a lesson while the engineering students focus on how to design and develop supporting technology. This collaboration gives each group purpose and expertise while allowing them opportunities to develop communication and project management skills. The result of these collaborations have ranged from robotic cars that move up and down the number line to a robotic "Simon Says" that allowed children to explore patterns and simple machines. This presentation will discuss results from this collaboration.

Poster 5: Innovative Curriculums and Tools: From ROBOTables to Underwater Robotics

As Lego robotic technology becomes more widespread in schools, educators are challenged to develop new and innovative curriculums to continue to engage students in learning. Three new tools and related curriculums are presented: (a) underwater robotics, (b) ROBOTable, and (c) stop-action moviemaking (SAM). These tools and curriculums are able to be scaled for use in early-childhood classrooms up to college-level courses.

Underwater Robotics

The CEEO is developing a curriculum for underwater robotics that will give hands-on experiences for elementary students to explore concepts such as buoyancy, propulsion, and water properties. Underwater robotic activities allow students to experiment with many types of materials to explore how boats and submarines work. This new curriculum is early in its developmental stages, but has gained much interest and attention from both teachers and students. A number of underwater activity possibilities giving early elementary students an opportunity to design and build submersible vehicles will be presented.

The ROBOTable

The ROBOTable is a frosted glass or Plexiglas tabletop that acts as a rear-projection screen. Through a mounted projector below the table, an extended computer screen is projected on to the table via a mirror below (see Figure 1). The table uses video conferencing capabilities, a camera to track objects and user interactions, and an Internet connection for sharing data with other ROBOTables. Through the table, users can see two-dimensional projections of remote robots while they navigate the tabletop with their own robot.

Figure 1. ROBOTable set-up.

Development of the ROBOTable is progressing in two areas. The first is to create a self-contained learning environment for training industry professionals, teachers, and volunteers for mentorship and outreach work in schools. The aim is to familiarize teachers with engineering and engineers with teaching by practicing with pre-designed activities from an online database. The second is to create a distance-learning tool for communication, collaboration, and real-time competition. Participants at different geographic locations can share an activity or compete in the same shared workspace. Both goals can be realized by producing an interactive learning environment that is enhanced by judiciously including new technologies such as augmented reality (AR) and tangible user interface (TUI) devices. Five example activities have been developed aimed at assisting the user in learning how to build with LEGO bricks and program in ROBOLAB.

Stop-Action-Movies (SAM)

SAM is stop action movie making software that gives students the chance to make simple animations as a way to explore and share ideas. By taking single-frame images and controlling the speed at which they are played back, we empower students to make scientifically and mathematically accurate predictions of phenomena prior to experimentation or design. With robotics, students can make (a) predictions of how a robot will behave under certain conditions, (b) kinematic predictions of specific robot actions, or (c) an animation demonstrating what their robots can do. The power comes in allowing students to control time and thus demonstrate things through animation that may be difficult with video. For younger students, simply using the concept of demonstrating understanding in animation format offers another mode of expression but also a window for the teacher, researchers, etc. into what the student understands. For example, say a student is asked to make a movie explaining the “reasons for the seasons.” To effectively display this concept through an animation, the student must have a certain understanding of the content. With traditional written deliverables, students can copy what they have heard or read elsewhere. With an animation, the chance of them producing something simply from memory is quite rare. Thus the animation they produce will essentially be their personal understanding of the content at hand.

The actual process of making the animation also forces students to examine their beliefs on the subject. Building and watching the movie allows them to critique their own understanding—if something does not look “right” in the movie, they will either change their thought to match what they observed or change the movie to match their prior understanding. With robotics, SAM can be used as a method for younger students to communicate what their robot does. The relative ease-of-use in making single-frame animations makes this approachable for students of younger ages. In one school local to the CEEO, fourth-grade students animations explaining the phases of the moon to second graders. While there were some misconceptions in these animations, the students spent a longer time thinking more critically with the content than with the traditional written methods of reporting. This tool is an alternative media for students that provides a new dimension for sharing their knowledge with fellow students, teachers, parents, and others.

Poster 6: Using Activity Theory and Situated Cognition to Analyze and Describe Special Needs Students Understanding of Engineering Design Principles Through LEGO Robotics

This paper represents a pilot study of a LEGO Robotics Curriculum which is currently being used to teach the Engineering Design Principles that are presently tested on the Massachusetts Comprehensive Assessment System (MCAS) to a group of special needs students in grades one through five at the Chamberlain Elementary School (pseudonym) in Allston-Brighton, Massachusetts. The curriculum represents the current trend to move away from the traditionalist models of learning that are more didactic in their approach. Instead of conceptualizing knowledge and learning as being transmitted from the teachers to students, a social constructivist approach, with students emerging as active participants in their own learning experiences, has emerged.

Two special needs classes at Chamberlain Elementary were used in the study. Class A consisted of six students, all male, in a special needs class for grades one through three. Class B consisted of twelve students, eleven boys and one girl, in a fourth and fifth grade special needs class. These classes met with the science specialist once a week on Friday afternoons for fifty minutes.

This naturalistic inquiry study utilizes a mixed methodological approach with grounded interpretations (Guba & Lincoln, 1983). Quantitative surveys and drawings as well as qualitative ethnographic data was collected over a several month period of time through direct observation and field notes directed at specific groups participating in the activity. Activity theory was used as both the theoretical lens and tool of analysis in this study. The relation of the participant and the object as it was mediated by the components of the activity system were examined.

The preliminary data suggests that it is important to begin to look at the complexities of the dynamics of the LEGO robotic activity that exist. The dualities or tensions that arise may lead to outcomes which have not been anticipated as was seen in the Student / Classroom tensions and the Group A / Group B interaction tensions. These experiences will alter how future studies are situated. Additionally, it is important to harness tensions in order to analyze how they affect classroom culture and learning goals.

Additional Resources

Tufts University Center for Engineering Educational Outreach (CEEO): www.ceeo.tufts.edu

Developmental Technologies, Eliot-Pearson Department of Child Development, Tufts University: http://ase.tufts.edu/devtech/

Urban Sciences Research and Learning Group, Boston College: http://www2.bc.edu/%7Ebarnetge/urslg/urslhome.html

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