Tangible Programming in Education: A Research Approach

Michael S. Horn
Tufts University
Computer Science
161 College Ave.
Medford, MA 02155 USA
michael.horn@tufts.edu

Marina U. Bers
Tufts University
Child Development
105 College Ave.
Medford, MA 02155 USA
marina.bers@tufts.edu

Robert J.K. Jacob
Tufts University
Computer Science
161 College Ave.
Medford, MA 02155
jacob@cs.tufts.edu

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Abstract
In this position statement, we discuss our research involving tangible user interfaces in both a science museum and in Kindergarten classrooms. This research aims to compare the use of tangible programming to more conventional programming systems as well as to create opportunities for children to engage in meaningful, age-appropriate computer programming and robotics activities in diverse educational settings, both formal and informal.

Keywords
Tangible User Interfaces, education, kindergarten, robotics, computer programming, museums

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
We have arrived at a critical point in the field of tangible interaction for use in education. While the development of tangible interfaces for learning is widespread [8], there is comparatively little research that presents empirical evidence that the use of tangibles offers educational advantages over more conventional technology [7]. To make advances in this area, we must adopt a critical perspective and ground our technological designs in careful, evidence-based research.

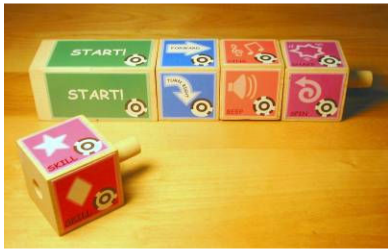

figure 1. Our tangible programming language prototype consists of interlocking wooden cubes with brightly color labels.

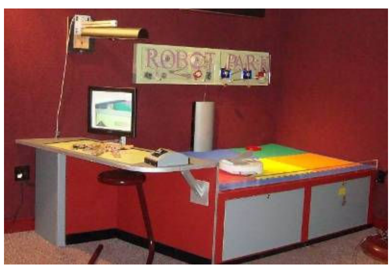

figure 2. A permanent exhibit on computer programming and robotics that we created in partnership with the Boston Museum of Science.

In this spirit, we have begun research to evaluate the use of tangible programming languages for controlling educational robots in both formal and informal learning settings. In this position statement we will first present a comparison study of tangible and graphical interfaces for computer programming at an exhibit at the Boston Museum of Science. Second, we will describe research comparing these same interaction techniques in Kindergarten classrooms. These efforts combine iterative technology design and formative evaluations with controlled comparison studies conducted in real-life educational settings. We will conclude with an overview of the research methodology for designing such studies.

Tangible Programming Technology

The tangible technology we are creating for these projects is based on prior work conducted at Tufts University [5]. Our system consists of interlocking wooden cubes with brightly colored labels (figure 1). The cubes can be chained together to create computer programs for both the LEGO Mindstorms RCX and the iRobot Create platforms. To compile programs, children place the cubes on a desk in front of a web camera connected to a standard desktop or laptop computer. We use a simple and robust computer vision system to convert physical programs into digital code. The blocks are durable and inexpensive. And, because they interlock, children can easily carry their programs, allowing them the freedom to work in any part of the classroom. Furthermore, the wooden blocks in our interface could easily be replaced with paper or other materials—only the digital camera and the computer vision fiducials are necessary for the system to function.

Tangible Programming in Science Museums

In partnership with the Boston Museum of Science, we have created a permanent exhibit on computer programming and robotics featuring our tangible programming language (figure 2). At the exhibit museum visitors use the tangible blocks to create programs for an iRobot Create robot on display. In its first year, the exhibit was visited by over 20,000 people.

We conducted an evaluation of this exhibit from an informal science learning perspective which included interviews with visiting parents and children and observations of over 260 museum visitors. We compared the use of the tangible (TUI) and an equivalent graphical (GUI) interface for programming. In the GUI condition, we replaced the tangible blocks with a standard computer mouse and presented a screen-based programming language. Museum visitors created programs that were similar in length and complexity in both conditions. However, visitors were much more likely try the exhibit in the tangible condition and were more likely to actively collaborate in small groups. These effects were especially large for children. For example, 33.3% of girls who noticed the graphical version of the exhibit stopped to interact with it, while 85.7% of girls who noticed the tangible version of the exhibit stopped to interact with it.

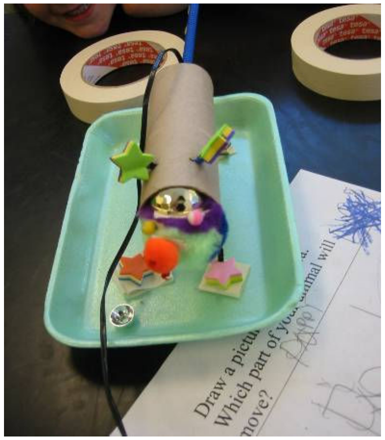

figure 3. A robot animal created in a Kindergarten classroom that combines the use of recycled materials, arts and crafts supplies, and select parts from a robotic construction kit.

Tangible Programming in Kindergarten Classrooms

We have also begun a three-year NSF-funded collaboration between the Child Development and Computer Science departments at Tufts University to explore the use of tangible programming languages in Kindergarten classrooms. We propose that if given age-appropriate tools, young children can actively engage in computer programming and robotics activities in a way that is consistent with developmentally appropriate practice. At the heart of this work is the claim that modern graphical user interfaces are ill-suited for use in early elementary school classrooms, especially for computer programming activities. Thus, the use of tangible technology creates a unique opportunity to separate the intellectual act of computer programming from the confounding factor of modern GUIs. And, in turn, it provides a means to better understand the capabilities of young children with respect to the powerful ideas involved in computer programming.

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 [1,2,3]. Furthermore, early studies with the text-based language, Logo, have shown that computer programming, when introduced in a structured way, can help very young children with variety of cognitive skills, including basic number sense, language skills, and visual memory [4]. However, modern educational programming environments are not well-suited for young children, in part because of the fine motor skills needed to use a mouse [6]. As a result, adults often have to sit with young children and give click-by-click instructions to make programming possible. This makes it difficult to implement computer programming in average schools, where there are often only one or two adults per classroom.

Thus, our project has three fundamental goals: 1) to develop an in-depth, age-appropriate computer programming and robotics curriculum that integrates tangible technology; 2) to determine from a human-computer interaction perspective how the use of tangibles might improve the classroom experience for students and teachers alike; and 3) to determine how the use of tangibles in the context of a structured intervention might promote the development of meta-cognitive thinking skills on the part of young children.

For this project, we emphasize the use of low-cost recycled materials with robotic manipulatives (figure 3). With the use of recyclable materials children can have the experience of building while only needing to incorporate select robotic parts, such as wheel and motors that give functionality and movement to their creations. This approach welcomes traditional use of art and crafts materials, which is another important aspect of early childhood education.

We are currently working with six classrooms in economically diverse schools in the Boston area to pilot our Kindergarten robotics curriculum and to iteratively develop age-appropriate tangible technology. We will also begin controlled research to compare the use of tangibles and more conventional technology in these classrooms. For this research we are collecting a variety of qualitative and quantitative data including video tapes of programming interactions, computer logs, interviews with students and teachers, and developmental assessments of individual children. We are adapting traditional child development experiments to test children's cognitive abilities in light of new technologies that put them in the role of programmers. In our case we are replacing old technologies, such as water, clay and marbles, with tangible programming elements. By the time of the workshop in April, we will have concluded our first round of interventions in schools and we will be ready to present results.

Conclusion

Based on our research efforts in both formal and informal learning settings, we believe that tangible interfaces have the potential to dramatically improve the use of computer technology in education. Our work in these areas aims not only to provide concrete evidence of these advantages, but also to provide an understanding of the context in which the use of these technologies will be most effective and appropriate.

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References

[1] Bers, M (2008). Blocks, Robots and Computers: Learning about Technology in Early Childhood. Teacher's College Press, NY, NY.

[2] Bers, M., Rogers, C., Beals, L., Portsmore, M., Staszowski, K., Cejka, E., Carberry, A., Gravel, B., Anderson, J., and Barnett, M. Early Childhood Robotics for Learning. Symposium at the International Conference on the Learning Sciences. (2006).

[3] Cejka, E., Rogers, C., and Portsmore, M. Kindergarten Robotics: Using Robotics to Motivate Math, Science, and Engineering Literacy in Elementary School. International Journal of Engineering Education, 22(4), (2006), 711-722.

[4] Clements, D. The Future of Educational Computing Research: The Case of Computer Programming. Information Technology in Childhood Education, (1999), 147-179.

[5] Horn, M.S. and Jacob, R.J.K. Designing Tangible Programming Languages for Classroom Use. In *Proc. TEI'07*, ACM Press (2007).

[6] Hourcade, J. P., Bederson, B. B., Druin, A., and Guimbretière, F. Differences in pointing task performance between preschool children and adults using mice. ACM Transactions on Computer-Human Interaction, 11(4), ACM Press (2004), 357-386.

[7] Marshall, P. Do tangibles interfaces enhance learning? In *Proc. TEI'07*, ACM Press (2007).

[8] O'Malley, C. and Stanton Fraser, D. Literature Review in Learning with Tangible Technologies. NESTA. Nesta Futurelab series, report 12. (2004).