Beyond the Lab: Using Technology Toys to Engage South African Youth in Computational Thinking

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Abstract
We present a two-part case study to explore how technology toys can promote computational thinking for young children. First, we conducted a formal study using littleBits, a commercially available technology toy, to explore its potential as a learning tool for computational thinking in three different educational settings. Our findings revealed differences in learning indicators across settings. We applied these insights during a teaching project in Cape Town, South Africa, where we partnered with an educational NGO, ORT SA CAPE, to offer enriching learning opportunities for both privileged and impoverished children. We describe our methods, observations, and lessons learned using littleBits to teach computational thinking to children in early elementary school, and discuss how our lab study informed practical work in the developing world.

Author Keywords
Child-computer interaction; computational thinking; youth; education; tangible user interfaces.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces – evaluation/methodology, interaction styles. K.3.0 [Computers and Education]: General.

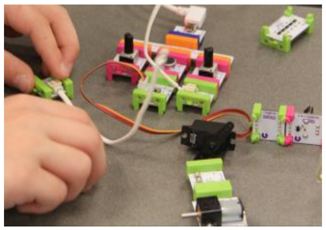

Figure 1: littleBits, made by littleBits Electronics, Inc.

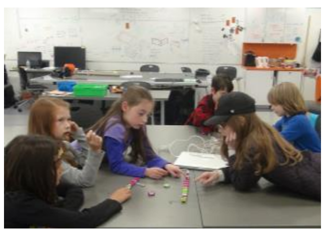

Figure 2: A laboratory study.

Introduction

Following the seminal Jeannette Wing article [7] about the importance and application of computational thinking (CT), the computer science education community has increasingly focused on embedding CT concepts into K-12 curriculum. In parallel, researchers suggested that tangible user interfaces (TUIs) support children's learning, specifically noting their ability to promote hands-on engagement, collaboration, exploration, and reflection [1]. Recent studies demonstrated the potential of using TUIs to promote the development of CT skills, however, most studies are conducted with early research prototypes rather than with commercially available tools accessible to the general public.

We studied the use of a commercially available tangible technology toy, littleBits, in three different formal and informal educational settings. Our findings demonstrated the capability of TUIs to support the learning of computational thinking skills for young children. We then extended our study beyond the lab to explore the benefits and challenges of using littleBits in a culturally and economically diverse setting - Cape Town, South Africa. The study revealed interesting differences between the American and South African youth, exposing the potential for technologies like littleBits to address some of South Africa's more basic, yet pressing issues in education.

Background

The development of TUIs for children is a growing research area. Many studies demonstrate how tangible technologies can engage children in CT during child's play. User studies of prototypes like CHERP [2], Tern [4], Robo-Blocks [5], and TanPro-Kit [6] demonstrate that TUIs can provide children with opportunities to learn CT concepts, practices, and perspectives.

South Africa lags behind other countries in the quality of its STEM education, largely due to the lack of adequately trained teachers. While its Department of Education attempts to improve performance in these subjects, organizations like ORT SA CAPE have stepped up to support this critical mission. Their work with technology and robotics education has already impacted thousands of students and teachers in the Cape Town area. Methods for teaching and evaluating CT are increasingly important for South African education.

Toys like littleBits (Figure 1) may help children in South Africa to develop CT skills. They include a variety of magnetic modules, each color-coded by function (power, output, input, wire), that snap together to make circuits. littleBits supports several dimensions of Brennan and Resnick's CT framework [3], including concepts (sequencing, events, parallelism), practices (being incremental and iterative, testing and debugging), and perspectives (expressing, connecting, questioning).

User Studies in Three Educational Settings

To investigate how littleBits promotes learning for children in lower elementary school (K-3), we conducted user studies in different educational settings.

Method and participants

We conducted three types of user studies with a total of 31 children in grades K-3 (7 male, 24 female): 1) lab setting (Figure 2): 4 male, 5 female; 2) classroom session: 3 male, 4 female; 3) Robogals workshops: 15

Figure 3: A robotic dog project (2 females, K, workshop setting)

Figure 4: A kitty project (1 female, grade 3, lab setting)

female. Although the time, environment, and number of participants varied for each setting, the basic protocol remained the same. Following an icebreaker activity, the facilitator demonstrated how littleBits works. Participants were given time to build circuits with the modules, and then the facilitator prompted participants to build a project in groups of 1-3 using the littleBits and crafts materials. We used "robotics animals" as an example. Figures 3 and 4 show some of the projects. Upon completing their project participants were asked to describe their project to the facilitators. All sessions were recorded with video cameras, and dialogue was transcribed afterwards. Inter-coder agreement based on 32% of the data was excellent with 90% agreement for video coding and 93% agreement for dialogue coding.

Results

We qualitatively coded the videos and dialogue to analyze physical gestures, facial expressions, and the nature of discussion. Combining physical and verbal indicators allowed us to measure learning, engagement, complexity, and collaboration. Our findings indicate that in each of the three settings, littleBits provided opportunities for reflection, problem solving, and application of computational thinking concepts, as shown by the participants' utterances in the relevant talk categories (Figure 5). This study also revealed differences between settings. Figure 6 compares the levels of engagement in each setting. Indicators of positive and negative engagement included physical (smiling and laughing vs. turning away from the task at hand) and verbal (talk classified as excitement vs. utterances of frustration, confusion, and disengagement) cues. Classroom participants showed the least amount of engagement and collaboration, while workshop participants exhibited high levels of both but received lower scores in complexity.

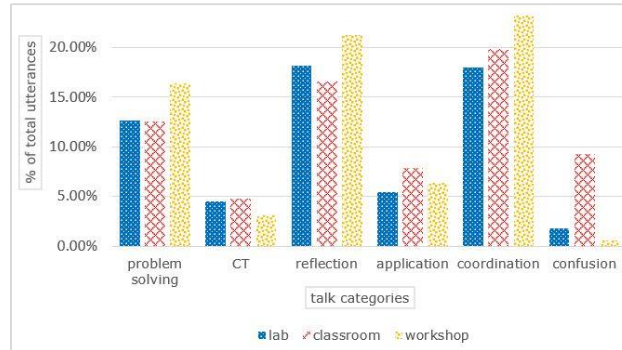

Figure 5: Distribution of talk categories per setting

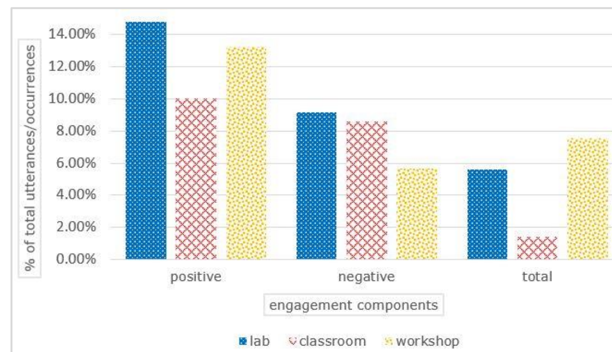

Figure 6: Engagement components per setting

Lessons learned

Our user studies with 31 children demonstrated the capability of littleBits to engage children in play and to provide opportunities for learning CT skills, practices, and perspectives. The differences in learning indicators across educational settings allowed us to provide practical recommendations to help educators better

Figure 7: Afterschool program

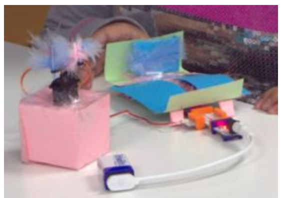

Figure 8: A “dream room”
(1 female, grade 5, workshop)

Figure 9: A bird project
(1 female, grade 4, workshop)

support the development of CT skills for children in early elementary school:

1. Physical space: Each setting facilitates a different learning experience. The familiarity of the space may influence children’s style of collaboration and willingness to ask questions and express confusion.
2. Other learners: Learning best occurs when participants consist of similar-aged children. For girls, it is beneficial to conduct CT-related activities in single-sex settings to help them feel more comfortable and confident.
3. Presence of adults: Too many adults may hinder children’s expression of creativity and complexity, but the presence of adults contributes to learning by increasing the amount of reflection. Adult involvement seems to be more useful in the classroom than in other settings.
4. Time: The optimal duration of a CT activity in a group setting depends on the age of participants and the setting in which it is conducted, but seems to be around an hour and a half. Participants of longer studies exhibited more disengagement towards the end, while participants of shorter studies demonstrated lower complexity levels.

Bringing littleBits to Cape Town

Drawing upon findings from our initial research study, we endeavored to teach CT to children in Cape Town.

Method and participants

In Cape Town, we introduced over 200 children to littleBits through holiday workshops and afterschool programs (Figure 7). All children were in elementary school and worked in groups of 1-3. They represented a diverse mix of socioeconomic backgrounds. For the workshops, we used a protocol similar to that of the lab studies (brief demonstration and project). Example projects are shown in Figures 8 and 9. During the afternoon sessions, which were shorter in duration, we focused instead on teaching CT concepts and building different circuits to understand the capabilities of each module. Due to the nature of our project, we could not collect quantitative data.

Observations

We observed similarities and differences in the way that American and South African children interacted with and understood littleBits. While the privileged children closely resembled the participants of our lab studies, the children of impoverished communities exhibited important differences.

1. Communication: The frequency of communication was much lower for students from disadvantaged backgrounds. While the more privileged children were not shy to verbally coordinate with their partners, the underprivileged children relied primarily on gestures to communicate with each other.
2. Gender stereotypes in technology: The children’s varying levels of exposure to technology seemed to affect their awareness of gender stereotypes. At workshops, which were mostly accessible to privileged children, the majority of participants were male and girls often made comments like “He should do the building part” or “I’m not good at this kind of stuff.” However, with the underprivileged

children, all participants contributed equally and such a gender divide was less noticeable. This may be explained by the lack of adult role models (male or female) who are technologically literate, which means girls are less likely to be exposed to gender stereotypes.

3. Benefits of using littleBits: The socioeconomic disparities also created differences in the impact that the littleBits had on the children. The privileged children, who already benefit from daily exposure to smart phones, tablets, and computers, were quicker to grasp CT concepts and could more effectively communicate their ideas and questions. The disadvantaged children were also able to express an understanding of the CT concepts, but the littleBits provided an opportunity for them to develop fine motor skills and practice basic language skills, such as using prepositions (i.e. before, after, next to) to describe their circuits. Although most of them develop fairly strong hand-eye coordination from playing on the streets, their lack of access to typical children's toys like LEGOs, racecars, and wooden letter blocks means that their language and manipulation skills are relatively weak. For these children, tangible technologies like littleBits can not only teach CT, but also stimulate motor and cognitive development.

Lessons learned

These differences forced us to revisit our previous recommendations. Next, we describe unexpected challenges and how we handled them.

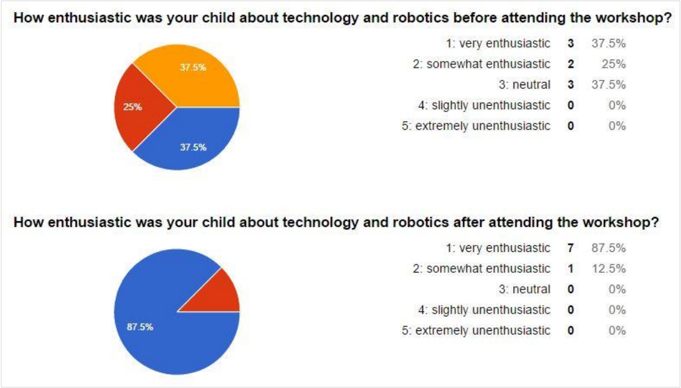

Figure 10: Feedback from parents of Girls in Action Workshop participants

1. Other learners: Because the varying levels of exposure to technology affect the children's awareness of gender stereotypes in technology, it may be the case that for girls, single-sex activities for learning CT can boost their confidence and lead to improved learning outcomes. We hosted two Girls in Action workshops in Cape Town to offer this opportunity. The post-workshop survey results (Figure 10) demonstrate the workshops' role in improving girls' attitudes towards technology and robotics. However, relative to co-ed workshops, such events may not be quite as beneficial for girls of disadvantaged backgrounds, who demonstrated less awareness of gender stereotypes in technology.
2. Curriculum and instructional content: Differences, such as the lack of communication between students of less privileged

backgrounds, may be addressed by adjusting the curriculum. Explaining and using technical terms, such as "input" and "module," can improve their ability to understand and describe their world. For disadvantaged children, educators may use littleBits as a platform to foster communication and problem solving skills. Curriculum should be adjusted to reflect different cultures. For instance, the children in Cape Town better understood the ideas behind the power module when it was compared to the "loadshedding" concept (intentionally engineered local power outages) of their everyday lives.

3. Other uses of tangible technologies: The underprivileged children reaped additional benefits from using littleBits, which suggests that tangible technologies like littleBits may have the potential to address other educational challenges in countries like South Africa. Participants of the Western Cape's Year Beyond Project identified peer pressure, low self-esteem, and unequal treatment by teachers as critical issues facing South African students. By offering opportunities for young children to play, learn, and express themselves, littleBits have the potential to engage students who struggle with more traditional methods of learning.

Conclusion

We evaluated littleBits as a learning tool of CT concepts with American and South African youth. Our findings from a study with 31 children in three different educational settings indicate that littleBits, in addition to engaging children in play, also provide opportunities to learn CT concepts, practices, and perspectives. The differences in learning indicators across educational settings allowed us to compile recommendations for conducting CT activities, which we then applied in Cape Town, South Africa. We discuss our observations and offer suggestions for handling some of the differences and challenges we encountered. This case study demonstrates how results from formal user studies can be used and adapted for diverse populations. It also furthers the discussion of how tangible technologies can be used to teach computational thinking.

Acknowledgements

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