Understanding Computational Thinking Outside the Classroom: Capturing Learning Vignettes in a Public Library Programming Club

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Abstract

This study explores how children approach and develop computational thinking as a result of their participation in a computer science after-school program in a public library offered through a university-library partnership. Specifically, this work captures learning vignettes that exemplify children's growing understanding of computational concepts, practices and perspectives.

Data were collected from multiple sources, including children's computational artifacts, children's interviews and program observation fieldnotes. The study findings provide insights on understanding children's CT development outside the classroom. Additionally, findings have implications for the design and implementation of effective learning experience that broaden children participation in computing.

Purpose & Research Questions

In 2006, Wing proposed that computational thinking (CT) should be a fundamental analytical skill for everyone. CT involves skills that help children analyze and solve real-world problems drawing on computer science (CS) principles. Wing's call generated a renewed interest in CS, particularly the types of skills that young students need to navigate the new digital age (Cuny, 2012).

However, many children experience and use new technologies in their daily lives mostly as *consumers* while few have opportunities to become *creators* of computing innovations and develop CT skills (Resnick et al., 2009). To address this issue, efforts to support the development of children's CT knowledge and skills are underway in both formal and informal settings (Mouza et al., 2014).

In this study, we examine how children learn fundamental CT concepts, practices and perspectives (Brennan & Resnick, 2012), in the context of an informal learning environment at a public library. Specifically, we present learning vignettes on children's learning developed through their participation in a programming club in the library, the *Scratch Technology Club* (STC).

Consequently, we explore two research questions:

1. **How do children experience computational practices during their participation in the STC?**
2. **How does participation in the STC influence participating children's learning of CT concepts, CT practices, and CT perspectives?**

Methods

Background and Context

The STC was founded through a strong partnership between university faculty, CS undergraduates, and library staff members and has been successfully implemented for three semesters. The overall intention of the program is to broaden participation in computing by providing equal access to CT knowledge and skills through opportunities to create computational artifacts using tools such as Scratch, a block-based programming language for novice programmers (Maloney et al., 2008). The STC was offered on Saturday mornings for 2 hours over a ten-week period each semester from Spring 2016 to 2017. Although interested children had to register for the event, it was not mandatory. On average, 5 - 14 children participated in each STC session. Most children had no prior experience with Scratch.

Participants

Eleven participants were selected for this study based on the following criteria: (a) regular participation in the STC, (b) different levels of programming experience, and (c) gender/ethnic diversity.

Data Sources

Data were collected from multiple sources including: (a) collections of children's Scratch projects at different stages of their participations in the STC (N=22); (b) interviews with children on their experience in the STC (N=11); (c) videos, pictures and field notes collected by the authors each semester. In addition, we examined reflective journals maintained by all STC facilitators as well as lesson planning materials to triangulate data collected by children.

Data Analysis

Interview data were analyzed qualitatively using a combination of *a priori* codes related to the study's questions and themes that emerged during the interviews. The six themes included in the coding scheme are:

a) background information, b) motivation and interest, c) surprises, d) enjoyable learning experience, e) challenges, and f) reflections.

Field notes and other qualitative data were analyzed and coded into two categories: (Brennan & Resnick, 2012).

a) CT practices: refer to how children learn about CT knowledge and skills which included "testing and debugging".

b) CT perspectives: refer to children' reflections or attitudes towards computing.

Children's Scratch projects were analyzed through an automatic analytical system "Dr. Scratch" that includes seven domains related to programming: (Moreno-León et al., 2015): a) flow control, b) data representation, c) abstraction, d) user interactivity, e) synchronization, f) parallelism, and g) logic.

Results

Computational Practices Experience

Participating children received a variety of options to approach CS concepts and to develop CT skills throughout constructing various artifacts. The content and activities offered at the STC are shown in Table 1.

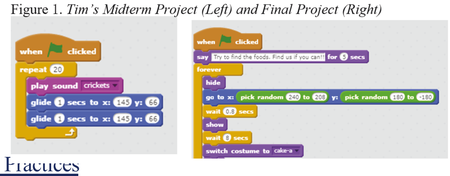
Week	Spring 2016 CT Activities	Fall 2016 CT Activities	Spring 2017 CT Activities
1	Exploring Scratch	Introduction to Scratch: conditional statement CS Unplugged Activity: Harold the Robot	Introduction to Computer Science
2	Introduction to Scratch (Basic Scratch Concepts on Sprite, Scripts etc.)	Simple Animation on Scratch: x- y coordinate; operator; sensing.	Programming on Scratch: Storyboarding Strategy
3	Learn To Code	Scratch & Math (I) – loop function; pen. CS Unplugged Activities: Image Representation	Creating your own Volleyball Game
4	Blocks on Loops	Making Scratch Game: Underwater Game	Introduction to 3D Printing: Basic
5	Variables and Operators	Scratch & Math (II) CS Unplugged Activity: Variables	Learning more about 3D Printing: Intermediate
6	CS unplugged and Problem Solving	Making Scratch Game: Pong Game	Robotics – Finch Bots: Introductory
7	Conditionals and Loops Creation of Individual Project	Finch Robots (I) – movement; sounds.	Robotics – Finch Bots: More Features
8	Creativity – Music Instrument Creation of Individual Project	Programming Technique with Finch Robots (II) : loop function; variables.	Creative Programming with Makey Makey
9	Motion Sensing Blocks Creation of Individual Project	Makey Makey: Create your piano with bananas Creating Scratch Project	Advanced Features in Scratch – Cloning and more
10	Creation of Individual Project Project Presentation	Arduino Scratch Activity – Broadcasting Scratch Project Presentation	Making your final project with Scratch/ Demo Day

Participants' CT Concepts, Practices and Perspectives

CT Concepts

Children demonstrated growth on CT concepts throughout their participation in the STC. In particular, children demonstrated growth in combining a greater number of CT concepts as they completed their individual computational products. Figure 1 illustrates Tim's progress. Tim entered the STC without any programming experience and without speaking English very well. The project he created early in the STC was basic (left). In contrast, the project he created at the end of the program demonstrated a variety of computational concepts including synchronization and logic (right).

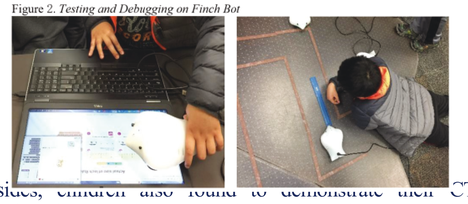
Figure 1. *Tim's Midterm Project (Left) and Final Project (Right)*



CT Practices

Interview and observation data revealed that children developed computational practices, particularly on how to solve a problem or how to develop new ideas. The below vignette illustrates the process of testing and debugging between a 9-year-old boy (Alex) and a 15-year-old student (John) as they attempted to program their Finch Robot go through the maze with different approaches.

Figure 2. *Testing and Debugging on Finch Bot*



Besides, children also found to demonstrate their CT practices by remixing or developing ideas based on other Scratch projects shared on the Scratch website.

Results (Cont.)

CT Perspectives

All children had the opportunity to create and develop interest in programming. Their interviews indicated that they were engaged in the process and development of personal meaningful artifacts, including computer games and robotics. Children were found to gradually develop interest and confidence in computing. One of the children who came to the STC without any prior experience in programming notably summarized his semester-long learning experience:

> ***"I didn't really know how to use Scratch before, but when I come to the Scratch club, I know how to do it. I just know many things about it, I can create many things that can be used (with) Scratch. It is cool!"***

Observation notes and other qualitative data indicated that children developed CT concepts and practices through a social learning environment with more access to new people and resources. Lily commented:

> ***"(Learning Scratch) it was pretty fun and I enjoyed playing on other people's projects and then make my own."***

Significance

In this work, we presented one approach to helping children acquire foundational CS concepts in a public library program designed as part of a school-university partnership. The STC provided opportunities to children aged between 7 - 15 from different cultural backgrounds to explore CT knowledge and practices. University students, library staff and research assistants worked closely to design an engaging learning environment for children, to deliver meaningful CT related activities as well as scaffold children's completion of different projects. Findings of this study provided insights related to the design, implementation and outcomes of informal computing programs for children from diverse backgrounds.

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