From Computational Thinking to Computational Action: Understanding Changes in Computational Identity through App Inventor and the Internet of Things

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Abstract: This paper advocates for a shift from teaching and assessing computational thinking towards one of computational action, which instead emphasizes learners' ability to develop computational artifacts that can impact their daily lives. We also discuss the importance of developing computational identity and digital empowerment as central to computational action. In order to understand how to support the development of computational identities and digital empowerment, we examined a group of students (ages 15-19) engaged in a 5-week summer camp that combined MIT's App Inventor and the Internet of Things (IoT). Results showed that participants significantly improved their ability to use IoT for meaningful impact in their worlds, and to develop IoT solutions to common problems in their everyday lives.

Introduction

In education, there has been a groundswell of research attempting to understand what it means for learners to "think computationally" (NAS, 2010). For many researchers, computational thinking has an epistemological goal, focusing on learners' understanding of the nuanced elements of computation, including type checking, aliasing, modularization, loops, parallelism, operators, and data handling (NAS, 2010). Focusing on the means of computing, rather than the process and ends, is one of the most persistent challenges of math and science education (Flegg et al., 2012), and risks reducing computing to something that feels irrelevant to learners' daily lives. In response, we argue that there is a need to move beyond computational thinking as the goal of computing education, to a perspective of *computational action*. Computational action emphasizes learners' ability to develop computational artifacts that impact their own lives and communities. By providing low-barrier means for students to design and implement solutions to personally relevant problems, we can help them develop their computational identities (i.e., being capable of creating meaningful change in their lives using computation and recognizing their place in the larger computing community) and their sense of digital empowerment (i.e., opportunities to put that identity into action) (Tissenbaum, Sheldon, Soep, Lee, 2017). With the growing ubiquity of mobile technologies, we have a unique opportunity to address this challenge by moving computation off of the computer and into their daily lives. Going one step further, the proliferation of the Internet of Things (IoT) has embedded computation into everyday objects that connect with each other, and opens up new opportunities for people to computationally connect with their surroundings.

This paper describes one strand of research that seeks to understand how a summer camp that combined blocks-based mobile app development using MIT's App Inventor (appinventor.mit.edu) with Arduino-Based IoT devices promoted students' computational action. To this end, two research questions drove this work: 1) How did the summer camp change students' perceptions of their role with smartphones and IoT?; 2) How did the camp support students' ability to develop computational solutions to personally relevant problems?

Below, we discuss the theoretical background for this work, the computational tools used, the structure of the summer camp, our findings from pre- post-surveys, and implications for computational action.

Methods

Participants and setting

This study took place over five two-hour sessions as part of a summer camp with an organization that aims to support underrepresented youth (mainly K-12 students) to develop STEM literacy. In total, 23 students took part in the camp, composed of 12 female and 11 male students. The participants ranged in age from 14 to 19 (mean age 15.9). The sessions were held at an East Coast university as part of the camp's regular activities. Members of the research team served as instructors for each of the five sessions.

Intervention design

This study employed a design-based approach that built upon previous iterations of an App Inventor + IoT camp. In the first session of the summer camp, participants were introduced to the App Inventor authoring environment and were given two introductory tutorials. In the second session, they were introduced to the IoT functionality of App Inventor. Next, the participants were split up into groups of two or three, and each group was given another IoT + App Inventor element to learn. In session three, students were placed into groups of three to four to collaboratively pinpoint a challenge in their everyday lives and then design a solution using IoT + App Inventor. The students were given the entire fourth and half of the fifth session to work on their. During the fifth session, the students presented their work to the rest of the camp, as well as a larger audience of academics and technologists.

Data collection

For the purposes of this study, we focused on three questions, each of which was on the pre- and post-surveys: 1) "How could the way you use smartphones impact your life?"; 2) "How could the way you use the Internet of Things impact your life?"; and 3) "How might you develop a system in your home that helps you monitor and take care of your pet(s)?" To assess changes in participants' thinking, we developed a set of rubrics to score the three pre-post survey questions. The rubrics for Questions 1 and 2 aimed to understand changes in students' development of computational identities and digital empowerment. The third question aimed to assess changes in students' ability to engage in basic design thinking around a problem using IoT. Interrater reliability was established between the lead researcher and another researcher well versed in the platform and domain.

Findings and discussion

For the first question (use of smartphone in their lives), changes were not significant between the pre-test (M=1.24, SD=0.83) and post-test (M=1.41, SD=0.94); t(16)=-0.58, p = 0.283. For the second question (use of Internet of Things), changes were significant between the pre-test (M=0.82, SD=0.88) and post-test (M=1.71, SD=0.96); t(16)=-2.75, p = .0049. The significant change in scores on Q2 revealed that participants developed more nuance in their understanding of the role that IoT can play in their world. More importantly, it also revealed an improved awareness of participants' ability to use IoT to solve problems in their lives. While changes in Q1 (use of smartphones) were not significant, the overall results showed positive change from pre- (M=1.24) to post-survey (M.1.41). This may be influenced by students already having strongly entrenched notions of what a smartphone can do in their daily lives, as compared to IoT. For the third question (develop a system to monitor and take care of your pet), changes were significant at between the pre- (M=1.17, SD=1.015) and post-surveys (M=1.88, SD=1.219); t(16)= -1.84, p = .0379. These gains seem to indicate that the enacted curriculum helped students to develop approaches for articulating computational solutions to everyday problems. When we examined the participants' answers individually, 8 of the 17 respondents got a perfect score on Q3 in the post-test, as compared to only 3 in the pre-test. In many cases, students transitioned from vague descriptions ("I could create a system that would feed my animals and clean out their cages daily") in their pre-test answers, to more detailed and actionable solutions ("You can use a light sensor to sense if the light in a room turns too dark, sync your phone and be able to turn on the lights for them if you aren't home").

The findings above indicate several interesting aspects about the enacted curriculum and its focus on computational action. The overall shift in students' perceptions of their own roles as producers, rather than consumers of digital technologies is encouraging. This is particularly true in the context of students who are traditionally underrepresented in computing and STEM disciplines (Pinkard et al., 2017). The results of this study, especially regarding the change in the participants' perceptions of the role of the Internet of Things and their ability to create with it, lay important groundwork for supporting students in the development of their computational identities. The results of the third question show how curricula that engage students in authentic opportunities to construct personally meaningful computational artifacts can help students to articulate more complex and complete computational solutions to other everyday problems.

References

Flegg, J., Mallet, D., & Lupton, M. (2012). Students' perceptions of the relevance of mathematics in engineering. *Intl. Journal of Mathematical Education in Science and Technology*, *43*(6), 717-732.

National Academies of Science. (2010). Report of a workshop on the scope and nature of computational thinking. Washington DC: National Academies Press.

Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital Youth Divas: Exploring Narrative-Driven Curriculum to Spark Middle School Girls' Interest in Computational Activities. *Journal of the Learning Sciences*, (just-accepted).

Tissenbaum, M., Sheldon, J., Seop, L., Lee, C., (2017, April). Critical Computational Empowerment: Engaging Youth as Shapers of the Digital Future. *IEEE Global Engineering Education Conference*, Greece.