Learning to Think Computationally: Comparative Outcomes of a Robotics Workshop for Girls

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Abstract: This paper reports quantitative results derived from a larger exploratory case study devoted to examining the development of computational thinking (CT) in students during a one-day, all-girl robotics workshop. Here we report on the relationship of CT conversations to programming outcomes. Results indicate that groups who engaged in more frequent algorithmic thinking and debugging conversations attempted more difficult missions than those who engaged in these conversations less frequently.

Dearth of women in computer science

Due to societal bias, girls and women have less exposure, access, and experience with important domains of learning, such as computer science (Cheryan, Ziegler, Montoya, & Jiang, 2017). Therefore, their entrance into these fields is hindered. Indeed, the lack of women entering the field of CS in college and as a career is a well known phenomenon (National Science Foundation, 2015). Providing girls with opportunities to achieve personal accomplishments in the area of computer science is an important means of supporting their entrance into the field. Moreover, developing a clear understanding of how girls learn in computer science based learning environments, such as robotics, is a key aspect of creating meaningful opportunities for them. Here we examine girls' computational thinking as they work in collaborative groups to solve robotics missions in the context of a one-day introduction to the FIRST LEGO League ® workshop. Our overarching research goal in this work is to identify which aspects of computational thinking novice girl programmers engage with as they "do" robotics and examine how these ideas develop, collaboratively, over time.

Computational thinking and doing with robotics

Robotics kits are computational manipulatives that enable student engagement in computational thinking and doing (Sullivan & Heffernan, 2016). Students working with robotics, typically enact a troubleshooting cycle (TSC) that consists of designing, programming, testing, and debugging their creations (Sullivan, 2011). Engagement in this TSC is the essence of computational thinking and doing for students and includes the creation of algorithms and systems analysis (Sullivan, 2008).

Methods

Research design, participants, and data collection

This observational case study took place at a one-day, all-girl introduction to robotics event called "Girls Connect." The workshop featured the FLL's 2011 challenge: "Food Factor." This challenge features 11 missions of varying degrees of difficulty. The students were allowed to select the mission(s) they wished to solve. The participants in this study included 17 girls, ages 8-13 (M = 11.725) who attended 5 different schools in New England. The students were divided into six teams (five teams of 3 and one team of 2); girls from the same schools were on the same team and wore t-shirts of the same color. We collected audio and video data at the one-day event. Each group of girls had their own worktable, a LEGO Mindstorms EV3 robotics kit and a laptop computer. Two challenge arenas were set up in the room so that the girls could test their solutions. We created a video and audio recording of each group's activity and discussion for the day as they moved between their individual worktables and the challenge arenas. We also ran a screen capture program on each groups' laptop. In this way, we collected all of the robotics programming activity engaged in by each group. This data includes the final robotics program(s) created by each group.

Data analysis

This study features three units of analysis, including the TSCs the students enacted, the utterances that were spoken during each TSC, and the final programs created by each group. We first segmented the data into TSCs, we then coded student talk in each TSC using a CT coding scheme derived from our own prior research (Sullivan, 2008; Sullivan, 2011) and from definitions of computational thinking created by other researchers as summarized in Grover and Pea (2013). Simple interrater reliability was calculated at 94% between two raters. Next we developed a rubric to score student programs. This rubric is based on the difficulty of the mission tasks presented on the FLL challenge arena. Once we had segmented, coded, and scored the data, we tabulated the instances of the CT codes in each TSC for each group. In the next step, we focused on examining the relationship between the frequency of the discussions that are the most relevant to computational thinking and the overall difficulty scores for the groups.

Results and discussion

Our results are encapsulate in this scatter plot, which visualizes the relationship of student scores on their final programs (y-axis) and the amount and type of CT talk each group engaged in during each TSC (x-axis). The scatter plot is presented in Figure 1.

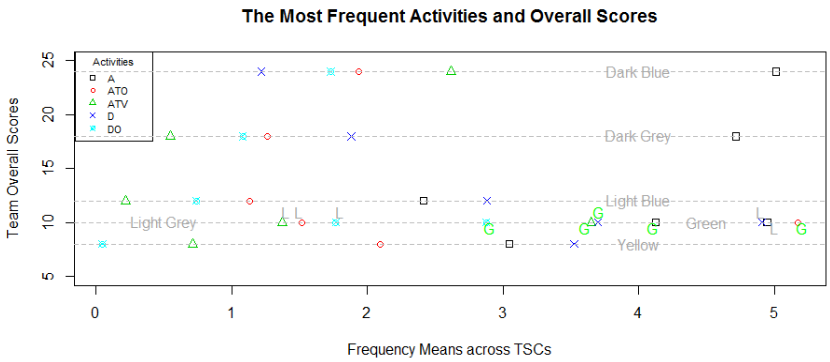

Figure 1. Scatter Plots for the Most Frequent CT Codes and Program Scores

The scatter plot indicates that the dark blue team, who had the highest programming score, also had the highest mean for the analysis and algorithmic thinking variable codes. They also had the second highest means for both algorithmic thinking operation and debugging operation codes. The dark blue team had the lowest mean related to discussion of the physical design of the robotic device. We also notice that the dark blue group discussed variables at a higher level than operations, in terms of algorithmic thinking. We argue this is significant, as discussion of the variables indicates increasing conceptual understanding of the programming block being used. Our next steps with this data set is to examine the nature of the actual conversations of each group to identify the qualities of the conversations that support conceptual understanding.

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