Reaction to Bugs During Robot Programming

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Abstract

It is often said that computer science is for all students. This implies that it is also for early childhood students, including preschoolers, kindergarteners, and early elementary schoolers. To integrate computer science education into early childhood education, it is necessary to prepare early childhood teachers to do so. In this study, we investigated how and why 15 preservice, early childhood teachers reacted to and addressed challenges when creating block-based programming to control robots. Data sources included classroom recordings, interviews, lesson artifacts, and questionnaires. Analysis strategies included open and axial coding. Findings on hypothesis generation, guess-and-check practice, stereotypical conception, and adaptive attribution to success in programming are discussed.

Keywords
Debugging, early childhood education, teacher preparation, computer science education, programming, educational robotics

Purpose

This study examined how future early childhood teachers address challenges during robot programming. If one wishes to help early grades students learn computer science (K-12 Computer Science Framework Steering Committee, 2016), it is critical that their teachers have the requisite knowledge/skill and adaptive motivation to engage in debugging. Without such knowledge/skill and adaptive motivation, teachers may simply advise students to tinker with the programming code in a haphazard manner or remove malfunctioning sections of code – which are examples of poor debugging strategies (Bers, Flannery, Kazakoff, & Sullivan, 2014; Kim, Yuan, Vasconcelos, Shin, & Hill, 2018; Perkins & Martin, 1985). Simple elimination of a buggy segment of block-based programming code, rather than persistent striving to fix the bug using logical reasoning, has been observed among young children (i.e., 5-6 year-olds) as well as preservice early childhood teachers (Bers et al., 2014; Kim et al., 2018).

Perspectives

Robotics has been successfully integrated into early childhood education contexts, including preschool (Di Lieto et al., 2017; Elkin, Sullivan, & Bers, 2016), kindergarten (Kazakoff & Bers, 2012a), and early elementary (Francis & Poscente, 2017). Key to the success is using robotics not as an end in itself, but rather as a vehicle to help children learn computer science, consistent with the K-12 computer science framework (K-12 Computer Science Framework Steering Committee, 2016). First, by using robotics, one provides something that shows tangible results from writing computer code. This may enhance children's situational interest, and contribute to an enhancement of individual interest related to computer science and engineering over time (Hidi, 2006; Hidi & Harackiewicz, 2000; Linnenbrink-Garcia et al., 2010; Schraw & Lehman, 2001). This, in turn, could lead to such children actively pursuing opportunities to learn more about computer science and engineering as they proceed through their schooling, and also in out of school contexts. To do so, teachers need the skills and dispositions to help their students succeed in this context. That is what this study seeks to address.

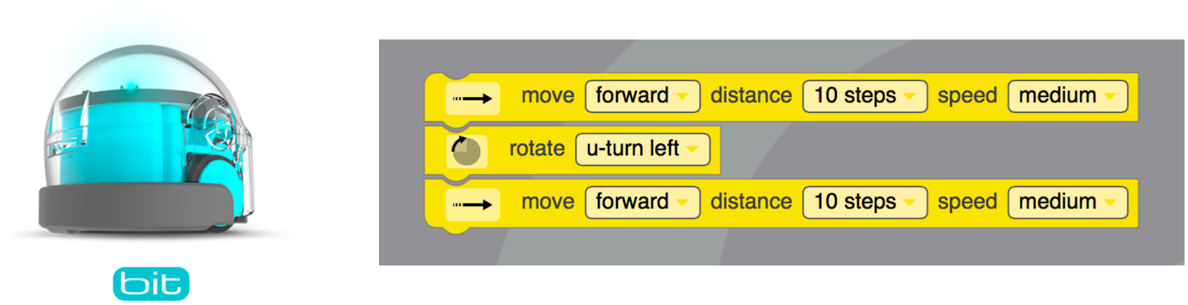

Figure 1. Ozobot and OzoBlockly

To control robot movements, students need to engage in block-based programming (Bers, 2010; Kazakoff & Bers, 2012). While text-based programming languages require abstract syntax (Lye & Koh, 2014), in block-based programming, programming elements are dragged and dropped to form a program (see Figure 1). Block-based programming has been used successfully among early childhood populations. For example, 5-6 year olds instructed a robot to dance the hokey-pokey using block-based programming (Bers et al., 2014). But a persistent challenge has been with debugging. Students who produce buggy programs to control robot movements need to determine the source of the problem and how to resolve it. In one study in kindergarten, as complexity increased (e.g., sensors were added), students tended to choose an alternative program rather than debugging the original program (Bers et al., 2014). Guess-and-check through tinkering was commonly used by students at all levels including kindergarteners (Bers et al., 2014; Silk, Higashi, Shoop, & Schunn, 2009). These debugging behaviors were observed also among pre-service early childhood teachers (Kim et al., 2018), which suggests that few teachers are prepared to help students engage in this kind of problem-solving.

Teachers' problem-solving approach influences that of children. Children often mimic and are guided by teacher behaviors. Such teacher modeling has been used in a variety of contexts including problem-solving contexts (Haston, 2007; Hendy & Raudenbush, 2000; Samarapungavan, Patrick, & Mantzicopoulos, 2011). With young children, teacher modeling can be powerful also in non-academic problem-solving contexts such as pretend play and meal times. Not only what teachers do to model a desired behavior but also how they do so matters. For example, teacher modeling of new food acceptance to preschoolers was effective when the teacher exhibited enthusiasm (Hendy & Raudenbush, 2000). Even without the teacher's intention of modeling, young children often imitate the teacher. In a study with the first and second graders (Beilock, Gunderson, Ramirez, & Levine, 2010), a female teacher's math anxiety was impactful to girls, but not to boys. Deleterious gender stereotypes can occur even without explicit comments related to stereotypical threats (Beilock et al., 2010). Such young children's imitation of teacher emotions (Plante, Protzko, & Aronson, 2010) suggest that early childhood teachers are in the position to implant stereotypical or counter-stereotypical conceptions in young children. In a study with 6-10 year-olds, children began exhibiting math-gender stereotypes in their second grade (Cvencek, Meltzoff, & Greenwald, 2011). Teachers also impact children's adaptive motivation such as growth mindset (Dweck & Yeager, 2019), mastery goal orientations, intrinsic motivation, and persistence during problem-solving. It is argued that early childhood teachers should model mastery motivation and persistence in playful contexts (Sawyer, 2017).

Along these lines, what and how preservice early childhood teachers are prepared to do during debugging could impact what and how their future students do with computer science and problem-solving. For example, girls seeing their female kindergarten teacher be confident and enthusiastic during robot programming may also feel confident when engaging in computer science-related tasks (Burnette et al., 2019).

Thus, the purpose of the present study was to examine how pre-service early childhood teachers approach problem-solving during robot programming. We were specifically interested in their reactions to *challenges*. The research question was: How and why do pre-service early childhood teachers react to and address challenges when creating block-based programming to control robots?

Methods

Research Design

This research is a case study aiming for an in-depth understanding of participants' programming and debugging processes. The unit of analysis was a class of early child childhood preservice teachers who engaged with robotics programming for three weeks. Data examined include video recordings of pair programming and debugging, lesson design using the code, reflections, interviews, and questionnaires.

Participants

Participants were 15 preservice, early child childhood education teachers enrolled in an art-based early childhood education course in a large university in the southeastern United States. Ten indicated low or no knowledge of programming and five indicated intermediate level. The average age was 19.86. Two were African Americans, one was Asian, one was multiracial, and the rest were Caucasians.

Robot Programming Unit

The unit was comprised of three 3-hour classes. In Class 1, educational robotics was overviewed and coding was practiced with Hour of Code and Ozoblockly. Participants also learned a model lesson to be used during their field experience and practiced teaching the lesson with Ozobots. In Class 2, participants debriefed on their field experience and developed a new lesson using the Ozobots with a partner. The lesson was implemented that week during the field experience. In Class 3, participants did another debriefing on their field experience, and were introduced to additional educational robots such as Dash & Dot and Lego WeDo.

Data Collection

The following data were collected for about a month. Classroom recordings (870 minutes and 37924 words), interviews (97 minutes and 17755 words), and reflections (104 prompts and 8042 words). Artifacts included mind maps about teaching with robots, lesson plans, and field experience report on the lesson implementation in preschool classrooms. Questionnaires contained borrowed or adapted items from the STEM Semantics Survey (Tyler-Wood, Knezek,

& Christensen, 2010), Domain Identification Measure (Smith & White, 2001), Patterns of Adaptive Learning Scales (Midgley et al., 2013) and Views of Coding (Yadav, Zhou, Mayfield, Hambrusch, & Korb, 2011).

Data Analysis

Interviews and classroom videos were transcribed, and imported into NVivo 12 along with other data. An initial coding scheme was constructed by the first author based on her open coding of transcripts and literature related on programming and debugging, stereotypical conceptions, goal orientations, and domain-specific beliefs. The initial coding scheme was revised after discussions among the first, second, and third authors. The third author applied the revised coding scheme to coding two interview transcripts, three reflections, and one classroom video. The first and second authors reviewed the third author's coding independently, and then discussed the coding and revised the coding scheme with the third author. The third author applied the re-revised coding scheme to another dataset, and three authors discussed the process and finalized the coding scheme. Then, the third author coded all the data, and the first author reviewed all the coded data to reconcile disagreements.

Findings

The following themes were developed from the data analysis. Only six participants' data are included to illustrate the themes due to space limitations.

Hypothesis generation was guessing immediately before checking

During the interview, participants were asked if they formulated a hypothesis when facing problems with Ozobots. Joy reported no hypothesis because she immediately knew how to fix the bug described as follows: "… just because we knew pretty much what the issue was from seeing it [the Ozobot]." Except for Joy, no one gave a definite "no" answer. Interestingly, even Joy's partner, Zoey, indicated she hypothesized why the Ozobot was not working as intended. However, if there was a testing, participants seem to recall they had a hypothesis – something that was not explicitly spoken about during debugging but that was tested. Similarly, Mia reported she had a hypothesis in her interview but a video segment showing Mia's debugging process illustrates what she meant by a hypothesis: a quick guess during guess-and-check.

Trial-and-error was repeated regardless of its success or failure

Many reported successful trial and error. For example, during her interview, Zoey said she ended trial and error when she got a positive result. Even the trial-and-error without success was repeated as Mia describes: "We had to like be very specific with our code and added a lot of different things to make a turn the way we wanted. And we never really did figure out how to get it go..."

Pleasure from serendipitous discoveries and expectation for such pleasure seem a force for repetitive actions of trial and error as depicted in discourse between Joy and Zoey during debugging:

Joy: And then I'd have it turn left. Slight left maybe? That's what I'll say. Slight left.
Zoey: Instead of rotating left, maybe just slight left.
Joy: Yeah. Try this.
Joy: Alright, let's see. Here we go. Oh my gosh, I did it. I did it. Wow! The slight left!
Zoey: The slight left, it worked.

Even vicarious pleasure from seeing others' serendipitous discoveries motivated repeating trial and error. A scene from Luna's video shows that her vicarious success from her partner's success motivated her to continue trial-and-error.

Luna: Wow, yours is doing good [to her partner]. I think I need to do it again.

Luna: It worked! It worked! It worked this time.

Deleterious stereotypical conception about programming disappeared among self-efficacious participants

Zoey began the unit with deleterious stereotypical conception about programming. Such conception was from no early exposure, according to her. Later her interview suggests, her stereotypical conception was removed: "It [programming] was fun for me because, well first it's easy. I had never had much experience with it before... But with Ozoblockly it's just block coding, you're just dragging blocks and it's a lot easier than what people think."

However, with a lack of self-efficacy, it seems stereotypical threat remained. In her reflection during Week 2, Belle said "Technology stresses me out" and during Week 3, she noted "Robot makes me too anxious, I'm not good with tech…" In contract, Joy who thought she was good at technology exhibited changes in her conception about programming like Zoey.

Adaptive attribution to success in programming was reflected in persistent actions despite discourse implying impersistence

Participants with adaptative attribution continued their work even when they expressed a desire to give up. For instance, Mia attributed success in programming to interest, patience, and time investment, which was aligned with her persistent action during debugging shown in her classroom video even though she sometime said "I give up" out of frustration.

Conclusion and Significance

The findings inform redesign of the robotics unit in ways to (a) facilitate adaptive attribution to success in programming, (b) remove stereotypical threat about programming through self-efficacy building, and (c) benefit from persistent guess-and-check practice. Detailed findings and discussions in light of the literature will be included in the full paper.

[Word Count: 1995]

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