SciGirls Code: Computational Participation and Computer Science With Middle School Girls

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Abstract: SciGirls Code is a project comprised of 16 STEM outreach programs that provided 160+ middle school girls with computational thinking (CT) and coding skills between September 2017- June 2018. The research study investigates the ways in which these learning experiences impact girls' development of CT; interest and attitudes toward computer science; and their understandings of how participation in creation with technology impacts themselves and the world around them. Utilizing a qualitative multi-site case study design, the study found that a connected learning approach boosted the development of girls' CT skills, positively impacted attitudes towards computing pathways/careers, and increased understandings of computational participation. In addition, the educational experiences happening throughout the SciGirls Code program exemplifies the 4E learning model. Implications include how technology can be leveraged towards creating an inherently collaborative setting, acknowledging social, emotional, cultural, technological, and cognitive intersections in learning.

Major issue addressed and potential significance

Women remain significantly underrepresented in the STEM workforce within the United States, particularly computer science. Women constitute only 25% of the computing workforce despite it being the STEM area with the most demand (Pew Research Center, 2018). Notably, the number of women in computing occupations has actually declined over the past 25 years (Pew Research Center, 2018). While NCWIT (2017) reports that 1.1 million computing job openings are expected by 2024, men constitute 81% of the computer/information sciences degrees conferred in the 2015-2016 academic year. Although more bachelor's degrees are conferred to women, computer/information sciences degrees make up only 1% of degrees conferred to women (NCES, 2017).

The issues that contribute to the computer science pipeline deficits are complex, and they begin early. For example, in 2018 girls represented only 28% of AP Computer Science (CS) test-takers (www.code.org). While this represents a slight increase from 2017 (26%), it demonstrates a continued, dramatic discrepancy between genders. *Girls in IT: The Facts* (Ashcraft, Eger, & Friend, 2012), a summary of research regarding factors that contribute to the gender gap in computer science education, suggests these ongoing issues: 1) curriculum that is irrelevant; 2) pedagogies that discourage collaboration; 3) lack of opportunities to take risks and make mistakes; and 4) heavy reliance on lecturing instead of hands-on, project-based learning. Starting early with interventions that introduce girls to computer science in elementary and middle school can help increase interest in CS; cultivating early interest is paramount because *interest* in STEM fields in high school, rather than *achievement* in these areas, is more closely associated with pursuit of careers in computer science (Corbett & Hill, 2015).

SciGirls Code is a project that aims to address the gender equity issue in the field of computer science by targeting middle school girls (Blikstein, 2018), which is the age when girls begin losing interest in STEM areas (Microsoft & KRC Research, 2018). SciGirls Code worked with 16 STEM outreach programs to provide 160+ middle school girls with computational thinking (CT) and coding skills within informal education spaces. The project theorized that a connected learning approach, which is based on sociocultural learning theory (Cole, 1998; Vygotsky, 1978), with the active support of trained educators and role models, would boost the development of middle school girls' CT skills, attitudes towards computing pathways/careers, and understandings of how participation in technology creation impacts themselves and the world around them.

Theoretical approaches

Connected learning and computational participation

The connected learning model advocates that "the most resilient, adaptive, and effective learning involves individual interest as well as social support to overcome adversity and provide recognition" (Ito et al., 2013, p.4). With an emphasis in meaningful practices and supportive connections with others, this model identifies three contexts for learning: peer-supported, interest-powered, and academically-oriented. We applied connected learning in this project in order to understand how girls expanded their interest within production-focused CS activities and how they empowered their own learning within a gender-equitable, peer-supported environment.

Connected learning, in combination with computational participation, anchors our project and its research agenda. Computational participation (CP) is explained as "connecting through making, which leads to deeper, richer, and healthier connections among online youth" (Kafai & Burke, 2014, p. 132). With sharing and collaboration at its core, CP is described as "solving problems with others, designing intuitive systems with and for others, and learning about the cultural and social nature of human behavior through the concepts, practices, and perspectives of computer science" (Kafai & Burke, 2014, p. 128). CP, therefore, represents a shift from the previous "individualistic view of computing" to a view that focuses on "sociological and cultural dimensions" (Fields, Kafai, & Giang, 2017, p.2). Kafai and Burke (2014) suggest that computer programming "represents a crucial beginning step", "a form of expressing oneself", and "a community practice" to approach CP (p. 128).

Computational thinking

Rooted in computer science, computational thinking (CT) is viewed as "a universally applicable attitude and skill" (Wing, 2006, p.33) that involves analytical thinking (Bers, 2018) and the process of problem-solving (ISTE, 2016). Bers (2018) argues, based on Papert's (1980, 1999) earlier ideas of learning through making and "hard fun," that CT is not only "involved problem solving, but also a notion of expression" (p.60). Operationally, this study's research methods are grounded in a CT framework (Brennan & Resnick, 2012), which encompasses three dimensions: 1) concepts (e.g., sequence, loops), 2) practices (e.g., debugging, remixing, and 3) perspectives (e.g., expressing, connecting). We documented and assessed girls' knowledge of computational concepts and abilities to employ them using computational practices.

Fusion of ideas

We integrate a CP framework with connected learning in order to examine how middle school girls made sense of their participation with respect to their social and cultural contexts as they learn to code (Kafai & Burke, 2014; Ito et al., 2013). Burke and colleagues note that "whereas computational thinking uses an algorithmic lens toward problem-solving, computational participation extends this thinking beyond the individual to integrate social networks and digital tools in a networked society" (Burke, O'Byrne & Kafai, 2016, p.373). Similarly, we believe that a computational participation framework enables us to conceptualize how connected learning contributes to various aspects of CT development as well as interest in computer science.

Methodological approaches

Overview

The research study investigated the ways in which computational learning experiences impacted girls' development of CT *[RQ1: Learning]*; interest and attitudes toward computer science *[RQ2: Interest]*; and their understanding/appreciation of how participation in creating with technology impacts themselves and the world around them *[RQ3: Participation]*. This study utilized a qualitative embedded, multi-case study design (Merriam, 2009). The 7 focal cases represent an array of settings (rural, suburban, urban) as well as a variety of programming contexts (museums, community centers, after school). The remaining 9 sites comprise the participating cases.

Data collection paralleled curriculum implementation at program sites occurring between late August 2017 – early August 2018. There were multiple data sources with different data collected at focal and participating sites. Focal programs were visited face-to-face, and participating site participants were engaged digitally. Notably, artifact-based interviews (in-person at focal sites) and shorts (video at participating cases) were collected from girls at three moments in the programming (beginning, middle, and end) in order to document any changes/growth in understandings and skills. Other data sources include girls' pre- and post-program survey, curriculum artifacts including FlipGrid videos (https://flipgrid.com), and facilitator interviews. Approximately 88 girls across all sites participated in all research activities during the year-long programming.

Analysis

There were two distinct stages of analysis; the first stage was the within-case analysis and the second stage was the cross-case analysis. For the within-case analysis, each case category (focus or participating) was first treated as its own case. Sub-unit analysis resulted in portraits of individual programs. Portraits were woven together to develop separate case narratives for focal and participating cases (within-case analysis). Next, these narratives were used to inform the cross-case analysis of all programs (in progress). All data were reviewed and coded first to align with related research questions and hypotheses. Next, using research questions as the anchors, open-ended survey data as well as interview/short transcripts were analyzed using qualitative content analysis (Saldaña, 2013). Open coding processes were followed by grouping open codes into analytical/interpretive codes resulting in thematic findings (Harry, Sturgis, Klingner, 2005). Both open and analytical coding were done with common data sets by at least two researchers who engaged in clarifying conversations during these iterative stages.

Major findings and implications

Due to this project's timing and CSCL's deadlines, this proposal briefly highlights initial findings related to our study's third research question [RQ3: Participation].

Girls' overall attitude about teamwork

In the preliminary survey findings, girls' responses to the question, "*I can do different things when I work with others than I can when I work alone*" identified that the majority of girls hold positive attitudes toward teamwork (e.g., 68% indicated strongly agree or agree in the pre-survey compared to 75% in the post-survey). There is evidence that some girls who shared their concerns about teamwork in the pre-survey changed their attitudes in the post-survey.

Cross-case analysis of girls' reflections on teamwork

Teamwork is essential in CS activities

Teamwork with others is valued by girls. By the final interview, many girls reported teamwork and the ability to work with others as the biggest takeaway from their experiences in SciGirls Code. In general, girls had an evolving sense of how teamwork was a significant part of doing CS activities.

Teamwork contributes to growth in problem solving

Overall, girls' view of the SciGirls Code group work was positive, with girls citing building strong friendships, growth in problem solving, and gaining teamwork skills. Despite feelings of frustration and stress, many girls mentioned how helpful it was to have other people to work with and to assist in troubleshooting when problems arise.

Teamwork nurtures creative freedom and ownership

Teamwork was instrumental in nurturing girls' sense of creative freedom and ownership through channeling their friendships towards choices and decisions related to how they engaged with tasks.

Themes situated with the 4E learning model

The educational experiences happening throughout the program exemplify the 4E learning model: embodied, enactive, extended, and embedded cognition. While the individual program sites provide unique contexts for learning, we found central themes derived from the program design and curriculum that resulted in common outcomes for the girls. For purposes of this paper, we situating these themes within two aspects the 4E learning model: embodied and enactive cognition.

Embodied

Findings indicate that the participants at multiple sites wrestled with sense-making of both CT concepts and practices while engaged in physical interactions with technologies and other aspects of their learning environment. For example, at the end of each unit was a makeathon that challenged the girls to use the computational knowledge and skills scaffolded throughout the unit to create an end project in teams. These products were often the highlight of girls' experiences in the program. The teams had autonomy over their final artifact including its aesthetic, applicability, and functionality. The process of making decisions and having independence over their creations resulted in the girls' ownership and pride in their creations. Another source of pride was the success they experienced after facing constant challenges with the technology. Girls indicated they consistently used the CT practices of debugging and problem solving. The physical act of examining code, (de)constructing their code to understand the issue, and then celebrating when challenges were overcame made learning visible. "When we figured something out, I think that we felt like, you know that feeling when the light bulb goes off in your head?" (Hannah, Team Draco, Interview 1). The girls began to expect challenges when computing and their confidence grew as the program went on; "I think that they have the confidence that they can problem-solve when they come up against something they're not familiar with. I don't know that they had that before" (Adult facilitator, Canis Major).

Enactive

Through our multiple interviews with the girls during the year, we were able to understand how the girls conceptualized new understandings about computing over time. The dynamic interaction between each girl and their peers, their adult facilitator, the curriculum, the physical setting, the volunteer mentors, and the technology, resulted in transformational perspectives of themselves and their role within computing. All of the activities in the SciGirls Code curriculum were designed with collaboration in mind and allowed girls to reconceptualize computer science as a participatory field rather than seeing it as an isolated relationship between a person and a computer. For instance, in the mobile app-making unit girls learned about pair programming, where one is given the role of driver and another is the navigator. Pair programming was a popular concept many girls throughout the sites identified as something they learned: “Pair programming--I didn’t know that two people could work on the same thing, and like help each other. I thought it was like maybe just one person and then another person just check[s] over it” (Katelyn, Team Mensa). Emma from Team Lynx found group work to be important to the coding process: “Yeah working in groups I feel with coding is a lot easier than working by yourself.”

New models for learning 4E

Each of the SciGirls Code program sites serve as uniquely complex system but all sites had collaborative, computer-supported, and interdisciplinary factors. The 4E cognition aligns with the connected learning framework in that girls move from embodied and individual views of computing to the role of computing in society and embedded settings (Fields, Kafai, & Giang, 2017; Ito et al., 2013, Newen, De Bruin, & Gallagher, 2018). The result of these embedded factors included girls’ increased understandings of and skills related to computational thinking; increased interest and confidence in computer science; expanded understanding of the role of computing in society; and how they can engage in and shape technology. We offer collaborative learning as not just a learning phenomenon that needs to be further understood by researchers but as an essential factor for addressing gender equity within computing.

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Acknowledgments

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