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Equitable approaches: opportunities for computational thinking with emphasis on creative production and connections to community

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ABSTRACT

Decisions about participation in computer science and engineering opportunities are often made prior to high school, and these decisions are frequently mediated by prior experience, interest, and sense of fit with community. In this article, we investigate how the Digital Youth Divas, an out-of-school program for middle school girls from non-dominant communities, engaged participants in computational thinking linked to their broader interests, home networks, and continuing opportunities. Results indicate increases in knowledge measures for girls with and without prior learning experiences and provide evidence that through project work and a strong focus on building community, girls engaged in computational practices in ways that shifted or provided new computational perceptions about themselves and the domain. This exploratory study of the Digital Youth Divas program emphasizes the importance of understanding and supporting computational perceptions alongside deepening knowledge and experience.

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Computational thinking; identity; equity; learning ecologies; out-of-school learning

Introduction

In the United States, equitable opportunities to develop computational thinking fluencies are especially critical for women and students of color, who tend to have less access to rigorous math and science classes and who continue to be underrepresented in computing and engineering fields (NSF, 2017; US Civil Rights Data Collection, 2014). A number of recent initiatives attempt to address the lack of diversity and inclusion in the computing education landscape. Code.org has curated and organized free online coding activities and used media campaigns to launch participation at scale through events such as Hour of Code (Hour of Code, 2017). The *Exploring Computer Science* curriculum (Goode & Chapman, 2016) and *Principles of CS AP* (UC Berkeley & EDC, 2017) offer computational topics and projects to high school students in ways that do not assume prior experience. Despite more resources and opportunities, there are persisting disconnects between introductory experiences and next steps in computational thinking and learning pathways, and this is true especially for underrepresented populations (e.g. Margolis, Goode, & Chapman, 2015; Pinkard et al., 2016). Studies have found that pervasiveness of social orientations, including negative stereotypes about girls and non-dominant students' STEM abilities and interests and a lack of sense of community and belonging within STEM classrooms and fields, impact interest, engagement, and ultimately participation (e.g. Cheryan, Davies, Plaut, & Steele, 2009; Margolis, Estrella, Goode, Jellison Holme, & Nao, 2008). Recent work by Fields, Kafai, Nakajima, Goode, and Margolis (2018), summarizes

that there are in fact three critical issues of equity that need to be addressed in order to support all young people in computational learning and related pursuits: broadening access; diversifying representations of people, practices, and artifacts; and deepening participation and knowledge.

In this paper, we contribute to the broader research and design work that understands inequity as more than just an issue of access. We share the intentional design of a learning environment that supports middle school girls to engage in *computational making* while simultaneously developing a community that makes and learns together. We describe the Digital Youth Divas program (DYD), including specific components of the environment intended to address issues of equity, and investigate outcomes related to deepening knowledge and developing new perspectives about computational work. The results are organized around three primary questions: (1) Did participants develop and deepen their computational knowledge? (2) To what extent did participants experience computational thinking concepts and practices? (3) How did participant computational thinking perceptions shift or emerge over the course of the program? We close with design implications.

Multidimensional views of computational thinking

The urgency behind ensuring that all youth can think computationally is often linked to skills and understandings required to adapt to the quickly changing workforce. Without better preparation, increased gender and race inequality and income polarization is predicted (McKinsey Global Institute, 2017). But while the term computational thinking frequently describes learning outcomes and expectations, exact definitions vary. Wing's original definition is expansive (2006), emphasizing the scope of ideas and processes in computer science that are transferable. Operationalized definitions for computational thinking in K-12 commonly include learning concepts of sequences, conditionals, iterative loops, and parallel processing, as well as practices of decomposition, abstraction, developing algorithms, debugging, and automation (e.g. Barr & Stephenson, 2011; Brennan & Resnick, 2012; Grover & Pea, 2013). Some definitions take a holistic approach. DiSessa (2001) uses the term computational literacy to describe fluency with computational materials, ideas, and representations that can be shared with others. Brennan and Resnick (2012) use a tripartite framework of concepts, practices, and perspectives to articulate computational thinking, the latter referring to ways in which individuals see themselves as computational thinkers. Tissenbaum, Sheldon, Soep, Lee, and Lao (2017) describe computational identity as being able to think computationally and participate in the computational community more broadly.

In this paper, we refer to the more multidimensional views of computational thinking that give attention to a youth's larger learning ecology (Barron, 2006), identity, and social network and we regard those factors as essential to encouraging and supporting participation from underrepresented groups. Young women, especially those of color, frequently face an "identity gap" in terms of science and engineering, finding it difficult to imagine themselves in these roles (Tan & Barton, 2016). Environments that allow learners to engage in STEM-related practices alongside practices that connect with other parts of their identities can support recognition and development of STEM identities (Tan, Calabrese-Barton, Kang, & O'Neill, 2013).

Engagement through computational making and participation

Quantitative and qualitative research has linked youth computational making projects to important outcomes. Practices and artifacts are connected to the development of computational maker identities for youth participants (Barron & Martin, 2016; Kafai & Burke, 2014; Pinkard, Erete, Martin, & McKinney deRoyston, 2017). Transparency of materials and construction can support the development of conceptual STEM understanding (Peppler & Glosson, 2013) and open-ended design challenges encourage the engineering practice of persistence (Litts, Kafai, Searle, & Dieckmeyer, 2016). Opportunities and support for youth deepening participation and knowledge beyond an initial experience, however, continues to be of concern for those interested in addressing inequities in

computing learning and education. Even in open-access programming environments such as Scratch, with millions of registered users, only a relatively small group is participating fully in the community (Fields, Kafai, & Giang, 2017) and girls are less likely to be the ones engaging with more advanced programming tools and practices (Fields, Giang, & Kafai, 2014).

Recent work emphasizes how the practice of making is always linked to individual and social histories (Barton, Tan, & Greenberg, 2016), providing both barriers and potential learning opportunities for individuals and learning environments. Computing and engineering curricula that leverages non-traditional computing and engineering materials and practices (e.g. textiles, stitching, creating wearable designs (Buechley, Eisenberg, & Elumeze, 2007), 3D storytelling (Kelleher, Pausch, Pausch, & Kiesler, 2017), and embodied dance (Champion, 2018; Daily et al., 2014) is one approach to connecting to youth practice-linked identities while deepening computational knowledge. In their research in indigenous communities, Searle and Kafai (2015a , 2015b) highlighted how culturally-responsive e-textile projects afforded the development of youth design agency as they made decisions about what they created, and artifact boundary crossing between home and school as students and families shared knowledge and expertise.

Studies also highlight the importance of making and production activities not in isolation, but grounded in social communities, where people work side-by-side and showcase and discuss work and ideas. Kafai and Burke (2014) highlight that computational work is creative and social, reframing a more isolated view of computational thinking and programming to one that involves *computational participation*, including creating artifacts that can be shared and remixed, and developing personalized projects. Research in learning through computational making has revealed the importance of social practices such as mentoring and collaboration (Barron, Gomez, Pinkard, & Martin, 2014; Pinkard et al., 2017), informal discussion about content areas (Peppler & Glosson, 2013), social interaction through shared activity and play (Vossoughi, Hooper, & Escudé, 2016), and how support of communities of practice can change perceptions about connections between STEM content and larger networks, including families (Martin, Pinkard, Erete, & Sandherr, 2017; Roque, 2016).

Digital Youth Divas

Recruitment for the free program focuses on sixth grade girls from communities underrepresented in computer science and engineering, particularly those who may not consider themselves to be interested in computing and technology. Five components are intended to support participation and identification with a community of computational makers alongside broadening and deepening computational experiences and knowledge through design-based project work: (1) self-paced, project-based computational learning activities; (2) a face-to-face community of learners including adult mentors and collaborative peers; (3) an online social learning platform where girls access project instructions and other learning resources, develop a portfolio of submitted work, and interact with others around projects; (4) alternative instructional resources including narrative stories that launch project work; and (5) resources and workshops to establish a network of parents and caring adults (Pinkard et al., 2017). Below we describe more about how the components work together to support girls in gaining experience, understanding, and practice.

Design and personalization through project-based work

The Digital Youth Divas program is developed to support participants with varying levels of prior experience through open-ended project work. The majority of program time is open studio, with girls making progress on projects and seeking help from available resources, peers, and mentors. Program units are sequential, but open-ended project descriptions and instructional supports embedded into the online platform allow girls to go at their own pace and connect to the program from home as needed.

Projects use fashion and dance as contexts for computational work in engineering (the e-Fashion unit) and programming (the e-Dance unit), building on existing non-traditional computational

curriculum (Peppler, Gresalfi, Tekinbas, & Santo, 2014) and tools (Daily et al., 2014). The e-Cuff project requires two submissions: the ideation and construction of a paper prototype and the design and development of a bracelet using fabric, decorations, conductive thread, a snap (used as a switch), a battery, and LED lights. The dance challenge requires written pseudocode and a finished program in the Virtual Environment Interactions (VENVI) introductory programming environment, emphasizing creativity in the development of a dance routine in a system which itself supports personalization through customization of gender, skin tone, and body shape of dancers (Lin et al., 2017).

Alternative representations through community and learning resources

The Digital Youth Divas community of learners includes adult mentors supporting girls on and offline, peers working collaboratively and sharing ideas, and parents and/or caring adults supporting the girls outside of the program. The face-to-face program offers regular opportunities for formative feedback as girls work side-by-side and mentors check in on progress at each session, with more summative feedback at parent showcase events. Weekly emails home to parents and caring adults share images of projects and suggested questions to ask girls about content and design decisions. The online space allows girls to receive feedback from mentors and peers and to view and critique the work of others, and supports girls to share their personal online portfolio outside the program. Additionally, representations of computational practitioners in learning highlight a range of people engaging in computing and engineering. Narrative stories used to launch projects include middle school characters from a variety of racial and ethnic backgrounds and with a range of interests. How-to visual guides feature experts who are young African American women.

Computational thinking

In Table 1, we operationalize computational thinking for Digital Youth Divas using Brennan and Resnick's framework (2012) and incorporating other multidimensional interpretations (e.g. DiSessa, 2001; Kafai & Burke, 2014; Tissenbaum et al., 2017). This is not a definitive interpretation, but rather a framework aligned with DYD intentions to support shared understanding for program researchers and practitioners.

Methods

Participants

We share results from one cohort of 98 girls over the course of a 20-week Digital Youth Divas implementation. The program met for three hours on Saturdays at a central location in the city. Fifty nine percent of participants identified as Black, 18% as Latina, and 11% as mixed race.

Table 1. Organizing and operationalizing computational thinking for DYD.

Dimension	Component	Description
<i>Concepts</i>	Algorithms	A process or set of instructions to solve a particular problem
	Conditionals	Decisions made based on defined conditions
	Efficiency	Ways to make a working solution even better
	Iteration	A step or series of steps <i>repeated multiple times</i>
	Sequence	A specific order that a series of steps follows
	Parallelism	Steps that happen at the same time
<i>Practices</i>	Abstraction	Finding patterns and selecting what to focus on
	Automation	Using an information processing agent (machine or human) to interpret solution
	Computational collaboration	Working on and sharing computational projects and discussing work and ideas
	Decomposition	Breaking down a complex problem into manageable parts
<i>Perceptions</i>	Testing and debugging	Finding and solving problems
	Computational identity	Thinking of oneself as someone who can create using computational practices
	Connecting to other topics	Recognizing connections between computational projects and other topics
	Connecting to community	Recognition of people/places outside program that can connect to computational projects
	Expressing	Realizing that computational projects can be creative and expressive

Socioeconomic status varied. Household income spanned from under \$20 K (12%) to over \$100 K (22%), with a median range of \$50–70 K (23%). While 37% of girls' parents did not graduate from college, 31% had advanced graduate degrees. Girls ranged in age from 10 to 14 years old, with the largest proportion (33%) being in the sixth grade. Girls were distributed across five classrooms, roughly organized by age. Each classroom was facilitated by two mentors who were female undergraduate students majoring in non-engineering disciplines.

Data collection and analysis

We used multiple methods at different levels of analysis to address our research questions. At the cohort level ($N = 98$ girls), we collected pre and post program measures and documented activity in the online platform. To document how production unfolded in the face-to-face space, we observed one focal classroom regularly ($n = 24$ girls, 25% of the cohort). To learn more about individual experiences and ideas for the future, we conducted interviews with a subset of girls in the focal classroom ($n = 6$, 25% of the class). Our approach reflects growing understanding that supplementing traditional methods of STEM assessment (e.g. surveys) with socially-grounded strategies that look across spaces is critical, especially to better understand and design for unique populations of learners (Barron & Bell, 2015; Bevan & Michalchik, 2013). Strategies are described in more detail below.

Pre-post survey knowledge assessment

We administered a 10-min pencil and paper knowledge assessment to all participants at the beginning and end of the program to analyze knowledge gains over time. Program attendance varied from week to week, resulting in pre/post comparisons for 42 girls.

The assessment included questions about circuitry and programming adapted from those used with similar curricular projects (Daily et al., 2014; Peppler & Glosson, 2013). In this paper, we present results from two questions that were related to computational thinking and that were program and context independent. The circuitry item asked participants to draw the connections required to model a working series circuit from a battery and an LED light both with positive and negative terminals. The programming item asked participants to define programming in their own words.

The lead researcher and two research assistants developed a scoring framework on a 4-point scale from 1 (did not try to answer or not at all correct) to 4 (fully correct) for each question. The research assistants independently scored a subset (25%) of assessments from a prior program implementation and achieved an acceptable inter-rater reliability of 76% (Erete, Martin, & Pinkard, 2017). In this analysis, the same two research assistants scored the assessments stripped of identifying information and discrepancies were resolved as a group.

Thematic coding of qualitative field and interview data

Qualitative data included field notes from observation of on and offline environments and interview transcripts (36 documents totaling 256 pages). One member of the team conducted weekly digital ethnographies (Hine, 2008) of the Digital Youth Divas platform using field notes and screenshots to document online activity and interactions (98 pages). The sixth grade classroom was selected for in-person observation as representative of the program target age group. Observations were recorded through field notes with embedded photographs (109 pages). Six girls were selected from the focal classroom as case learners. Girls who came regularly to the first three sessions were chosen randomly from those that represented more and less prior experience. Case learners were interviewed two times during the program (in the middle and near the end). Artifact-based interviews (Barron et al., 2014) used the online portfolio as a shared reference point to discuss process, connections to people or practice outside the program, and plans for learning more. Four girls participated in both interviews, and two participated in the first only due to absences. Interviews were approximately 20 min and were audio recorded and transcribed (49 pages).

The research team coded the corpus of qualitative data using a codebook developed during a prior program implementation (Pinkard et al., 2017) consisting of 77 emergent codes. In this article we present data from four codes that relate most closely to our research questions: *STEM identity* (relates to or positions a student's STEM identity, someone who engages in science, technology, math, and engineering work), *artifact identity* (youth connecting a specific artifact or material object to some aspect of their own identity), *programming* (reference or interaction that relates to programming or coding activities, tasks, interests, or challenges), and *circuitry* (reference or interaction that relates to circuitry activities, tasks, interests, or challenges). Throughout this paper, pseudonyms are used to refer to individual learners.

Results

Developing and deepening knowledge

Half of the participants reported prior classes in circuits and electricity, and 65% reported classes in computer programming or computer science. Because lack of prior experience is a documented barrier to engagement with computational learning for women and minorities (e.g. Margolis et al., 2008), and because the Digital Youth Divas model intends girls at different levels of expertise to participate in the same community of practice, we wanted to ensure that all girls increase their knowledge. Our first analysis utilized traditional pre/post measures to look at the change in recognition and understanding of computational concepts.

Repeated measures ANOVA with prior experience as the between-subjects factor yielded positive gains for both items. Participant drawings of a series circuit become more accurate over the course of the program ($F(1,38) = 20.87, p < .001$), and this was true for those who had and had not had prior coursework in or out of school with circuits and electricity (Figure 1). Those who had prior knowledge scored higher at both pre and post than their less experienced counterparts.

Participant definitions of programming also improved significantly over the course of the program ($F(1,43) = 39.25, p < .001$), and again this was true regardless of prior experience in computer science or programming (Figure 2). For this item, experienced groups scored almost identically at pre and

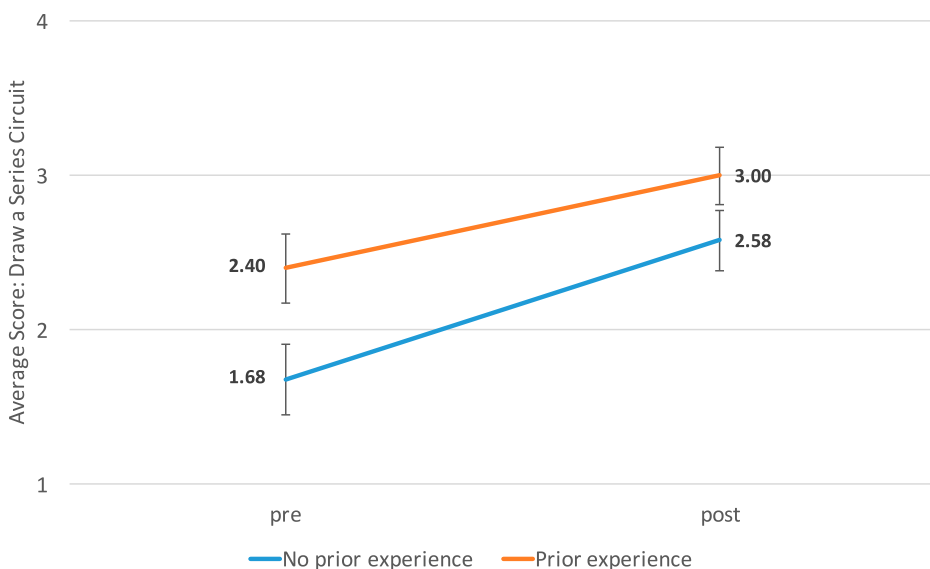


Figure 1. Average participant circuitry knowledge assessment score at pre and post-test by prior circuitry learning experience.

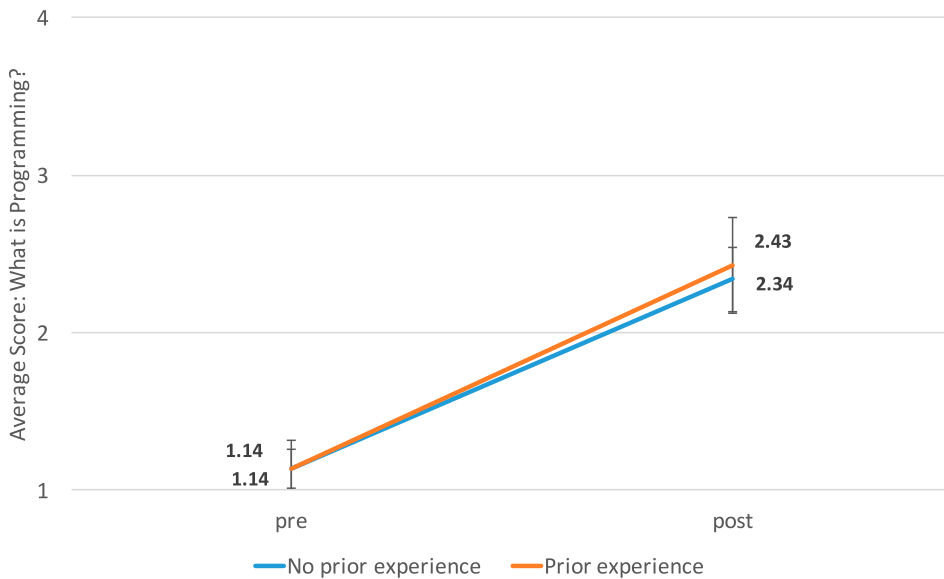


Figure 2. Average participant programming knowledge assessment score at pre and post-test by prior programming learning experience.

post surveys. In qualitative data, girls describe school opportunities like Hour of Code that emphasized engagement in programming practices, but were limited and did not often include sustained work or additional opportunities, perhaps accounting for girls' affirmation of experience but lack of evidence of prior knowledge.

Extent of experiences with computational thinking

Concepts and practices encountered during creative computational projects

To look more explicitly at what computational content (Table 1 concepts and practices) girls encountered across the two project units and to what extent, especially given the open-ended design and production process, we explored qualitative data documenting the two focal design projects. Projects offered opportunities for a number of computational concepts (algorithms, iteration, efficiency, sequence, parallelism) and practices (abstraction, automation, collaboration, testing and debugging), but these were variable for individual learners and even when evidenced, they were not necessarily named or recognized by mentors or girls.

For example, the e-Cuff project evidenced girls thinking through the sequence of steps that enabled a working bracelet (Figure 3) and testing and debugging their work. Peppler and Glosson (2013) suggest that the tangible constructed artifacts of projects like the e-Cuff can make visible the underlying structure of the series circuit. As case learners explained their design process for the e-Cuff, all articulated a *sequence* of procedural project steps, understanding the problem space and materials that are required for that sequence to work. One participant described the flow of electricity as a “circle” when explaining why her bracelet worked, saying that when the pieces are in place “they would just fit like a puzzle piece” [Jude interview]. Girls also shared evidence of sustained *testing and debugging* techniques to achieve a working solution (bracelet lighting up).

It's a bracelet that you make, and you design it yourself. And then you have to set up the LED, and you have to make sure that you have the conductive thread in the right place, and that you sew everything right. If you have the negative on the wrong side, it won't function. And if you have your conductive thread, if it's not sewn right, it's not gonna work. Like mine, it didn't work. I had to take out the conductive thread. And then me and my dad, we sewed it back. [Khelani interview]

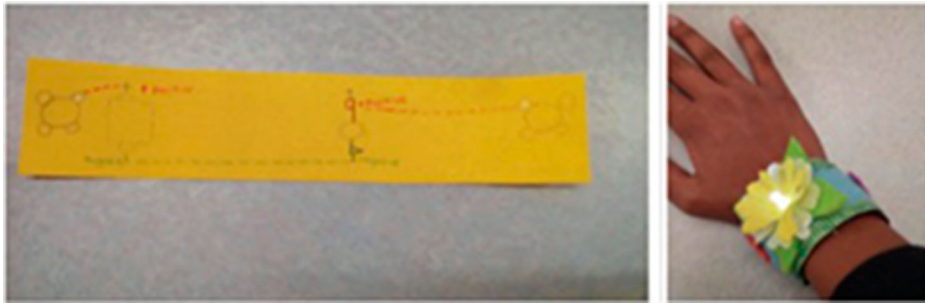


Figure 3. e-Cuff paper design prototype submission and final artifact submission.

In the focal classroom, four girls who finished their e-Cuffs early created and submitted related designs using the same technical structure and materials, such as an LED purse and a light-up bow tie. These girls designed a creative solution as they developed and used a slightly different *algorithm* to achieve their planned artifact.

As another example, the VENVI dance routine challenge provided explicit opportunities for new computational concepts such as efficiency, parallelism, conditionals, and iteration and practices of abstraction and automation, but these were less uniformly utilized when girls worked on their own. At first the girls worked together as a class. Participants started on paper by breaking popular dances into a sequence of steps, identifying *sequences* and those that happened in *parallel* (like hands and feet together), and chunking dance sequences that repeated (*abstracting* out the high-level patterns). Mentors did not use these formal terms in the program, but did explain the practices and concepts to the girls as related to their activity. Teams then developed their own dance as a written series of commands and engaged in the computational practice of *automation* as a human information-processing agent (Wing, 2008) interpreted written instructions. Some team members called out commands, some enacted the commands (Figure 4(a)), and one edited their written code as necessary. During this phase, girls articulated ideas for arranging commands, organizing and reorganizing them.

Yasmine is watching the [dance] demo video. Nayomi sees one of the moves she needs and says to herself, “I think this one should be before the other one.” Nayomi goes back to the table and starts writing the moves on the paper. [Field notes]

For the remaining weeks, individuals and pairs worked independently to further the automation process, translating their dance to the VENVI programming environment. Although girls chunked



Figure 4. (a) Girls performing the dance moves as written out by their team members and (b) VENVI character designed by girls.

and repeated instructions in the pseudocode activities, a number of girls used only sequential steps of pre-programmed moves to map out the dances in VENVI. Others created more efficient instructions for the characters using parallel processing (*do together* command), iterative loops (*repeat* command), and creating their own function holding their proposed dance steps (*my move* command). In three classrooms, upwards of 80% of final programs used at least one of these VENVI commands while in the other two classrooms over 75% of students used only line-by-line sequential steps to create programs. Although the code may have worked to create the intended dance, there was no attention to *efficiency*. This suggests that it was not the features of the VENVI system or the project, but rather the within-class social practices of the mentor or the girls that led to more computational thinking strategies such as reusing code through iteration and enhancing their moves using parallel processing, and perhaps more emphasis on the concept of efficiency.

One consistent practice for all learners in both projects was that of *computational collaboration*, evident through field notes and photographs as the girls worked side-by-side at large communal tables over multiple weeks, talking about their projects fluidly with other topics of interest and sharing classroom resources. Also consistent was student personalization of the projects. For the e-Cuff, girls chose their color palette, technical structure, and attached sewing notions such as ribbon and sequins. As found in previous research regarding engagement with computational thinking (Lin et al., 2017), girls adjusted VENVI character features to resemble themselves in terms of skin tone and body shape (Figure 4(b)).

Individualized use of resources to support open-ended computational project work

In both projects, girls were tenacious in their quest to create what they had prototyped. The majority of final submissions were accompanied by comments suggesting extensive testing and debugging, such as, “It was hard work and it took a while, but we FINALLY got it” [Online field notes]. For both projects, production speed ranged from learner to learner. The period from project introduction to final submission of the e-Cuff ranged from two to five weeks and the duration for the VENVI project ranged from one to three weeks.

Girls used various programmatic learning resources to make progress. Some learners embraced the website and used it outside of program time, including launching the how-to videos and taking screenshots of PDF guides for later use. Others did not use the website beyond required submissions, instead getting help in the face-to-face space from mentors and peers. Girls also looked at completed work as a learning method, and this happened both in the classroom and online, sometimes leading to more expansive learning and teaching opportunities.

I looked at some people’s work [online] and it was really, really good, and I thought, “How can I make mine like that?” And I learned that I could ask some of the people that was in my group. And I asked them how did they get theirs so good. And some, they told me the process and stuff. [Khelani interview]

Developing computational thinking perceptions

One case study learner described the online Digital Youth Divas space as a place where “people won’t make fun of [my work] and stuff, and they understand the process that you went through and they see all the hard work that you did” [Khelani interview]. In this environment, girls exhibited shifts in computational thinking perceptions, including more creative interpretations of computational work, identification with computational artifacts and practices, and making connections between computational projects and their lives outside of the program.

New perceptions of self and computational work

Shifts in perception were apparent at both the program and the domain level as girls broadened their perceptions of computer practices and computer professionals. Some girls initially did not think this program was for them but came to perceive the computational activities as creative collaborative work.

I was like, “Why do I have to go here on Saturday?” And I just thought it was gonna be very, very boring, because I already go to computer class at school, twice a week. ... I thought that it was just gonna be like, we just sat in front of computers and learned about coding, but it’s not. We had to do team work, and you had to ... You just had to be unique and different. And you had to think a lot because if you didn’t think you wouldn’t know what to do about your designs. [*Khelani interview*]

One case learner described a computer scientist at the beginning of the program as, “Lab coats and nerdy; Kinda glasses, sweat ... No. Like a long sleeved, buttoned up shirt, and then a t-shirt on top of it with a collar, and like a top hat or something” while near the end of the program she answered the same question with, “They’re kinda like an artist person and they also like engineering and technology, because that’s like me, everyday” [*Michelle interview*].

There was also evidence of shifts in confidence for computational work, as girls reconsidered potential participation to continue their learning trajectories. After a Minecraft exploration segment during the programming unit, one case learner expressed “If there is another Hack for Kids event, I want to go. Now that I know Minecraft better I could probably become better at building” [*Jude interview*].

Connections between projects and personal interests

Connections were established between computational projects and other domains related to girls’ creative interests and practices. Tangible circuitry projects like the e-Cuff were especially generative in this area. Girls talked about wearing their personalized LED-embedded hairclip and bracelet creations to school and parties. One created a paper e-Card and added it to her horse-themed bedroom.

So, we just had to make a card and just design it any way you wanted to. So, mine was kind of themed off of wild horses ... I just had the LED light in the hay and above the horse’s head. ... Well, I liked it so much that now at home I have a little area for, everything I have. And in my certain horse area, the card matches with it ... [*Nayomi interview*]

Some girls noticed e-fashions on the runway or in popular culture, such as Kanye West’s reflective jacket at the 2016 Met Gala event celebrating the opening of an exhibit entitled *Manus x Machina: Fashion in an Age of Technology*. One girl who wanted to be a fashion designer envisioned new possible futures for the industry: “LED lights, you can put it on dresses and maybe even shirts, and it will look very nice and I’m just thinking it will be a whole other form of fashion.”

Connections between computational projects and home

The online platform allowed girls to share their portfolio of work and showcases during the program generated explicit conversations about projects with family.

Tasmine shows her flower to her mom. Her mom: “Let’s see, oh I like!!!” Tasmine: “I’m wearing this to school.” Tasmine’s mom: “Is it going to distract at school? (laughs) I’m just kidding. You have to take it apart?” [*Field notes*]

Aaliyah is showing her dad. Her dad looks at it and asks it she put a switch in it. Sees that there is not one. Aaliyah’s dad: “We’ll have to put one in. Very cool.” [*Field notes*]

One learner shared her programming work with her 85-year-old great-grandmother, who cried from happiness that her young relative was working with technology and noted ways she could use help with technology in the house. These types of connections have implications for intergenerational learning, as the young participants are positioned as and take on roles of computational experts and broaden family learning networks.

In sharing computational projects with family, girls also recognized practices at home as relevant to their computational work and in some cases sparked new ideas for collaboration. Existing work reveals the generative learning support roles parents can play in developing computational and technical expertise (Barron, Martin, Takeuchi, & Fithian, 2009). Recognition of related knowledge or expertise at home, even if that expertise is not computational in nature, can provide rich opportunities for

what Barron et al. (2009) call non-technical consulting, when parents support youth technology learning by supporting project work in other areas of familiarity.

[The routine I am creating] is dances that I basically know, and me and my mom grew up with them, my grandma grew up with them. And it's just nice for me to know them. Yeah, they're always try to teach me some new dance. Like yesterday, they were trying to teach me a dance called the bus stop. [Michelle interview]

I had to take out the conductive thread. And then me and my dad, we sewed it back ... it was fun, and it was hard ... because my dad didn't know what to do. I had to explain it to him ... I thought he was gonna know because he's a fashion designer, but he didn't. [Khelani interview]

Discussion

The Digital Youth Divas program provided non-traditional computational project challenges and learning resources and supported work within a diverse community of learners. Within this structure, girls worked at their own pace to create what they imagined, shared and learned with others, and had opportunities to engage with a number of computational concepts and practices. There is evidence that participants increased their scores on two measures used to investigate computational thinking, shifted to more positive perceptions of computer science and computational work, and connected computational work to their own interests, practices, and communities. There was also evidence of variability in the degree to which girls experienced and extended practice within the program and identified concrete next steps.

Digital Youth Divas was not a controlled design experiment but rather an ongoing program that changed from week-to-week and classroom-to-classroom responding to the needs of the community. As such, it is difficult to identify distinct design decisions that resulted in the successes we saw or to draw causal connections. Additionally, while we made an effort to be systematic in our articulation of computational thinking to provide a shared language for our design and research team and our readers, we realize that the expansive interpretation may diffuse the argument that computational thinking is a unique domain and that results are not simply reflective of STEM more broadly. While we continue to refine the program design and research approach to address these issues, the exploratory work presented in this paper suggests three potential strategies to support an emphasis on computational perspectives that align with existing research:

- (1) *Design and understand computational activity in relation to youth interests and practices outside of the program.* A growing body of research frames learning as a cultural process, highlighting the need for environments that recognize and integrate existing cultural practices, values, and materials (e.g. Gutiérrez & Rogoff, 2003; Nasir, Rosebery, Warren, & Lee, 2006). Attention to interest as a resource for learning is well-documented (Hidi & Renninger, 2006) and interest is often connected to family practices (Dabney, Chakraverty, & Tai, 2013). The non-computational aspects of the design projects in Digital Youth Divas like fashion and dance easily connected with youth pre-existing interests as well as practice and expertise at home. The program explicitly used non-traditional representations of computational materials (e.g. fabric, thread, and music) and social networks (e.g. how-to guides and programming environments represented characters and experts from non-dominant race and ethnicities) to better connect with the girls' lives.
- (2) *Engage learners in open-ended computational design projects and provide redundant learning resources and opportunities for sharing work.* A large body of work focusing on project-based learning, including computational making, highlights how opportunities to design and work through challenges are powerful and often lead to building and recognizing expertise (Barron & Darling Hammond, 2010; Heath, 2012; Litts et al., 2016). Trying on learning roles within a community of practice can support the development of practice-linked identities (Nasir & Hand, 2008). In Digital Youth Divas, girls persisted through multi-week computational challenges, testing and troubleshooting to achieve their final project submission. Variability in the ways

girls moved through the projects using different material and networked resources on and offline suggests that redundancy of these supports allowed different learners to find their own way at their own pace. The physical/tangible nature of the projects as an artifact and forums for showcasing work connected with girls as they wore their creative fashions or engaged in physical dance moves, invited attention and support from peers, parents, and program mentors, and created opportunities for family engagement.

- (3) *Broaden definitions of computational thinking and explore ways to deepen practice.* Digital Youth Divas mentors worked with the girls and helped to organize resources and troubleshoot, as opposed to being more expert teachers. This allowed participants to navigate their own project work but also meant that computational practices were not always explicitly recognized or emphasized. Although girls increased their knowledge scores and engaged in computational practices, computational language was not a systematic part of the community of practice and there was variability in the practices that girls engaged in, as with the use of VENVI coding commands. Unequal coverage of the different “tools” that support agentic experimentation and development of computational artifacts and did not negatively affect overall program experience and documented impact, but there are implications for girls’ next steps. Girls and parents frequently asked about what they should do after the program was over, and were unsure what or how to search for follow-up opportunities (Martin et al., 2017). If out-of-school programs like Digital Youth Divas, however, are pressured to formalize language and expectations for participant progress, programming elements such as flexibility and creativity may be negatively impacted. Relatedly, our recent work has shifted from program design to working with formal and informal educators across a school district to determine expectations for learning and progress at a community level, exploring and supporting how to connect opportunities to make it easier for youth and families to find experiences that foster continuation and deepening of computational knowledge and participation over time and across locations, leveraging different strengths of the network of environments.

Conclusion

As we think about programs like Digital Youth Divas as part of broader computational learning pathways, potentially influencing long-term participation and decision-making, we need ways to translate current enthusiasm for computational thinking into equitable and sustained support for young learners. We posit that looking at computational perceptions alongside knowledge and experience is critical, and that the Digital Youth Divas components can provide a framework for doing this. For youth who may not consider themselves or their communities as connected to computational thinking, computational projects with individual and family connections were highly influential.

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