Mending the Gap, Growing the Pipeline: Increasing Female Representation in Computing

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Abstract

In order to address the gender inequities in computing fields, the Computer and Science Engineering department at Mississippi State University has been providing summer computing experiences for girls since 2011. This paper reports on the results of the summer 2014 camp for middle school girls, Bulldog Bytes: Digital Divas, focusing on how campers assessed their engagements with the interdisciplinary (Art, Computer Science and Engineering, and English) curricular experiment. Based on our findings, we argue for the utility of project-based curricular design and present the use of robotics as one way to integrate critical and collaborative thinking, communication, design, and programming skills.

Keywords

STEM, middle school outreach, robotics, computing

Background

The number of jobs in computing professions, such as system analysts and software engineers, continues to grow; however, the number of students in the US choosing majors needed for these professions has steadily declined.[1,2] While there is a general need to recruit professionals into computing professions, this need is particularly pronounced with regards to women. According to The National Organization for Women in Information Technology (NCWIT), though women earned the majority of college degrees in 2012 (57%), they represented just 18% of undergraduate degree holders in computing and information sciences.[3] Similarly, of the computing professionals already employed in 2013, women represented only 26%.[4] There is more at stake, however, than disproportionate statistics. John Naughton, writing for *The Guardian,* implores educators and parents to look beyond the economic or career demands for programming literacies. Naughton argues that the issue is a "moral" matter: "They [children] live in a world that is shaped by physics, chemistry, biology and history, and so we – rightly – want them to understand these things. But their world will be also shaped and configured by networked computing and if they don't have a deeper understanding of this stuff then they will effectively be intellectually crippled."[5] Similarly, addressing the underrepresentation of women in tech fields, Judy Wajcman points out: "To be in command of the very latest technology signifies a greater involvement in, if not power over, the future."[6] Though women are earning the majority of college degrees, that they represent only a quarter of professionals in the largest growing fields warrants further investigation and curricular intervention.

There is no shortage of research investigating the causes related to the low percentage of females pursuing computing degrees and careers. Scholars have critiqued initial programming course

assignments that are generic (like sorting a list of numbers), arguing that students of both genders become disengaged with computing under curricula that neglect the social relevance of computing.[7] This is particularly important for female students; for example, Kelly et. al. found that "high school girls are interested in the social relevance of computing skills, seeing the skills as the means to greater ends, and not the end in itself."[8] Kelleher et.al. found additional reasons for the lack of female interest in computing study and careers: "disinterest in computers, concerns about the computing culture, lack of encouragement from peers, parents, and educators, and relatively fewer opportunities to interact with computers."[9,10] In light of the low numbers of females pursuing computing degrees, many researchers advocate for a girl-centered curricular approach to introducing computing. Zimmerman and Sprung found that women prefer to work with teams and collaborate more than men and that women use computers more for communication and entertainment than men who prefer direct interaction with the computer through installing and modifying the device itself.[11] Using a programming platform that provides learners with an opportunity for self-expression and to relate their work to one another and to personal issues has also been shown to increase motivation in girls for computing.[7] Literature reveals a frequent theme of using games and game design as a pathway to introduction of computing concepts to students. However, with electronic gaming being heavily male-dominated[7], this is likely not the best approach for females.

In order to address the gender inequities in computing fields, the Computer and Science Engineering department at Mississippi State University has been providing summer computing experiences for girls since 2011. In response to research demonstrating that the high school years may be too late to influence perceptions about career options[12] in addition to the fact that middle school is an important time when students consider high school elective courses and career choices, Mississippi State's CSE department has been offering middle school camps since 2013. This paper reports on the results of the summer 2014 camp for middle school girls, Bulldog Bytes: Digital Divas. Female faculty and students from the CSE department collaborated with female faculty from the Art and English departments in order to experiment with an interdisciplinary project-based computing curriculum using Finch and Hummingbird Robot Kits.[13,14]

Robotics in Engineering Education

Robotics have been used in a variety of projects intended to stimulate interest in the study of computing.[15] For example, the Increasing Student Participation in Research Development (INSPIRED) project used robots in a one-day workshop with a focus on females and under-represented minorities. Results of INSPIRED revealed that the robot-based curriculum increased interest, confidence, and knowledge in computing among the middle school participants.[16] Balch et. al. describe a joint project between Georgia Tech and Bryn Mawr institutions in which a curriculum was designed to utilize robotics that are easy for a novice to learn yet powerful enough for an experienced user to exploit. Georgia Tech and Bryn Mawr's curriculum is designed to enhance the perception of participants' about computing.[17] However, Fagin and Merkle[18] found that students who are only able to use robots during assigned lab hours suffer when compared to peers who are able to work on non-robotic programs in a more informal learning environment. Similarly, Balch, et. al. advocate a personal robot that is small enough to be carried by the student and available for use outside of a formal learning environment.[17]

The CSE department has used Finch robots in multiple summer camp offerings. Prior results with middle school girls indicated that the girls responded favorably to hands on activities that involved programming a robot[19]. The Finch offers a very hands-on approach to programming instruction, and students receive instant visual feedback.[13] While the Finch supports multiple programming languages, *Snap!*, a visual, drag and drop language, was used with the middle school girls to program the Finch robots.[20] This simple interface enables the students to focus on programming concepts rather than syntactical purity and error correction. Hummingbird Robot Kits were piloted with a group of the more advanced participants, providing them the opportunity to design "robots, kinetic sculptures, and animatronics built out of a combination of kit parts and crafting materials."[14]

Cross Curricular Connections

The field of computer science influences a broad range of disciplines including but not limited to communications, medical, and business fields as well as basic science. Recognizing its broad applicability, educators and major figures in the computing industry advocate that programming, like reading and writing, be considered a necessary 21st century literacy.[21] This broad influence makes it imperative that not just the brightest students or students who are already interested in computing are attracted to computing degrees and careers. A diverse population in computing fields will inevitably lead to more innovation to meet the diverse needs of a multi-disciplinary global population.[7]

Many students are not aware of the multi-disciplinary impact of computing technology, which can be significant for girls for whom the social relevance of computing is important in their engagement decision.[8,22] Zimmerman and Sprung concluded that motivation and self-confidence in computing study is increased among females when they are able to work with and build upon a subject that they already feel comfortable with.[11] Recognizing this, several cross-disciplinary computing experiences have been designed and implemented with success. For example, Art2STEM emphasized design and creativity as an introduction to opportunities in science, technology, engineering, and math. The project was designed to "tap into girls' talents and interests in the creative arts and illuminate how their creativity can be applied in the context of STEM careers."[23] In Carnegie Melon CREATE lab's Arts & Bots robotics program, students wrote a biography of an historical figure, then built a robotic model that was programmed to tell the figure's story.[24] The Digital Mirror project—a residential computing experience for middle school girls hosted by Bowling Green State University—introduced various publishing platforms, design skills and principles, and rhetoric to help the girls understand the identity politics of the Internet as they built their own personal websites.[25]

Camp Overview

In the 2013-14 academic year, women faculty from Art, Computer Science and Engineering, and English (ACE) were awarded a cross-college research grant from MSU to create an interdisciplinary strategy to engage middle school girls' interests in computer programing (building off of summer camps hosted by CSE in the summers of 2011, 2012, and 2013). The initial collaboration formed in response to research from The National Center for Women and Information Technology (NCWIT)[4] and the American Association of University Women (AAUW)[26] whose independent research reports have and continue to expose gender gaps in

technology rich fields, but particularly within programming fields. Similarly, both organizations also recommend addressing this issue by creating opportunities for girls to experiment with technology in girls-only spaces. The initial and continuing goals of this interdisciplinary collaboration are (1) to experiment with a computing curriculum that integrates digital composing and design with engineering education in recognition of girls' needs to see the social relevance of computing and (2) to establish a pipeline from Mississippi schools to higher education computing programs and careers in order to address the gender gap within the CSE community (which is particularly pronounced in rural areas[8]).

With the support of the cross-college grant, NCWIT's AspireIT grant, and the Toyota CREATE foundation, the ACE team offered a free 5-night residential camp for middle school girls aimed at bolstering girls' attitudes towards and interests in working with technology. Participant recruitment focused on students from underrepresented minority groups and those working to overcome the hardships of a lower socioeconomic conditions. Sixty-five percent of the twenty middle school participants self-identified as African American.

The intent of an interdisciplinary approach was to engage young women in creative design and writing in addition to computer programming. In order to emphasize the social relevance of computing, campers were introduced to a number of open access programs (like Gimp[28]—a photo editing program, and Prezi[29]—a presentation program); encouraged to be social media active, documenting their experiences on the camp's Facebook page, on Instagram, and reflectively blogging on WordPress; introduced to Snap! and Scratch[27] programing; introduced to a number of successful female alum from the CSE program who work as small business owners, STEM teachers, and in corporate IT settings. The camp culminated in teams of girls collaborating to program a Finch Robot and, finally, to demonstrate their programming to their family members and a panel of judges from the CSE department who evaluated each team based on the complexity of their program and the sophistication of their presentation. Every girl who attended the camp was able to leave with her own Finch robot ($99.00 retail)[13] in order to continue her own programming education beyond the camp and also to extend the reach of the camp to those who could not or did not attend.

Assessment Results

In order to assess the effectiveness of Bulldog Bytes: Digital Divas, on the last day of the camp, as girls were preparing for their project presentations, the middle school girls were organized into four focus groups and interviewed by an outside researcher. The number of participants in each focus group is shown below in Table 1. Using loosely based and dialogic interview methods, the outside researcher prompted the girls to talk through their favorite parts of the camp, whether or not the camp influenced their future education and career decisions and pathways, and their opinions regarding the camp being by women and girls for middle school girls.

Table 1.0 Focus Group Breakdown

Focus Group	Number of Campers	Breakdown by Race
1	5	5 African American
2	5	2 African American; 3 Caucasian
3	5	1 African American; 1 Asian; 3 Caucasian
4	5	5 African American
TOTAL:	20	13 African American; 1 Asian; 6 Caucasian

In general, girls assessed the camp favorably, commenting that they would recommend the camp to their friends and encourage them to apply next year. Reaffirming the need for this kind of computing experience in rural Mississippi, one camper explained: "It's a good learning experience. You don't learn any of this outside of this program." Girls across all five focus groups unanimously reported that what they most valued about the camp was the opportunity to spend time on a college campus.

Out of the different experiences with technology that they were exposed to (including blogging, using social media, photo editing, and programming), working with the Finch robots and working in Code Academy (particularly on an activity that taught them how to animate their names), were most frequently mentioned as aspects of the camp that the girls favored. In fact, even though the girls struggled most when working with the Finch robot (both in terms of the programming and collaborative demands), two of the four focus groups indicated that they would have liked to have learned more sophisticated programming languages to work with the Finch (Python, for example, in addition to Snap!). As one of the girls explained, she enjoyed the programming aspects of the camp the most because "It's frustrating, but once you realize your mistake, then it gets easy […] It's a challenge." Additionally, one of the campers in the third focus group expressed an interest in not just learning how to do things with computers but also learning how the hardware itself works. She explained, "They could have done an activity where you had a computer that was just little small glitches to it and you had to figure out what they were," and another camper jumped in, "Yeah. Or like take it apart and see what each part does or something." Such feedback suggests that girls are engaged by rather than intimidated by the problem solving aspects of computational thinking and that they appreciate being challenged.

Multiple girls across all four focus groups responded positively when asked if the camp encouraged them to take classes in STEM disciplines, explaining that the camp made them "want to know more" and want to "spend more time in the [computer] lab." When asked about the camp's influence on their future course and career trajectories, girls in three of the focus groups specifically mentioned the positive impact of the CSE alum who spoke with them. One of the speakers, a previous employee of NASA, is currently teaching at the Mississippi School for Math and Sciences (MSMS); thus, her talk with the girls focused on her route from a CSE student to a STEM teacher and the different opportunities MSMS could offer the girls if they applied and were accepted. One of the girls commented that though she came to the camp already interested in MSMS, the chance to hear about the curriculum and options further convinced her to pursue admittance to the school: "it gave me more insight, like what I want to do." Girls from two additional focus groups also noted that the speakers helped them to talk through and think about

their interests and aspirations in terms of computing: "So I think the speakers, they helped me, you know, take a look more into computer sciences."

When asked explicitly about their opinions on speakers, not focusing on education or career paths, girls in all four focus groups commented on how the women who came to speak with them had positive impacts, mentoring them to consider how computing education paired with their current interests and future career hopes. The girls particularly appreciated one-on-one time with the speakers and the concrete ideas they provided for the many different ways campers could use a degree in CSE: "They could be like well you could do this, and then describe it, and then actually tell you how to get it." They reported that they speakers inspired them and multiple girls explicitly articulated that the speakers made them "feel smart" and made them feel like they could be successful within the computing world: "I was like, 'well, if she can do it, then we can do it.'" Such feedback emphasizes the importance of networking middle school girls with female mentors within computing fields both in terms of helping girls to better envision the diversity of the computing field and their own potential places within that field as well as helping the girls to see themselves, their gender and, perhaps more importantly, their races, represented within a predominately male field.

Though some of the girls reported that the camp did not directly influence their future education paths—they came in with an idea of their future professions and the camp did not sway them to consider careers and subsequently educational pursuits in computing—these campers acknowledged that the camp still had a positive effect on them. For example, one camper explained: "I feel like I'll be able to use what I learned later on in life with things. And if I major in something else then I'll be able to use what I learned here." Another camper explained that though she planned to pursue an education and career in the culinary arts, the camp made her think about the entrepreneurial opportunities programming literacies would open for her, mentioning specifically her interest in creating her own app. Though such feedback seems contrary to the goal of the camp—to build a computing pipeline in Mississippi—it also suggests that the camp helped girls to contextualize computing as an interdisciplinary and empowering literacy.

In all of the conversation regarding the assessment of the camp, being asked their opinion about the girls-only nature of the camp inspired the most spirited and sustained dialogue from the girls. Two focus groups responded immediately and unanimously that it was helpful for the camp to include girls only. All four focus groups confirmed in conversation that they appreciated the opportunity to learn about and experiment with technology without boys. In general, campers championed a girls-only environment primarily because their experience with boys in learning environments proved to be distracting and discouraging. In terms of distraction, the girls simply noted that when boys were in the mix, they found it more difficult to concentrate and that their attention was divided between social interaction and learning/working. However, in terms of discouragement, the girls relayed and confirmed troubling information and experiences:

- "Guys are going to be judgmental."
- "Boys hog things and they can't, they don't think we can do it. And so, if I can, it's like 'ok [so and so], don't do this, you can do pottery now, we know what we're doing.' And when I try to input, it's like, 'ok fine you've got it.'"

- "I was in a group with a bunch of boys, you know, so they were like hogging the robot and all, so I went to talk with my other group because that's where my friend was and then they said that I wasn't helping out at all. But whenever I tried, they were like, 'no, that's a stupid idea.'"
- "I have a problem with guys. Even with a lot of the guys, they think they're better than girls."
- "The boys would have tried to push us around."
- "Some boys do try and make you look stupid."

The girls repeatedly explained that their experiences working in co-ed groups on technology projects made them feel stupid and, worse, silenced and dismissed. Such findings reaffirm the importance of creating safe spaces for girls to experiment and play with technology, girls-only spaces without the ever present tension caused by the baggage of gender stereotypes in STEM. Though the camp does not identify itself as a feminist project in its marketing and informational materials or in any of its programming, one group did critique the camp because of its implicit feminism:

> Girl: I feel like we should look from like a guy's perspective too.
> INTERVIEWER: How do you think that would be helpful?
> Girl: Well I think people, the women, think about themselves, and they don't really look at the guys view.
> Girl: Yeah.
> INTERVIEWER: Say that again.
> Girl: They're feminists.
> Girl: Yeah.
> Girl: They're more biased.

Though the transcript dialogue here is not detailed enough to draw definitive conclusions, it is worth noting that a boys- and men-free technological zone was interpreted by some campers as feminist, and, in turn, "biased," leading them to want to hear from men, to want men to affirm the information that the women and girls they encountered were relaying. The transcripts seem to suggest that even implicit feminism can lead some girls to reject the safe-space constructed through a girls- and women-only environment. However, as the transcripts also suggest that girls regularly experience gendered STEM stereotyping in unproductive ways within their school learning contexts, we feel the merits of a girls-only extracurricular environment is worth the risk of being unproductively interpreted as motived by feminism and perhaps even accentuates a need to reframe feminism for middle school girls in ways that confront popular negative stereotyping.

Future Plans

As educators, co-designing a curriculum helped us each to better understand the already implicit interdisciplinary nature of computing education and how to make those interdisciplinary connections more explicit both for ourselves and for campers. Thus, in future camps, there is a need for our collaboration to expand in order to include female faculty from the college of Education, allowing us to work with middle school and high school teachers. In order to grow the pipeline in Mississippi, it is essential to involve educators at all levels in this effort so that

summer camps hosted on Mississippi State's campus are not isolated experiences but rather co-curricular complements to what is happening in Mississippi's middle and high schools.

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Ms. Rian Walker

Rian Walker is a software engineering major at Mississippi State University. She was an NCWIT Aspirations in Computing Regional Winner and National Runner-up. She represented NCWIT at the 2013 White House Science Fair, hosted by President Obama. Reflecting on her role as project leader in the 2013 middle school girl camp, she says that one of her most rewarding moments occurred while helping a participant. Rian stated, "She was eager to get my attention to show me that she had completed her project, but she was interested in taking the project further. ….. and it further solidified my reasoning to work in computer science."