Making Physical and Digital Games with E-Textiles: A Workshop for Youth Making Responsive Wearable Games and Controllers

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ABSTRACT
Most research on game making has been limited to digital games, not including the design of physical peripherals and controllers. In this paper, we illustrate how youth created wearable and physically interactive controllers by combining digital and tangible construction kits such as Scratch, ModKit, MaKey MaKey, and Lilypad Arduino. In an eight-session workshop, 14-15-year-old youth coded and created their own Scratch games and created wearable or electronic textile-based bidirectionally responsive game controllers, using sensors to activate a response on the screen, through the physical artifact, or both interfaces. We analyzed students' design of game controllers, as well as post-workshop interviews, to understand how they articulated an understanding of bidirectionally responsive design and its affordances, focusing on a case study. In the discussion we address some of the insights and challenges presented through the workshop, and offer suggestions for future work.

Categories and Subject Descriptors
K.3.2 [Computers and Education]: Computer and Information Science Education

General Terms
Design, Human Factors, Languages.

Keywords
Electronic textiles, game design, physical computing, tangible design, hybrid crafting, bidirectional design

1. INTRODUCTION AND BACKGROUND
Many efforts have been made to design workshops and curricula that introduce youth to key ideas in computer science, digital games, engineering and electronic textiles. For example, numerous efforts have sought to understand the best ways to teach youth how to think computationally through media design and coding [3, 11, 18, 30, 31]. A long line of research has explored robotics and tangible interfaces in education, from LEGO and LOGO to modern construction kits [2, 14, 19, 21, 22, 24, 25, 27, 32]. Further efforts have been made to introduce students to game design and coding with different platforms, such as Kodu [6] and Scratch [3, 20]. Additional efforts have been made to introduce youth to coding through crafting and soft circuits [4, 10, 11, 15, 17] as well as understanding the role that competitions play in learning hardware and software interface design for youth and adults [9, 23]. Some efforts have even tried to bring many of these strands together through the design of "bifocal" models that can help instruct through multiple modalities, which are digital and physical [2]. However, all or most aspects of the interfaces are designed for the learners, as opposed to the learners designing their own systems (i.e., instructionist instead of constructivist) [8]. Other efforts have sought to create tools that can enable "hybrid crafting" or the blending of digital and physical modalities that novices can build their own systems with [7]. Despite the term "crafting," the hybrid crafting approach uses a LEGO-like building block system with multiple components, such as screens and sensors or actuators (such as lights) that can be physically connected and coded, as opposed to working with textiles and craft materials.

Here we propose an approach that integrates gaming, crafting and computing using currently available toolkits combined in ways that facilitate the design of wearable and responsive games. There are three components of this approach that are novel: (1) the focus on bidirectionally responsive making with physical and digital affordances, (2) the combination of electronic textiles and digital games with contemporary toolkits and block-based coding environments, and (3) a curriculum that is focused on learner-centered designs, akin to Druin's work [5]. Most efforts to teach tangible computing have centered on interaction in one direction, by either concentrating on screen-based interaction or focusing on physically interactive responses (such as light or vibration). This paper is about a workshop to engage youth in wearable and electronic textile design, combined with digital games, that have reactive components in each interface.

In this paper, we present the design and overview of activities and findings from a workshop in which youth ages 14-15 learned not only how to program their own Scratch games but also how to make wearable and responsive controllers. We encouraged that the controller design be bidirectionally responsive, meaning that sensors would activate a response on the screen and through the physical artifact. An example of bidirectional design would be a wearable game controller glove, where touching the glove would not only result in a change in the digital game but would also light up the glove, thus providing tangible feedback in the wearable

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device. To accomplish such responsive designs, students needed to program in Scratch, integrate textile elements using the Lilypad Arduino [4] programmed via ModKit [1], a visual block-based programming language similar to Scratch but used to code microcontrollers, and incorporate the Makey Makey [24] to facilitate physical computing [13] with Scratch. Using conductive fabric and other conductive materials, they would integrate the Lilypad Arduino, to create a physical response in the wearable or textile-based game controller, and the MaKey MaKey, to control elements of their game in Scratch.

Table 1. Sequence of Workshop Activities

Week 1	Showing inspirational videos of projects created with the Lilypad Arduino or the MaKey MaKey and Scratch. Brainstorming session on combining the Lilypad, MaKey MaKey and Scratch. Lesson on basic circuits, sensors and actuators. Working with the Lilypad and ModKit to design a basic circuit with an LED. ModKit used as a model for block-based coding.
Week 2	Coding exercises with variables, loops, conditional statements and reading in analog values from sensors received through the Lilypad. Playing with different sensors of their choosing (temperature, light, etc,) with different actuators (LEDs, vibrators, etc.). Sewing connections with conductive thread and fabric.
Week 3	Working with the MaKey MaKey and concepts on basic circuits. Playing with different materials, such as Play-Doh, graphite, aluminum and conductive fabric to understanding conductivity. Remixing and creating code in Scratch to add different functionality.
Week 4	Integrating the Lilypad with the MaKey MaKey to control a game in Scratch with LEDs. Brainstorming and discussing ideas for final projects.
Weeks 5-8	Working on design teams for final projects. Showcasing final prototypes during final session.

In the analysis of students' wearable game controller designs and their understanding of what they designed, we addressed the following research questions: (1) How did student projects and interviews provide evidence of CS practices? and (2) How did students' perceptions of CS broaden?

2. WORKSHOP DESIGN

In this workshop, we wanted to incorporate the Lilypad Arduino and Scratch activities with the kinds of contemporary tools and affordances already accessible in the informal learning space. On the hardware side, the curriculum used the Lilypad Arduino Simple Board kit and the MaKey MaKey toolkit (see figure 1); on the software side, we incorporated both Scratch and ModKit, which have similar block based coding environments (see figure 2). This arrangement kept the programming modality consistent and lowered the complexity for our novice designers. Also, ModKit had successfully been used in similar past workshops [17]. We used Scratch 2.0 and ModKit Micro Alpha [1], a newer version that has worked out some of its initial bugs (see figure 2). While we wanted the workshop to focus on discovery learning through construction, we also recognized that, with the novelty of the combination of materials used, and the experimental nature of the class, some level of instruction had to be involved. Within instructionist environments, findings demonstrate that effective teacher-lead instruction utilizes both knowledge scaffolding through instruction, followed by problem solving [27]. To instill a sense of agency learners worked in teams and became design partners [5], so they conceived of and created their own designs in teams.

Figure 1. MaKey MaKey (left); Lilypad Arduino Simple (right)

Figure 2. Modkit Micro (Alpha) coding environment (left); Scratch media making and coding environment (right).

4. METHODS

The workshop took place in a science center in partnership with a local public high school in the Northeastern United States. The workshop ran for eight weeks in spring 2014, meeting two hours each week in the afternoon.. Thirteen ninth grade students (6 male, 7 female), aged 14-15, choose to participate in the workshop. The racial makeup was 62% White, 15% Black or African American, 15% Asian American, and 7% biracial. The workshop was designed and implemented by the first author.

In this paper, we focus on one team who was able to create a fully bi-directional design and examined how students engaged with computational practices and perspectives using a framework developed by Brennan and Resnick [3]. Computational concepts refer to programming structures apparent in most coding environments while computational practices refer to common programming practices, such as remixing or troubleshooting, and computational perspectives describe how students connect computational practices and value computation in their lives.

5. RESULTS

Overview of One-way Tangible Designs

Most teams created successful final projects with one-way tangible designs that utilized MaKey MaKey and Scratch. Two such games are highlighted here. **The jousting game** consisted of vests with conductive fabric, which were connected to different arrows on the MaKey MaKey, "swords" made out of metal coat hangers, which were connected to ground on the MaKey MaKey, as well as a fighting game, that kept score through a pie-chart interface, designed in Scratch (figure 3). Each player would use the swords to block their opponents or hit the conductive parts of their opponents' vests, which would trigger action in the game (figure 4). **The flappy star game** incorporated a wearable, partial glove controller in conjunction with a modded version of Flappy Bird, created through remixing (figure 5). The conductive fabric was connected to the MaKey MaKey, such that the thumb piece was connected to ground, and the forefinger piece was connected to the spacebar.

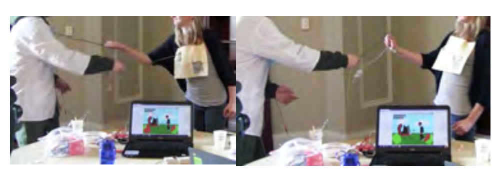

Figure 3. Game creators playing the jousting game.

Figure 4. Screenshots of different game states in Scratch.

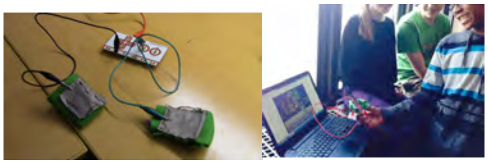

Figure 5. (Left) partial glove controller; (Right) designers with the Flappy Star game.

Case Study of Bidirectional Tangible Design

One team of two students (Tuyet, female, and Quinn, male) was able to successfully create a fully bidirectional trivia game with a responsive, colorful e-textile interface that, when touched, would trigger interaction in a trivia game designed in Scratch (see figure 6). Here the MaKey MaKey was connected to the conductive fabric and interfaced with the Scratch game to control the randomized trivia and dice in the game, while the Lilypad Arduino was connected to the same conductive fabric and controlled LEDs embedded in the fabric, which would turn off when touched. Tuyet explains their design processes:

> We used the Lilypad for lights and we used the MaKey MaKey system to control the dice that was located on the computer…We knew how to turn on the lights, because that's really simple, but then we had to make them blink [when touched]… We found out that you can't always have it the way you want the first time. So… certain parts that we originally thought we'd have in there or we originally thought we wouldn't need we ended up either taking out or putting in, depending on the situation… The MaKey MaKey… was easy because we took [a game we remixed in Scratch]... We just created, or deleted certain parts of that dice and then we used that for the MaKey MaKey system and plugged that into the board… [But we had to learn] the building blocks of Scratch. We had to learn the different meanings and how to use them properly. Or else, obviously… it would … not even work.

In describing how they incorporated the different construction kits, Tuyet articulates several computational practices: being incremental and iterative, by responding to changes between the intended design and the needs as they arose; troubleshooting issues along the way; reusing code through remixing, which allowed for more complex design than they could have done in the time allotted; and modularizing, by utilizing the different toolkits effectively for different parts of the design. She further explains how she came to understand bidirectional design and its affordances working collaboratively with her partner:

> Originally [our design] was quite simple… Then as it grew we had multiple parts which made it more dynamic in the fact that is was not just one simple board game that only had one function. It had multiple functions and you could do multiple things if you wanted it to… To combine all of them it's not easy….You got to see that they can also work cohesively with each other…. You just need to know how to use and connect the dots between them because they are not the same system whatsoever but they end up can work together… It's much easier… with a partner… you've got a buddy to lean on and work through the issues. You really bounce ideas off of each other… I'm actually most proud of my partner and I because the project itself ...

Tuyet's explanation illustrates that she came to a newfound understanding of the value of creating a system with multiple points of responsiveness. By expressing how "cohesively" and "dynamic" their final project became by adding these elements, she is articulating a perspective change in her understanding of how different computational elements can add to the design of games and interactivity. She further demonstrates computational thinking perspectives by working with someone else to do more than she could have done on her own, an important element of computational perspectives [3].

Figure 6. Trivia Game: (Left) When the game board is touched, the LEDs turn off. (Right) Close-up of game board.

6. DISCUSSION

While only one team was able to achieve a fully bidirectional design during the workshop, this case provides an illustration of the computational practices and perspectives the workshop students came away with, whether they created fully bidirectional designs or not. As expressed by a member of the flappy star team, the workshop allowed him to think differently about how systems are designed and put together to be responsive in different ways: "Now I'm thinking, because we know how it works, I'm thinking how does it work. I want to go in depth with it…" His newfound understanding was evident of questioning and empowerment, deeply meaningful aspects of computational perspectives [3]. Another implication we are exploring further is how the use of multiple toolkits and e-textiles capitalized on different interests and skills, allowing for multiple entry points to computing, which we have seen elsewhere [23]. In response to some of the time limitations of the workshop, as well as the need for greater scaffolding of computational practices related to combining physical and digital interfaces, we redesigned the workshop so that activities are hands on right from the beginning, using projects, such as the flappy star game, as buildable models that students design during the workshop, instead of just engaging in a final project after learning how all of the systems worked. Future work will explore the effectiveness of learning through buildable projects of increasing complexity, which has been successful in similar workshops [22].

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