The Education Arcade: Crafting, Remixing, and Playing with Controllers for Scratch Games

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ABSTRACT
The recent development of low cost tangible construction kits has lowered the barriers to entry for amateur and youth hardware designers. In this paper, we discuss the outcomes of a pilot study in which middle school youths set up a game arcade by remixing Scratch games and crafting physical game controllers using the MaKey MaKey and Play-Doh. The analyses focused on the youths' designs and reflections on Scratch remixes, their game controllers, and the culminating arcade. Designing game controllers and setting up the arcade was a productive learning experience for the youths in which they were able to glean insights about how to improve their designs by watching younger students play their games. In the discussion we highlight the parts of the workshop that were most successful, address what we learned about the youths' experiences, develop suggestions for the design of future workshops, and discuss the significance of authentic audience designs.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer science education*; K.8.0 [**Computers and Education**]: General – Games.

General Terms
Human Factors

Keywords
Interface Design, MaKey MaKey, Scratch, Game Design, Arcade, Tangibles

1. INTRODUCTION
In the last decade, the design and study of games for learning has received considerable attention. Research has focused on learning by playing games [14], learning by making games [5], creating tools for game design [9], and studying communities of game designers [6]. One area that has received little attention so far is the inclusion of physical interface design, even though game controllers are an essential part of the gameplay experience [1]. Until recently, building custom physical and tangible interfaces typically required access to costly tools, technology, and technical understanding that lie well beyond the reach of most K-12 students and teachers. The development of tangible interface construction kits (TICKs) such as the Lego WeDo, the PicoBoard, and the MaKey MaKey have made it substantially easier for amateur and children designers to create tangible interfaces, extending game design activities into the physical realm. Just like learning programming can be contextualized in the design of games, robots, or interactive stories, tangible design activities can benefit from connections to relevant cultural and social activities such as setting up a gaming arcade. In the 1970s and 1980s arcades provided many with their first and public access to video game play [8].

In this paper, we describe our efforts to implement and evaluate an eight-week workshop in which seven youths designed or remixed a game in Scratch and built a custom game controller using the MaKey MaKey. At the culmination of the workshop, the youths set up an education arcade in a large computer lab and invited the entire fifth grade of their school to play their games. The following research questions guided our analyses: What kind of controllers would youth create for their games with the MaKey MaKey? How would beginning programmers deal with the complexities of coordinating the screen and tangible designs of their games? How does framing the workshop within the context of an arcade impact youth's understanding of their designs? In our discussion, we address the pedagogical and technological opportunities and challenges of our approach.

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2. BACKGROUND
Over the past decade, the number of game design platforms has increased dramatically. Designing games has been shown to foster computational thinking [13], provide motivation for learning programming [4], and increase technological fluency [12]. So far educational game design activities are limited to the screen, but the appearance of several new TICKs has provided a way of creating tangible interfaces for games. TICKs are part of a larger group of construction kits that aim to lower the barrier of entry to the design of computational hardware. This larger category includes robotics toolkits like the Lego Mindstorms, tangible programming languages like Tern, and simplified microcontroller platforms like Arduino. Because low cost TICKs are a relatively recent addition, their use in the design of educational activities

and contexts (other than robotic designs and competitions) has not been received much attention.

Most relevant to our research is Millner's pioneering work with 'Hook-Ups' that illustrated how youth can learn about electricity, design, and programming while crafting tangible interfaces from found materials [10]. Millner developed the Hook-Ups TICK to provide lower-cost access and minimize programming. The MaKey MaKey builds on this tradition by requiring no drivers, no specialized software, and no prior knowledge of programming [3]. In this study, our research focused how game design activities could be expanded with the MaKey MaKey so that participants could design custom physical controllers to go along with their Scratch games. Such an activity, in particular for middle school students, provides a good introduction to software and hardware design because it builds on their prior experience with popular gaming platforms and can draw from the large repertoire of games available on the Scratch site [15].

In addition, we wanted to further expand the social and cultural dimensions of game design contexts. When Papert [11] described successful learning environments, he drew on Brazilian samba schools that have the annual Carnival festival as a public, culturally relevant event to work towards. Zagal and Bruckman [16] found that "having an explicit audience for whom the entire school must prepare is a way to focus the objectives and activities of the school" (p. 94). One such example is the recent development of online game competitions [7] that, much like robotics competitions [9], provide a high level of motivation and expose participants to new ideas. In our workshop, we organized an arcade as our culminating, public event. The entire fifth grade was invited to come to the computer lab and try out the games and controllers that participants created in the workshop.

3. PARTICIPANTS, CONTEXT, AND APPROACH

3.1 Participants and Setting

This study took place at a K-8 neighborhood school situated in a metropolitan city in a northeastern state of the United States. Youths in 6th–8th grade chose this eight-week long workshop as an elective that met twice a week for about 50 minutes each time. A group of nine youths (5 boys, 4 girls ages 11-12 years) participated in the workshop, but only seven consented to research. The workshop was taught by two of the authors (Davis, Vasudevan) and an occasional graduate volunteer.

3.2 Workshop and Education Arcade

To prepare for the arcade, participants were asked to create or remix Scratch games and design their own game controller. The youths' main goal was to make their games playable for younger students in a final arcade. In the first four sessions the youths were introduced to the Scratch environment and spent time creating a simple Scratch game through guided practice in class. In the next two sessions they spent time modifying (remixing) their games. After selecting a specific game to remix for their final projects, the youths designed physical interfaces using a MaKey MaKey and Play-Doh. In the final three sessions they developed and tested their interfaces, modified their games, and presented them at an arcade which was visited by other students in their school.

3.3 Data Collection and Analysis

We documented group interactions and design work in observational field notes and video recordings. In addition, we collected the youths' programs at the end of each class to document their remixes of Scratch code. We also captured photos of their individual game controller designs and their final arcade setups. We analyzed the Scratch programs for computational concepts (e.g., loops, conditionals) and design practices (e.g., remixing) using a framework developed by Brennan & Resnick [2] and analyzed the game controllers with respect to functionality and aesthetics. We conducted post interviews that asked participants to reflect on their experience in the arcade, discuss their design decisions, and give feedback on working with MaKey MaKey. The interviews were coded in a two-step process.

4. Findings

In the workshop sessions leading up to the arcade, student designers were focused on ensuring the functionality, usability and overall aesthetics of their games were satisfactory. In the following sections, we will present what we learned about (1) the remixing of games, (2) the crafting of game controllers, (3) the playing in the arcade experience, and (4) youth reflecting on learning and design.

4.1 Remixing of Scratch Game Programs

In the workshop, four participants created new games while three opted to remix code they had developed in a previous workshop. All of the participants spent significant effort on the aesthetic elements of their games, doing things like drawing or downloading new sprites (characters), designing custom backgrounds, modifying existing sprites, and adding sound effects. They also attended to common usability conventions in game design like adding scores, adding bad guys/distractors, and adding a way to win or end the game. When we analyzed their final Scratch programs using Brennan and Resnick's computational thinking framework [2], we found that 100% of the projects used sequential statements, loops, conditional statements, event handling, and 85.7% (or 6/7) of the projects used operators.

Two cases more clearly illustrate these findings. Amani opted to further improve her original zombie game, which she had worked on in a previous workshop [15]. Her original game required participants to move the zombie around so it could "eat" brains. In her remixed version, she opted to have good brains (pink) and bad brains (green), each labeled with point values so users could distinguish good from bad. She associated the size of the sprite to the point value, so sprites with higher point values were larger and vice versa. She also added a total score and a final win/lose screen. These adjustments made the game more usable, especially younger audiences that are not as adept at playing games. In contrast, Isabel created a new game even though she had the option to remix an older game. She designed a two-player game where the main character, a carrot, is controlled by the arrow keys and the second character, a donkey, is controlled by the mouse. The goal of her game is for the carrot to catch the donkey. This game was unique because it allowed two people to play at once.

4.2 Crafting Game Controllers

All participants developed a tangible interface that aligned with and controlled their Scratch games. We identified two groups of controllers: those which incorporated both aesthetic and functional elements (see figure 1), and those which seemed mainly functional (see figure 2). The interfaces in the first group varied from the extremely detailed, with Isabel and Ishita matching their controller components to the sprites (characters) in their video games (see figure 3), to the less nuanced, with Amani, Marcus, and Jonathan matching the colors or themes of their games to their controllers. We also observed that all three girls used multiple colors on each button, whereas only one boy, Marcus, used more than one color in his buttons.

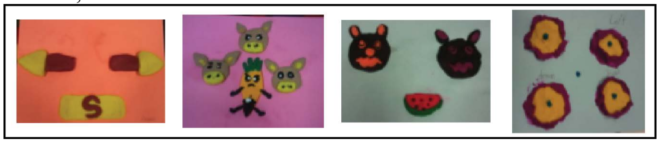

Figure 1: Examples of controllers that balance aesthetics and functionality, designed by Isabel, Ishita, Amani, and Marcus

The second group of controllers was built from solid colors of Play-Doh that represented the directions that the sprites in the games could move (e.g., up, right, left) but did not aesthetically match their accompanying Scratch game designs.

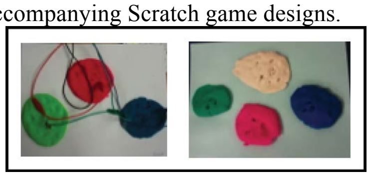

Figure 2: Purely functional controllers (minimal aesthetic considerations), designed by Earl and Cole

Figure 3: Ishita's matching game and controller

Some youths expressed that they were constrained by using Play-Doh for their controller designs. Others struggled to ensure the alligator clips remained in their Play-Doh. Some of the youths' Play-Doh controllers leaked moisture onto their background paper and created short circuits. This forced several participants to cut their pieces out and maintain them as separate pieces instead of one "game pad." Despite these challenges, they generally enjoyed making their controllers. For instance, Isabel reflected on how much she enjoyed creating a controller with Play-Doh and MaKey MaKey, saying that it was more fun than a regular keyboard. Many youths were also impressed by the range and flexibility of the MaKey MaKey. Amani said, "I like that you could like connect it to anything. Like when we watched the video for the MaKey MaKey, like you could like connect it to the steps, to the bananas," recalling the original video that was shown to them. When asked about how they might improve the MaKey MaKey, the participants had useful recommendations, ranging from improving it's aesthetic design (e.g., make it prettier) to making it easier to plug the alligator clips, to removing the concept of earth because the youths found it confusing. This type of thinking indicates an attention to functionality and usability in all aspects of the youths' participation in the workshop.

4.3 Participating in the Arcade

The arcade was a positive culminating experience for all participants. As younger students entered the school's computer lab where the arcade was set up, an array of challenges came up, ranging from alligator clips falling out of controllers, to controller pieces falling on the ground, to realizing they needed to adjust their game by adding score so that more students could play their game. During the arcade three youths made on the spot changes to their Scratch code while four youths made changes to their controller designs. When they saw that new players did not realize that they needed to touch the earth clip for the interfaces to function properly, they added conductive bracelets and touch pads to make this more obvious. Participants also made numerous small fixes to ensure the integrity of their controllers. This rapid prototyping happened during the breaks between visiting fourth and fifth grade classes.

4.4 Reflections on Design and Play

All youths were proud of their final games and controllers, but also mentioned both functional and aesthetic changes they would make if they had more time and skill to work with Scratch and the MaKey MaKey. In terms of their Scratch games, many youths expressed they would add levels, more bad guys, and other functionality to make the games more challenging. Others shared that they were unable to execute their imagined vision because they found some of the Scratch programming challenging. For example, Cole explains why he chose to make his Kill the Alien game, saying, "I was trying to make a football game, but I couldn't. Because I found that I couldn't, so I picked Kill the Alien, I guess." However, even with these challenges, participants were able to develop games and controllers for their peers to play in the arcade.

In terms of the arcade experience, the youths learned a great deal from watching others interact and play with their games. Some felt an increased sense of confidence when they observed younger students having fun with their games. Ishita explains that "spending the time with those kids, it was kinda fun cause they really like my game." Another participant, Earl, explains that he originally thought his game was boring but then "when the fifth graders just played it a lot... they played it, said it was fun and that made me think that okay, it's... it's good, fun." The youths also gained some valuable insights about design and usability from seeing others playing their game and having to make real-time adjustments. For example, Isabel mentioned one of the improvements she thought of while observing game play: "The keyboard (game controller) have more Play-Doh because it so thin. And the MaKey MaKey go out all the time," referring to the alligator clips slipping out of her thin component pieces. Another participant, Jonathan, eventually had to switch back to having users play with the regular keyboard because his interface was only intermittently working. Throughout their feedback, the youths explicated that watching others play their games provided insights and gave them ideas that they hadn't otherwise considered.

5. DISCUSSION

The arcade provided a meaningful context in which participants were able to test and view their work. It also provided them with an authentic audience of younger students and teachers who played with their games and controllers. This experience led to insights about the quality, complexity, and usefulness of their game and controller designs. It also helped the youths see their game in an interactive context, where they could make connections between their games, their peers' games, and the larger experience they were helping to develop. In addition to the learning benefits, we also gathered insights about working with construction materials and the MaKey MaKey, increasing diversity of controller designs, and expanding the arcade contexts and collaborations.

Designing Play-Doh interfaces with the MaKey MaKey introduced participants to technical concepts like conductivity and electrical circuits in a fun and creative way. Although we provided participants with aluminum foil, metal tape, pipe cleaners, wire, and Play-Doh, all the participants chose to use Play-Doh exclusively. The benefits of using Play-Doh are that it is safe, easy to access in schools, and doesn't require special tools to mold, shape or build. However, once participants built an initial prototype the moisture started to dissipate, causing short circuits and eventually drying out the interfaces. Despite these challenges, we found that the creative opportunities offered by the Play-Doh outweighed the problems. Bringing the MaKey MaKey into the classroom also revealed some of the potential design improvements that could be made. Several youths mentioned that they found working with the alligator clips challenging, because the holes on the MaKey MaKey were small and the clips were difficult to open. In addition, three participants mentioned they would remove the requirement to connect to the Earth section on the MaKey MaKey because it was not intuitive.

The implementation of the workshop and arcade also provided additional insights into how to improve the quality and variety of tangible interface designs. One way to increase the diversity of participants' designs would be to incorporate periodic design challenges throughout the workshop. Challenges could include asking participants to work with conductive materials that aren't as easily crafted as Play-Doh, or asking them to generate different layouts than the traditional directional arrow keys. Another way could be to supply participants with different sensors and materials so they could create a wider variety of interfaces: soft interfaces using conductive fabrics, light-sensitive interfaces using photoresistors, and pressure-sensitive interfaces using strain gauges. Finally, by organizing an interim arcade, we can give participants an opportunity to reflect on potential improvements they could make to their games and controllers.

While setting up the arcade provided the youths with rich context to design, evaluate, and improve their tangible interface designs, it also provided us with insights on how to design more collaborative, interactive environments for authentic audiences. Future workshops could draw inspiration from youth-created spaces like Caine's Arcade, the arcade created entirely out of cardboard by an eight-year-old boy. This example could encourage young people to create interactive environments from found materials. Imagine children creating interactive playgrounds with musical slides and light-up ladders, immersive arcades that use computers to provide audio and visual effects, and houses or classrooms with door alarms and pet detectors. Given that TICKs like the MaKey MaKey provide a way for youth to create tangible interfaces that can be used in the construction of authentic, interactive environments, they provide a powerful and novel way for youth to learn about programming and design.

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