Joystick Designs: Middle School Youth Crafting Controllers with MaKey MaKey for Scratch Games

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Abstract: While there are many tools for making games, most of these have focused on designing screen interfaces leaving aside the potentially rich space of designing tangible game interfaces. This paper reports on a workshop with middle school youth who created game controllers with MaKey MaKey, a tangible construction kit, to interface with their remixed Scratch games. The analyses focus on the design of game interfaces and programs and indicate that youth mostly replicated common controller designs but varied in their attention to either functionality or aesthetics. The interface designs followed traditional gender lines with girls more focused on aesthetics and boys more focused on functionality and were, to some extent, replicated in the remixes of the Scratch games. In the discussion we address the pedagogical and technological opportunities and challenges of including the design of tangible interfaces in game making for learning.

Introduction

While much attention has been paid to the learning benefits of playing games (Gee, 2003; Squire, 2010), making games for learning has only recently been recognized as an equally productive approach (Kafai, 1995; Kafai & Peppler, 2011). Reviews of game making for learning identify multiple benefits (Hayes & Games, 2008) such as the development of programming skills, integration of academic content topics, and, exploration with systems thinking as youth design interfaces and consider complexities of user interactions. These production-oriented approaches to gaming have also been seen as a means to broaden interest in computing (Denner, Werner, Bean, & Campe, 2008; DiSalvo & Bruckman, 2011). For the most part, approaches to making games for learning have been limited to designing interfaces for screen play, leaving aside the potentially rich learning space of designing tangible interfaces that have gained widespread use with popular game platforms such as the Nintendo Wii™ and Playstation™ Move.

Some, like Bayliss (2007), have argued that tangible control features are an integral part of the gameplay experience, as important as visual and auditory media features. Including tangible control features in game making activities could provide an opportunity to expand the design space from the screen into the physical space, thus introducing budding game designers to some aspects of engineering in addition to programming and interface design. While learning about circuits, crafting, and conductivity of materials adds complexity to the game design process, it also has the potential to enrich the learning experience in different ways. The most obvious benefit is the added authenticity because the appeal of game making activities has always drawn on youths' personal experiences with playing commercially available games. In addition, benefits such as transparency and creativity are equally important. Some have argued that tangible inclusions can add to transparency of computational designs by helping learners better understand the workings of technology (Buechley, 2010) while others see room for creativity that supports learners in becoming more flexible in their technology designs (Smith, 2006).

In this paper, we set out to investigate the potential for authenticity, transparency, and creativity in tangible game design by setting up a workshop in which youth designed game controllers for Scratch games. The recent development of tangible interface construction kits (TICKs) has opened the possibilities for novice programmers to create their own physical controller designs (Millner, 2010). One example is MaKey MaKey (Silver et al., 2012), a small USB device that connects to conductive materials and transforms them into touch-sensitive buttons that can control and move objects on the computer screen. The following research questions guided our analyses: What kind of tangible interfaces would youth create for their games? How would beginning programmers deal with the complexities of coordinating the virtual and tangible designs of their games? What would reflections reveal about the young designers' experiences? In our discussion, we discuss the pedagogical and technological opportunities and challenges of tangible game making for learning.

Background

Over the past decade, the number of available game design tools has jumped dramatically (Burke & Kafai, in press). Numerous game design platforms have been developed, ranging from specialized tools to open-ended programming languages. Building on Resnick and Silverman's description of computational construction kits (2005), Burke and Kafai distinguish between two major types of game-design platforms: those with wide walls and those without. They define wide walls as the capacity of a tool to allow for a variety of creations, in this case, a wide variety of games. For example, Sploder is a game design platform that does not have wide walls, as it restricts the types of games users can create to four genres: platforms, puzzles, shooters, or algorithms. Although these more specific tools limit the variety of games users can create, they also provide a lower barrier of entry that is attractive to designers with limited experience. In contrast to these narrowly-focused platforms, Scratch is an example of a platform with wide walls that allows beginning designers to create many genres of interactive media, including stories, animations, and games. While game making activities have become quite popular, few efforts include the design of tangible controllers such as joysticks or touch pads, most likely because the technical and material components are not easily accessible.

In recent years however, a number of different TICKS have been developed that can be used by novice designers to craft their custom interfaces (Millner, 2010). Like the game-design platforms, these TICKs can be grouped by either specific or general purpose. Specific-purpose construction kits limit the user's options as a way of reducing complexity and lowering the barrier of entry. One example of this kind of kit is the Lego WeDo, which can only be used to create controllers that sense tilt or distance. As an additional restriction, these controllers can only interact with a small number of applications. More general-purpose construction kits such as the MaKey MaKey allow for the creation of a wider array of tangible interfaces that can be used with a larger number of software applications. By expanding game design for learning to include tangible interface design, we build on this rich tradition that is an integral part of gameplay (Bayliss, 2007). What can we expect to gain by giving youth the ability to design and construct interfaces to go along with their games? Though there are a handful of studies that describe interface-design courses (Martin & Roehr, 2010), none of them examine the benefits and challenges of this activity. While children as designers of tangible interfaces has not been studied, there are studies of children as users of tangible interfaces. Horn, Crouser, and Bers (2012) compared learning with tangible interfaces to more traditional methods and found that tangible interfaces are more inviting, better at supporting active collaboration, and, have broader appeal across genders. However, they also found that tangible interfaces are not easier to understand or more engaging than graphical user interfaces. This ambiguity may stem from the fact that introducing tangible interfaces into the classroom increases the complexity of not only the activity but also materials involved in the design.

Most relevant to our study is Millner's (2010) research on 'hook-ups' that illustrated how youth can craft various tangible interfaces with found materials. The recent development of Makey Makey (Silver et al., 2012) provides an example of construction kit that can be used with any type of conductive material. Due to the popularity of new gaming platforms, designing tangible interfaces for games is a meaningful extension within the context of gaming literacies. Salen's (2007) work on gaming literacy illustrates the range of knowledge and skills that youth need in order to be able to be successful game designers ranging from system-based thinking and interactive design to game logic and rules, and, programming skills. When considering tangible user interfaces within the context of gaming literacies, it is evident that these designs also lend themselves to the creative, iterative and complex thinking that are required of game designers and connect to current efforts to promote computational thinking (Brennan & Resnick, 2012; Pea & Grover, 2013). However, it is unclear how the addition of tangible activities to an already complex design process plays out with younger designers and how it connects to the design of the digital game itself. The current study is a first effort to see how game design can be extended from the digital to the physical through the design of tangible interfaces.

Participants, Context & Approach

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. Students in 6^{th}–8^{th} grade chose this workshop for a short-term elective that met twice a week, for 50 minutes. A group of nine youth (4 boys, 5 girls, ages 11-12 years) participated in the game design workshop, but only six consented to research. The workshop was co-taught by three of the authors.

Game Design Workshop. Youth were asked to remix existing Scratch games and design their own interface using a MaKey MaKey kit (see Figure 1). In the first three workshop sessions the youth were introduced to the Scratch environment, the MaKey MaKey, and the basics of creating circuits. In the next three sessions they spent time modifying (remixing) their games. After selecting a specific game to remix for their final projects, youth designed physical interfaces using Play-Doh and materials such as pipe cleaners, aluminum foil, metal tape and wire. In the final three sessions youth developed and tested their interfaces.

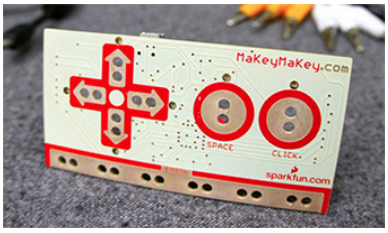


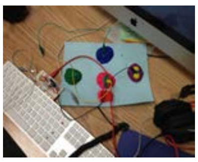
Figure 1: MaKey MaKey Tangible Interface Construction Kit.

Data Collection and Analysis. We documented workshop activities, group interactions and design work in observation notes, photographs, and video recordings. In addition, we collected the youths' interim and final programs. The variety and use of computational concepts (such as loops, conditionals, events) in youths' Scratch programs was analyzed using a framework developed by Brennan & Resnick (2012). In addition to computational concepts, they define computational practices such as remixing and debugging and perspectives such as connecting and questioning, that when brought together describe the knowledge, actions and ideas that embody computational thinking. We captured the progress of youth's game controller designs with photos. The game controllers, designed with the MaKey MaKey construction kits, were analyzed with respect to functionality and aesthetics. We also conducted post interviews with youth in which they reflected on the their design processes and approaches while looking at their Scratch programs and images of their game controllers. The interviews were coded using a two-step process that identified two themes: audience considerations when designers referred to players and device creation when designers reflected on the challenges and benefits of creating their own controllers.

Findings

All youth expressed surprise and excitement about creating their own tangible game interfaces. The most striking moment was when they connected for the first time their game controllers to the actual device and played games with their own controllers. In the following sections, we present what we learned about their (1) design of game controllers, (2) programming of games, and (3) reflections on designs and learning.

Designing Game Controllers. All workshop participants were successful in designing operable game controllers with MaKey MaKey and Play-Doh, but their designs differed in functionality and aesthetics (see Figures 2-3, a-f). The first group of controllers was mostly functional in nature: James used large buttons and explained that the smaller Play-Doh 'buttons' were to help the user's fingers grip them more easily while Marcus created four smiley faces, which were large enough for a user to place their hand on but, more importantly, easy enough to play his game. In contrast, Ethan used pipe cleaners to create a hand-held joystick and Play-Doh mounds as the touch points to complete the circuit for his game controller. His design stands out because he decided to incorporate pipe cleaners to emulate an existing type of game controller. Ethan mentioned in the post-interview that he what he liked about his design was that it was "unique from the other projects because I have a different kind of controller."

a. 

b. 

c. 

Figure 2: Game controllers designed by James (a), Marcus (b), and Ethan (c).

The second group of youth game controllers was functional as well, but showcased more aesthetic features by incorporating into their designs graphical elements of the Scratch program (see Figure 3). Two girls chose to recreate the specific characters (sprites) in their Scratch programs as elements of their game controller designs. While Isabel matched the details of the sea creatures in her Fish Chomp controller to the sprites in her game, as did Ishita for her Penguin Game, Amani used the colors of her sprites to inspire her controller design for the Zombie Game. She used pink to represent the brains and green to represent the Zombie's skin, also taking time to include the directionality of the buttons on her controller (e.g. right, left, up, down).

Figure 3: Game controllers designed by Isabel (d), Ishita (e), and Amani (f).

In designing their game controllers, youth dealt with challenges in creating and using them. Most youth had a hard time working with alligator clips and getting them into the small holes on the MaKey MaKey. Depending on how youth designed their interfaces, the alligator clips would occasionally fall out of their touchpad components, which resulted in having them stop play to reconnect their devices. In addition, some youth connected multiple parts of their controllers, thus causing short circuits. When this happened we reminded them about the principles of circuits and they made adjustments to their controller designs. Finally, students sometimes found it difficult to hold onto one alligator clip connected to the ground section of the MaKey MaKey, so we devised a solution by helping them to craft conductive bracelets out of tape or Play-Doh that they could wear while playing their games.

Designing Scratch Game Programs. All youth remixed the program code of selected Scratch games by adding elements such as a score, bad guys/distractors, or new ways to win the game. The analysis of final Scratch code indicated that youth used a wide range of computational concepts (Brennan & Resnick, 2012): all projects used sequential statements, five youth used loops, four youth used conditional statements and variables, and three youth used event handling and operators. Some youth also spent time rethinking the aesthetics and front-end aspects of their games by making changes to the main characters (sprites), drawing backgrounds, and, adding sound effects. These remixes in Scratch code replicated what we observed in the design of game controller: a difference in attention to functionality and aesthetics. Two case studies illustrate the range of efforts in adapting aesthetics (Ishita) and functionality (Marcus) in screen and tangible designs.

Ishita chose the *Monkey Game* as a starter project (see Figure 4). She spent considerable time on transforming the aesthetic design of the Monkey Game. She spent one class period to identify images on the web and modify them for her game, eventually selecting a penguin to replace the monkey and fish to replace the bananas. She also drew a background to go with her theme using the paint editor in Scratch. Once the aesthetics were complete, she turned her attention to modifying two aspects of the game dynamics. First, she added a shrinking piece of ice to the game so that the player had to eat all the fish before the ice melted. She also modified the code to include background music and sound effects whenever a fish was eaten.

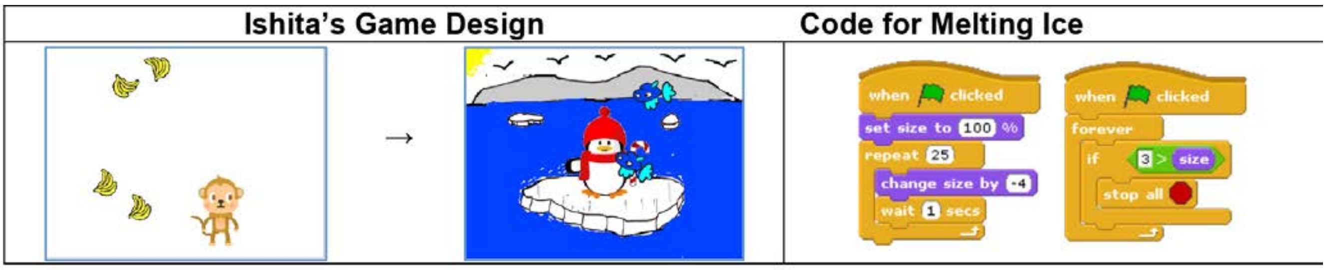


Figure 4: Ishita's game screens and sample Scratch code transformations.

To remix the starter project Fish Chomp*,* Marcus focused on finding a way to win or lose the game (see Figure 5). To win the game, Marcus changed the functionality so that the hungry fish (the main sprite) needed to reach a size of 105. Each time the hungry fish ate a smaller goldfish, Marcus incremented both the physical size of the fish and the score variable. However, if the hungry fish touched the killer seaweed before it reached the size of 105, then the player would lose the game. In addition to these changes, Marcus also switched control of the fish to the arrow keys (from the mouse), added sound and animation effects each time a goldfish was eaten, and had the hungry fish share the words "You win!" if the player met the conditions for winning or "Game over" if the hungry fish ran into the seaweed. The only aesthetic change he made was to add the killer seaweed sprite.

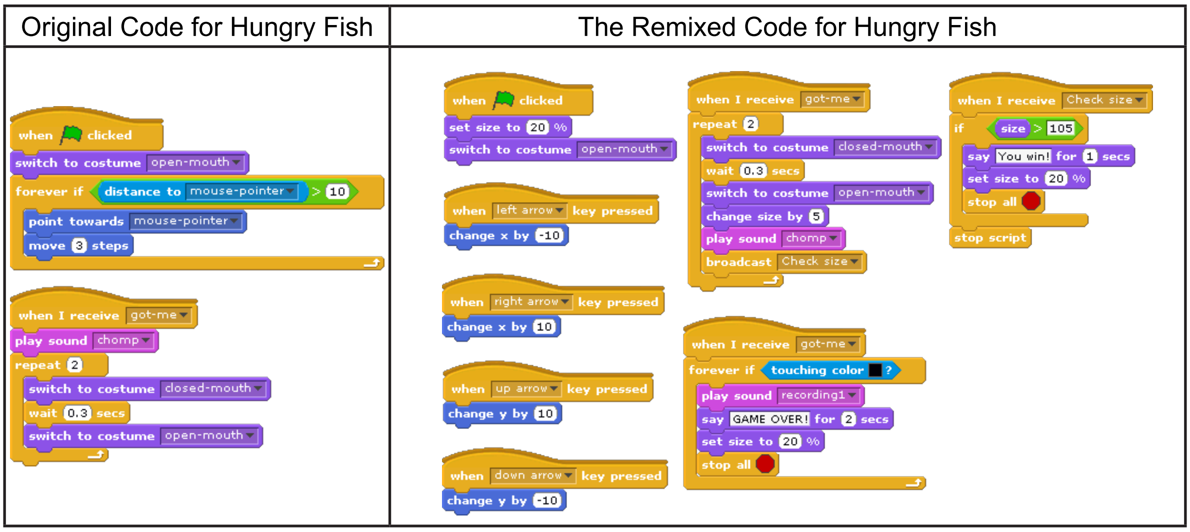


Figure 5: Marcus' Scratch screen and code transformations

Reflecting on Tangible Designs. Two themes—audience consideration and benefits of controller design—were prominent in youths' interviews. All youth referred to their Scratch programs and game controllers in relation to an intended player by mentioning "someone who might play" or "player". For instance, James reflected, "I think it's good, because it's pretty basic, if uh, like, like, in most games, like, there's like, in the arrow keys and space bar and that kind of stuff. So I, so I didn't really want to confuse the play- the person that's going to play." Amani, explained how her interface would be easier for her first-grade sister to use because the buttons are easier for younger kids to navigate: "Cuz she has to look up and down, but with the interface, she just goes like this (gestures by moving her hands to four spots on table). And it's like, she can use her whole hands, at some point her hands will be big enough to do it, but sometimes, right now, her hands are a little bit too small. So, with the interface, she can just put her whole hand on it. And it would just be fun and it wouldn't get her as frustrated." Reflections like these indicate how authentic game design experiences, both on and beyond the screen, provide youth with more opportunities to consider audience as they step into the role of a designer.

Another prominent theme in participants' reflections was the satisfaction in their ability to create their own controllers. Referring to a video that was shown at the start of the workshop and illustrated different applications of MaKey Makey, James said, "And at first, I didn't, I didn't know, I thought they were just like making it up or something, thought it was like special effects. But like, at the end, I knew that they were, like it was actually real." Others, adopted a DIY mentality and relished the opportunity to make their own devices: "Umm, so, umm, when I heard of it, I was like, it's so much better than using a regular keyboard, like a regular keyboard. It would be awesome, if we could actually use them like everyday. Like an everyday kind of thing. That would be cool too." Similarly, Ishita expressed what she thought the benefits were of designing game controllers: "I think this is better, because if someone was like going somewhere, and say their keyboard broke or something, they could just use MaKey MaKey and that thing, the thing they made, to make a keyboard..." Here, she is noting the flexibility that MaKey MaKey affords designers and users.

Discussion

In this study, we added the design of tangible interfaces to game making activities for learning. Our goal was to understand youths' creations, approaches, and perceptions as well as associated challenges and opportunities when game design moves beyond the screen. We observed that youths' tangible interface designs mostly replicated common controller designs—perhaps not a surprising finding given the personal experience that most young designers bring from playing console games at home. What varied though was attention to either functionality or aesthetics in their controller designs. We saw striking differences in how youth mapped out their physical designs ranging from unformed heaps of Play-Doh to carefully designed controller spaces. An unexpected finding was how these different approaches to controller design followed traditional gender lines, a pattern that was to some extent replicated in the remixes of youths' Scratch games. While the demographics of gamers have significantly shifted in the last decade to include more girls and women players (Kafai, Denner, Heeter, & Sun, 2008), it still remains a heavily segregated community, especially when considering technical production—the context of our study. While we do not want to overgeneralize these findings based on a small group of youth, such striking differences might point to different expectations and informal experiences that need to be considered when incorporating tangible design activities inside and outside of schools.

Functionality and aesthetics are important principles that need to be negotiated in every design, whether for the virtual space of the screen or in physical space of a controller or in conjunction with both, as it was the case in our study. One could argue that the challenge to both designing physical controllers *and* remixing a game were too challenging for novice designers. We tried to mitigate this by providing youth with starter Scratch games that they could remix or repurpose to their liking and develop controllers to fit their games. Youths' reflections revealed clear consideration for audience in the design of both their Scratch games and controllers. By no means are these considerations a trivial finding as we have found in previous studies (Kafai, 1998). For designers, it is difficult to shift perspective and take into account how someone else might approach playing a game. Designing a tangible interface, a touch pad or joystick in this project, made the different perspectives more apparent. Most importantly, youth moved beyond their perspective as designers to reflect on their understanding and knowing of technology, connecting their design experiences to everyday interfaces. This aspect most clearly connects to the 'transparency' argument developed by Buechley (2010) and others that illustrate how engaging learners in making technology artifacts can lead to understanding about functionality and design. The excitement and sense of accomplishment related to designing their games and controllers, expressed by participating youth, spoke to these aspects of transparency.

Less prominent in our study were creative variations on controller game designs. While all youth came up with unique controller designs, only one participant went outside of replicating the standard design of *up, down, right, and left,* arrow keys. Their lack of experience in working with computational construction kits is one likely explanation for this. The inclusion of material components adds another layer of complexity and requires an understanding of material science that few youth have. While many DIY activities aim at bringing back these types of hands-on manipulation and learning (Honey & Kanter, 2013), they are rarely encountered within the school context; robotic construction kits being the one exception but these are often inaccessible to youth due to cost and complexity. There are various ways in which we can think of broadening youths' approaches and perceptions of what a tangible game controllers can be or could look like might and result in more dynamic controllers. If future MaKey MaKey kits came with a collection of different switches and sensors, that could broaden the interface design possibilities achievable right out of the box. For example, pressure switches could be used to create touch-sensitive floor mats, or photoresistors could be used to add motion sensing. The inclusion of such parts could facilitate particular constructions without limiting the expressiveness and simplicity of the MaKey MaKey. This may also help when it comes to working with youth on usability design. Instead of spending time simply attending to detailed replications of their sprites, we want to get youth to think about how a particular design can make it easier to play certain games. To that end, in future iterations, we want to consider including some more interface and usability design as part of the instruction. We also want to give youth more time to iterate on their designs, so they can engage in a cycle of build, test, tweak. Ultimately, we want youth to move beyond and experiment more with conventions, not just to increase their understanding of technology but also to foster more creative and critical approaches to the design of everyday things. Participating in such design experiences will open a world of opportunity in gaming and computing, but also has potential to go beyond these genres.

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