Playing in the Arcade: Designing Tangible Interfaces with MaKey MaKey for Scratch Games

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Abstract Most tools for making games have focused on-screen-based design and ignored the potentially rich space of tangible interface design. In this chapter, we discuss how middle school youth (ages 10–12 years) designed and built their own tangible game interfaces to set up a game arcade. We conducted two workshops in which students used the MaKey MaKey, a low-cost tangible interface construction kit, to build touch-sensitive game controllers using everyday conductive materials for games they remixed in Scratch. We address the following research questions: (1) What types of tangible interfaces do youth create for their games? (2) How do youth designers deal with the complexities of coordinating the design of tangible interfaces with online Scratch games? (3) What do young users have to say about their tangible interface designs? We found that youth designers mostly replicated common controller designs but varied in their attention to either functionality or esthetics. An unexpected finding was how these different approaches followed traditional gender lines, with girls more focused on esthetics and boys more focused on functionality. These findings might point toward different expectations and informal experiences that need to be taken into consideration when bringing tangible design activities into educational settings. During the arcade, the youths' perspectives on their games and controllers changed as they observed other people playing their games. They expressed pride in their creations and saw ways to refine

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A. Nijholt (ed.), *Playful User Interfaces*, Gaming Media and Social Effects,
DOI: 10.1007/978-981-4560-96-2_13,

their designs in order to improve usability. In our discussion, we address how the inclusion of tangible interface design can extend game making activities for learning. Ultimately, we want youth to move beyond and experiment more with conventions, not just to increase their technological understanding and flexibility but also as a way to more critically approach the design of everyday things.

Keywords Tangible interfaces · Design · Interface construction kits · Game controllers · Scratch games · MaKey MaKey · Gaming arcade

1 Introduction

Over the past decade, new game controllers like the Nintendo Wii Remote, Microsoft Kinect, and the Sony Playstation Move have transformed console gaming by responding to gesture, body movement, or touch. In the rapidly growing arena of mobile gaming, such motion-responsive and touch-based controls have fast become the norm, not the exception. However, most youth never get the chance to build their own controllers because hacking or building custom physical interfaces typically requires access to costly tools, technology, and understanding that lie beyond the reach of most K-12 students. The recent development of low-cost tangible interface construction kits such as the Lego WeDo®, the PicoBoard, and the MaKey MaKey have made it substantially easier for amateurs to engage in interface construction (Millner 2010). These kits have opened the door to extending game making activities into the physical realm and added new opportunities for learning about topics like coding, circuitry, and interface design.

In this chapter, we report on what we learned in two workshops where middle school students' remixed Scratch games, designed tangible interfaces with the MaKey MaKey, and set up an arcade (Davis et al. 2013; Vasudevan et al. 2013). In the first workshop, students remixed a Scratch game and created a custom controller with the MaKey MaKey, 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 (Silver et al. 2012). In the second workshop, we expanded the social contexts by including a game arcade as a culminating public event in which other students from the school were invited to try out games and controllers. The following 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 screen and tangible designs of their games? How does framing the workshop within the context of an arcade impact participants' understanding of their work? We discuss what the findings from the two studies tell us about youths' creations, approaches, and perceptions as well as the associated challenges and opportunities that arise when game design activities move into the tangible realm.

2 Background

While much research has explored the learning benefits of playing video games (Gee 2003; Squire 2010), the focus has recently shifted to also consider the learning benefits of making games (Kafai 1995; Kafai and Peppler 2011). Involving learners in game design activities can have numerous learning benefits (Hayes and Games 2008). Designing games can foster computational thinking (Repenning et al. 2010), provide motivation for learning programming (Fowler and Cusack 2011), and increase technological fluency (Peppler and Kafai 2010). In addition, these production-oriented approaches have successfully broadened interest in gaming and computing (Denner et al. 2008; DiSalvo and Bruckman 2011).

Based on these successes, numerous platforms have been developed for novice game designers, ranging from specialized tools to open-ended programming languages (Burke and Kafai in press). For instance, Sploder is a game design platform that 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 game projects users can create, they also provide a lower barrier of entry that is attractive to designers with very little experience. In contrast, 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. Even Microsoft has released their own design platform called Kodu, bringing game design activities to anyone with an Xbox 360 (MacLaurin 2009).

While game making activities have become quite popular, there have been few efforts to include the design of tangible controllers such as joysticks, touch pads, or other devices, most likely because the technical and material components are not easily accessible. This is a conspicuous omission because controllers are an essential part of the gameplay experience (Bayliss 2007) and designing and building controllers could bring additional benefits to game design activities (Marshall 2007). Benefits might include offering opportunities for collaborative activity and providing ways of making abstract ideas more concrete (Antle 2007), in addition to promoting more active, physical engagement in learning activities (Marshall et al. 2003). When Horn et al. 2012 compared learning with tangible interfaces to more traditional methods, they found that tangible interfaces are not only more inviting but also are better at supporting active collaboration, and have broader appeal across genders.

With the development of easy-to-use tangible interface construction kits, it is now possible to investigate these learning benefits in more detail. What can youth learn by designing and constructing tangible interfaces to go along with their games? Though there are a handful of studies that describe interface-design courses (Martin and Roehr 2010), few of them examine the benefits and challenges of this activity. Most relevant to our work is Millner's pioneering research with the Hook-Ups tangible interface construction kit that enabled children to become creators of interactive tangible experiences by minimizing programming and providing lower cost access (2010). His research illustrated how youth can learn about electricity, design, and programming while crafting tangible interfaces from found materials. We built on this research by expanding it into game design activities using a commercially available tangible construction kit called MaKey MaKey (Silver et al. 2012). We wanted youth to design custom physical controllers to go along with their Scratch games. Such an activity provides a good introduction to software and hardware design, in particular for middle school students, 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. One of our research goals was to examine the opportunities for learning programming and tangible interface designs with MaKey Makey in a school context. For that reason also we focused on students remixing rather than designing games from scratch (no pun intended!) as to counterbalance their limited experience with programming.

In addition to designing tangible game interfaces and remixing Scratch games, we also wanted to better understand the social contexts in which these design activities can be situated. When Papert (1980) described successful learning environments, he drew on Brazilian samba schools that have the annual Carnival festival as a public, culturally relevant event to work toward. As we know from other research, having an explicit audience in mind helps groups of students to focus their efforts (Zagal and Bruckman 2005). One such example is the recent development of online game competitions (Kafai et al. 2012) that, much like robotics competitions (Manseur 2000), provide a high level of motivation and broader audience. With a gaming arcade as our culminating, public event, we chose a design that would be more about the social experience and less about winning or losing. We invited younger students in the school to come play the games, test the controllers, and provide us with feedback.

3 Methods

3.1 Participants and Settings

The two workshops took place at a K-8 neighborhood school in a metropolitan area in the northeastern United States. Students in 6–8th grades (11–12 years old) opted to participate in the game design workshops as part of their elective (or choice) time. These elective courses are offered throughout the school year and students can choose how they want to spend their time for two periods a week. While a total of 18 youth participated in the two game design workshops (workshop 1 had four boys and five girls while workshop 2 had five boys and four girls), only 13 assented to participate in the research (six in Workshop 1 and seven in Workshop 2). Four of the students who participated in the second workshop also participated in Workshop 1. The first game design workshop was co-taught by

Table 1 Workshop schedules

Sessions	Workshop 1	Workshop 2
1	Introduction to Scratch and MaKey MaKey	Introduction to Scratch and MaKey MaKey
2		
3		
4	Reusing and remixing Scratch games	
5		Reusing and remixing Scratch games
6		
7	Building and crafting game controllers	Building and crafting game controllers
8		
9		
10	-	Playing in the arcade

Fig. 1 Screenshots of Scratch programming interface (*left*) and the Internet Portal (*right*)

three of the authors (Davis, Lee, and Vasudevan) while two authors (Davis and Vasudevan) taught the second workshop. Each workshop met nine times, with each session lasting about 50 min each.

3.2 Game Design Workshops and Arcade Setup

The first workshop focused on game and controller design, and the second added the arcade experience (for an overview of workshop activities, see Table 1).

In the first game design workshop, youth were asked to remix existing Scratch games and design their own tangible interfaces. In the initial three sessions the youth were introduced to the Scratch environment, the basics of creating circuits, and working with MaKey MaKey construction kits (Figs. 1, 2).

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 the MaKey MaKey, Play-Doh (a modeling compound that is nontoxic and comes in several different colors, similar to clay), pipe cleaners, and

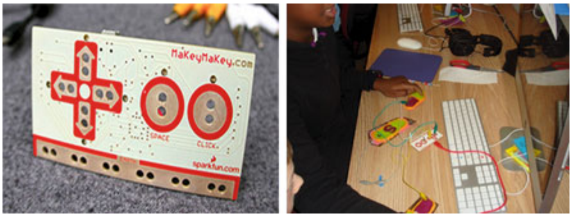

Fig. 2 The MaKey MaKey board (*left*) and a hooked up version (*right*)

other materials available in the classroom. In the final three sessions, the youths developed and tested their interfaces with their Scratch games. The MaKey MaKey (see Fig. 2) is 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 (Silver et al. 2012). It requires no drivers, no specialized software, and no knowledge of programming (Collective and Shaw 2012).

In the second workshop, youth also created video games and designed a controller (or interface) using a MaKey MaKey. However, with more scaffolding in using Scratch, youth also had the chance to create their own simple games. The main difference between the two workshops was the addition of a culminating arcade to showcase the games in the second workshop. To accomplish this, youth were introduced to the Scratch environment in the first four sessions during which they 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, youth designed physical interfaces using the MaKey MaKey and Play-Doh. In the final three sessions youth developed and tested their interfaces and modified their games. Finally, on the day of the arcade, youth made minor tweaks, set up their games, designed signs for their respective arcade stations, and hosted younger students at the arcade.

3.3 Data Collection and Analysis

We documented student design work and group interactions in observation notes, photographs, and video recordings for both workshops. In addition, we collected all final Scratch programs and used a framework developed by Brennan and Resnick (2012) to analyze the complexity of computational concepts (such as loops and conditionals) and use of design practices (remixing and debugging). We captured the progress of game controllers designed with the MaKey MaKey and Play-Doh with photos after each session and analyzed final designs in respect to functionality and esthetics. We also conducted post interviews with youth in which they reflected on the their approaches and experiences. These 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

Fig. 3 Example remixed Scratch games

the challenges and benefits for creating their own controllers. In addition, we asked players during the arcade to comment on the games and controllers in terms of what they liked and what they would improve.

4 Findings

In the following sections, we present findings on how youth designers remixed or constructed Scratch games and built and crafted tangible game controllers. We are combining the results from the two workshops. In addition, we present what youth learned about their games and controllers from other students who came to the arcade, an event that only took place in the second workshop.

4.1 Software Design: Remixing of Scratch Games

The youths in both workshops found different ways to remix games. The remixes included both functional (e.g., updating, removing, or tweaking code to change functionality) and esthetic (e.g., changing the appearance or other effects) changes. All of the participants spent significant time and effort on the esthetic features of their games by drawing new characters, designing custom backgrounds, modifying existing images, and adding background music. We also found that the youths used a wide range of computational concepts such as sequences, loops, conditionals, event handling, operators, and variables in their final games. Figure 3 shows different students remixes.

Many youth added graphic and sound effects in their remixes in addition to changing game mechanics. One example is Ishita, who added a shrinking piece of ice to her game because she wanted the penguin to eat all the fish before the ice melted (see Fig. 4). She also modified the code to include sound effects whenever

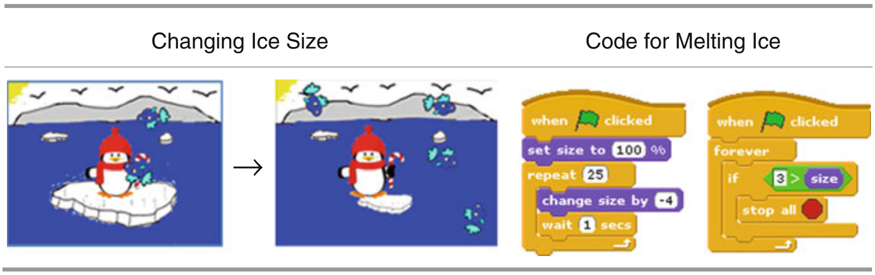

Fig. 4 Ishita's game screen and code for melting ice

Fig. 5 Amani's game screen with features for usability

a fish was eaten. Another youth, Amani, added good brains (pink) and bad brains (green) to her updated version of Zombie Attack. Each brain was labeled with point values so players could distinguish the good brains from the bad ones. She also linked the size of the brain to the point value, so brains with higher point values were larger and vice versa, and added a total score and a final win and lose screen (see Fig. 5).

In contrast, Marcus focused on the game mechanics of winning and losing in his remixed game. To win his game, the main sprite, a hungry fish, needed to reach a size of 105. Each time the hungry fish ate a smaller goldfish, the physical size of the fish incremented and the score increased. However, if the hungry fish touched the seaweed before it reached the size of 105, then the player would lose the game. To accomplish these changes, Marcus remixed the original game in the following ways: switching control of the fish to the arrow keys, adding sound and animation effects each time a goldfish was eaten, increasing the size of the fish, setting up a limit for when the fish exceeded a certain size, and establishing conditions for losing/winning game. The only graphic change he made in his remix of the game was to add a new seaweed sprite (see Fig. 6).

When reflecting on their design decisions in remixing games, audience consideration was a key factor in students' thinking and coding. In the case of James, this meant that he was aware that someone else might play his game: "I think it's

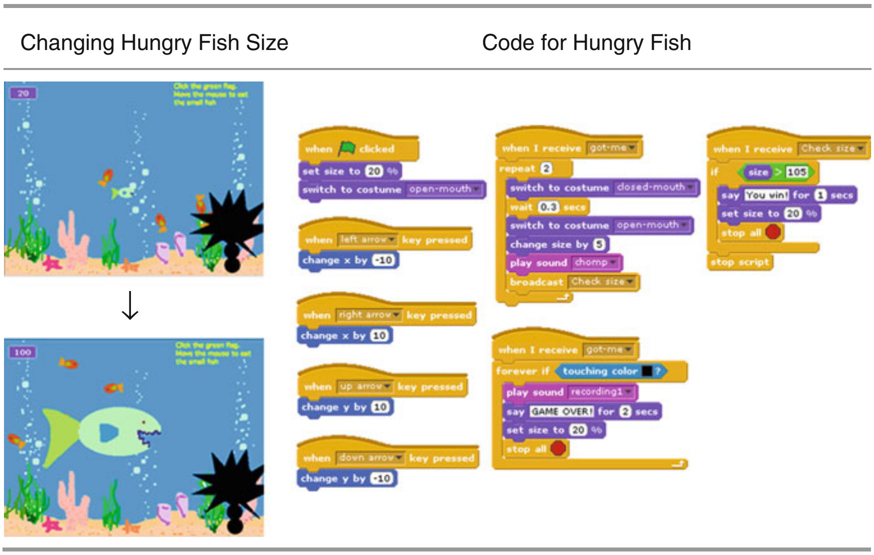

Fig. 6 Marcus' game screen and code for hungry fish

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, didn't really want to confuse the player, the person that's going to play." Others wanted to make their games harder and thus more interesting to play by adding levels or complexity such as a bad guy or a distractor. While Isabel mentioned that she would add more functionality to make enemies more difficult to chase, Amani intended to add more levels: "I think I would change, is for it [her game] to have levels. And then there would be more like enemies. Like, we said in the presentation the enemies would be thrown in there in the harder levels. And the levels would just get harder, and the monkey would be moving faster and faster and faster." These reflections illustrate how youth began to assume the role of game designers who focus on making games that are both playable and challenging enough to keep players' interest (Gee 2003).

4.2 Tangible Design: Building and Crafting Game Controllers

In addition to designing the screen interface in Scratch, youth also designed tangible game controllers for their games. Some of these tangible designs emphasized functional elements by making buttons large enough to touch while others focused more on esthetic elements such as matching colors to Scratch remixes or creating specific shapes.

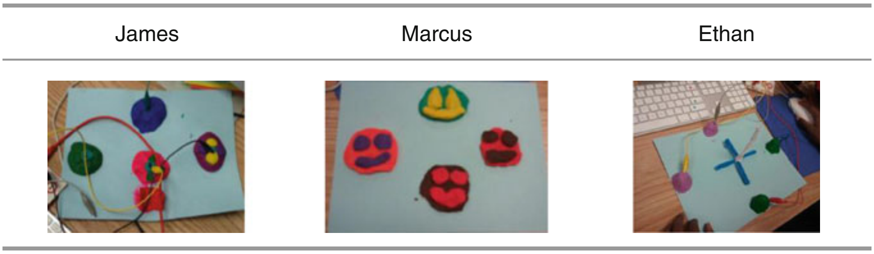

Fig. 7 Functional controllers with minimal esthetic considerations

Fig. 8 Examples of controllers and screens that balance esthetics and functionality

In the first workshop, we found that one group of students designed controllers that used directional arrow keys (up, down, right, and left), so that the main characters or sprites in the games could move. Many of these youth did not match their controller designs to the topical focus of their Scratch game design (see Fig. 7). For instance, James and Marcus created three or four round buttons which were large enough for a user to place their hand on and, more importantly, easy enough to play their games. In contrast to these controllers, Ethan's design stands out. Instead of creating directional touch pads, he used metal wire to create a hand-held joystick and Play-Doh mounds as the touchpoints to complete the circuit for his game controller. Ethan mentioned in the post-interview that he was proud of his design because he felt it was most unique when compared to others.

In the second workshop, the interfaces varied from the extremely detailed, with Isabel and Ishita matching their controller components to the sprites (characters) in their Scratch games (see Fig. 8), to the less nuanced, with Amani, Marcus, and Jonathan matching the colors or themes of their games to their controllers.

In reviewing trends across both workshops, we found that girls focused more on the esthetic elements whereas boys focused mostly on functional elements in the design of their controllers. Only one of the boys (Marcus) aligned the esthetics of his game controller with his Scratch game. Most girls referenced ‘usability’ as their design rationale. For instance, Isabel noted that she wanted to make sure that the fish in her game was represented on her game controller. Ishita explained that she “tried to like match it with the theme, like, on my picture. Because if someone was trying to play my game, I thought that umm, if I used like, different kind of, umm buttons, it would be hard for them to understand like, which part is which.” When asked about his second controller design for his Fish Chomp game, Marcus stated, “…what do you find, in this sea that actually can be put into a flat thing, you could touch?… So I finally thought oysters with pearls, and that will be perfect because then the MaKey MaKey clips could be touched to the pearls and would make more sense.” The change in Marcus’ design was prompted by one of the teachers who asked him think more about his design in the second workshop.

Others referenced not only usability but also personal preferences. For instance, Amani thought her initial interface would be easier for her first-grade sister than a regular keyboard because “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.” But she referred to the matching as a personal value saying that, “it wouldn’t make sense if I had like a princess keyboard with a zombie game… that’s kind of my thing, like I have to be matching.” In addition, some girls, unlike any of the boys, created extraneous, decorative Play-Doh pieces on their controllers (see Fig. 9). Amani built four arrow keys despite the fact that her game only needed two, and Ishita also built extra pieces to match her controller and game screen design. However, they removed these extraneous pieces when they created controllers again in the second workshop.

4.3 Arcade Design: Reflections of Designers and Players

In contrast to the first workshop that ended with youth designers playing each others’ games, the second workshop closed with an arcade in which younger students in the school were invited to come to the computer lab and try out the newly created Scratch games and controllers (see Fig. 10).

As the younger students moved between games, the youth designers explained their game and controller designs and provided help when players ran into challenges. These challenges ranged from alligator clips falling out of controllers, to controller pieces falling on the ground, to designers realizing they needed to adjust their game designs by adding a score so that more students could play their game. Three youths made on the spot changes to their Scratch code while four youths also made changes to their controller designs. For instance, Amani changed her

Amani	Ishita
	
↓	↓
	

Fig. 9 Changes in controller designs from the first to second workshop

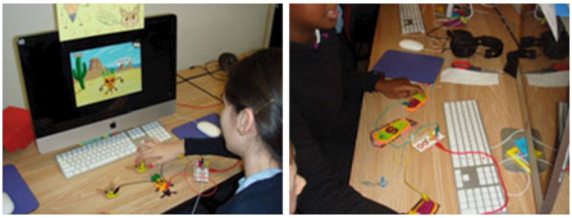

Fig. 10 Playing Isabel and Amani's game in the arcade

Scratch code to reduce the difficulty of the game by reducing the goal score value and increasing the speed and jumping height of the main character. These changes were made in response to players' feedback while playing her game. She also added a final information screen to show players if they won or lost the game. One of the major challenges of the controllers was that many players did not realize they needed to touch the earth clip. To address this issue, the designers quickly designed and added conductive bracelets and touch pads to make this connection more obvious. This rapid prototyping happened during the breaks between visiting fourth and fifth grade classes.

Coming to the arcade and playing the games was a rich experience for all of the players. The players openly expressed their likes and dislikes about the Scratch games and controllers and generated many ideas for changes in designs. The large majority of them (70 %) wanted designers to make the games more complex by adding more enemies or by making it harder to get points, while others wanted to make the games easier by increasing the main character's ability to jump higher or go faster, or by reducing the threshold score for leveling up. While players loved the tangible controllers because they were easy to control, they also had recommendations for changes. For example, players wanted the touch pads to be closer together in Isabel's controller, and similarly for Amani's controller, one player suggested connecting the touch pads together because the pieces of her controller were separated and often fell off the table.

The designers also learned a great deal from watching others interact and play with their games in the arcade. Some youths felt an increased sense of confidence when they observed younger students having fun with their games. Ishita explained that "spending the time with those kids, it was kinda fun cause they really like my game." Another participant, Earl, said 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." Youth 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. Throughout their feedback, youths explicated that watching others play their games provided insights and gave them ideas that they hadn't otherwise considered.

5 Discussion

In this chapter, we examined different ways of combining software game design with tangible interface design and situating the design experience in a social context, the arcade. Our goal was to understand youths' creations, approaches, and perceptions as well as the associated challenges and opportunities that arise when game design activities move into the tangible realm. We observed that youths' tangible interface designs replicated common controller designs. While the functional variations in the controller designs were minor, what did vary was the attention to esthetics. We saw striking differences in how youth mapped out their physical designs as controllers ranged from unformed heaps of Play-Doh to meticulously designed sculptures that mapped tightly to on-screen elements.

An unexpected observation was how the attention to esthetics in game controller designs was linked to gender, with girls paying more attention to balancing esthetics and functionality. Making tangible interfaces for games revealed that the girls, unlike the boys, were able to combine both technical functionality and graphical esthetics in their controller designs and thus, one could argue, created more user friendly designs. While these are preliminary findings based on a small group of participants, they point towards promising directions in expanding computing activities. Research on the users of textile computational construction kits has demonstrated that broadening the range of materials and activities in computing can also help broaden participation in computing (Buechley and Hill 2010). In these cases, tangible technologies seem to provide a promising way to bridge the gender gap in computing.

Designing interfaces with Play-Doh and the MaKey MaKey exposed participants to technical concepts like conductivity and electrical circuits in new and imaginative ways. Although we provided participants with aluminum foil, metal tape, pipe cleaners, wire, and Play-Doh, all the participants chose to use Play-Doh exclusively, a choice that determined particular creative opportunities and challenges. 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, which caused short circuits and other malfunctions. Despite these challenges, we found that the creative opportunities offered by the Play-Doh outweighed these 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 youth participants mentioned they would remove the requirement to connect to the Earth section on the MaKey MaKey because it was not intuitive.

As mentioned earlier, the vast majority of the controller designs replicated common gamepads. One explanation for this is that the open-ended design of the MaKey MaKey gave participants too much freedom, and that reasonable constraints could lead to more unique designs. One way to increase the diversity of designs would be to incorporate periodic 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 provide participants with different sensors and materials so they could create a wider variety of interfaces: soft interfaces using conductive fabrics, pressure-sensitive interfaces using strain gauges, or motion-sensitive interfaces using photoresistors.

The addition of the arcade provided a meaningful context in which youth designers 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 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. There was anecdotal evidence that the arcade led to changes in the participants' perception of their games, though this was not something we were looking for initially.

In future studies, we would consider interviewing the participants before and after the arcade to see how the experience changed their view of themselves and their designs. 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. While setting up the arcade provided youths with rich context to design, evaluate, and improve their tangible interface designs, it also provided us with insights on how to design future environments for authentic audiences. Game design workshops could draw inspiration from youth-created spaces like Caine's Arcade, an arcade created entirely out of cardboard by an eight-year-old boy. This example could encourage youths to create interactive environments from found materials beyond those provided. 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.

6 Conclusion

The inclusion of tangible game controller designs and the social context of an arcade provided compelling insights into how game making activities can be expanded to create richer learning opportunities. Tangible construction kits like the MaKey MaKey provide novel ways and create authentic, interactive environments for youth to learn about programming and design.

Acknowledgments The research reported in this chapter was supported by a collaborative grant from the National Science Foundation to Yasmin Kafai (NSF-CDI-1027736). The views expressed are those of the authors and do not necessarily represent the views of the Foundation or the University of Pennsylvania. We also would like to thank the teacher Peter Endriss and his students for participating in the study.

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