Hi-Lo Tech Games: Crafting, Coding and Collaboration of Augmented Board Games by High School Youth

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ABSTRACT

Most research on game making activities for learning has focused on programming screen-based designs. Only recently has research begun to include the design of tangible interfaces; connecting on-screen programming with hands-on crafting. In this paper, we examine the potential of a workshop that combines the high and low of technology with game design in which teams of high school youth crafted, coded and collaborated on their own augmented board games to highlight intersections between learning programming and making, and creating across digital and tangible modalities. We focused our analysis of students' projects, interactions, and reflections on how young designers conceptualized the integration of screen and board game elements, realized computational concepts and practices in their board game designs and augmentations, and reflected on their game design experience connecting crafting and coding. In the discussion, we review how the expansion of game making activities can create new opportunities for interaction design and research.

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

Game Design, Maker Activities, Board Games, MaKey MaKey, Scratch

1. INTRODUCTION

The serious gaming movement has promoted games as models for richer, more meaningful, complex and collaborative learning environments [12, 36]. While most efforts have focused on the benefits of instructionist gaming, i.e., students' playing games for learning (cf. [7]), other efforts have examined constructionist gaming, i.e., students making their own games for learning [19, 20]. A growing body of research collected over the last 20 years has identified many benefits of constructionist gaming in terms of students' learning programming and academic content, in addition to fostering collaboration and the development of creative and critical dimensions e.g. [12, 13, 15, 21]. Nearly all of these studies have engaged youth in making games for the screen on the computer or the web leaving aside connections to the physical world that increasingly have become a rich context for gaming whether it is in form of wearable controllers, mobile platforms, or even traditional board games—the latter just recently emerging as a new focal point of interest in game studies [31]. Such extensions can make constructionist gaming not only align with more recent technological advances but can also more appealing to broader audiences.

This connection between the digital and physical has always been an area of interest for interaction design and research and has resulted in the development and study of popular computational construction kits [33] such as Lego Mindstorms [35] or computer-enriched crafts such as Hypergami [9]. More recent Arduino developments have generated a wide variety of computational construction kits that have made creating augmented designs accessible to even novice designers [5, 38]. These new construction kits allow for designs that integrate coding with crafting [11] and can provide a rich context for engaging youth in computational thinking [24]. But so far only few studies have realized this potential of connecting coding and crafting in the context of gaming, for instance by having youth develop their own peripherals such as touch pads and joysticks for Scratch games [26]. Given commercial gaming's general move into the physical world, we expect that such extensions cannot only enrich computational thinking in constructionist gaming activities but also broaden its audience.

In this paper, we report on a workshop, in which teams of high school youth designed, coded and played their own augmented board games. These activities of crafting and coding make the workshop unlike previous game making projects that focused entirely on the screen. To better understand how game making activities can be expanded with hi-lo tech designs, we turned our attention to a new genre of augmented board games [27], called so because they can augment physical game boards and play pieces with digital extensions, for example digital dice. Such features are already available in many traditional and popular board games such as Monopoly Electronic Banking and others. We used these as inspiration to ask teams of 3-4 students (ages 13-15 years) to design and build their own board game and to craft and code digital extensions using MaKey MaKey and

IDC '15, June 21 - 25, 2015, Medford, MA, USA

ACM 978-1-4503-3590-4/15/06…$15.00

DOI: http://dx.doi.org/10.1145/2771839.2771863

Scratch over an eight week long project, meeting once a week. We wanted to know what kinds of board game and code designs would emerge when we posed this challenge to youth in our workshop and we addressed the following research questions: (1) What are the affordances of blending coding and making in the context of game design? (2) How do youth engage with computational concepts and practices in the context of designing augmented board games? and (3) How do youth experience the connection between coding and making? Our analysis focused on products and processes, in particular on how young designers conceptualized and crafted the integration of on and off-screen design elements in making and playing their board games, how computational concepts and practices were realized in the process, and how designers reflected on the inspiration, involvement, and considerations in their game efforts. In the discussion, we review how this expansion of game making activities can provide new inspirations for interaction design and research.

2. BACKGROUND

Our research of expanding the potential of game making activities brings together two distinct but intersecting developments—research on coding and making—which both draw heavily on Constructionist theory that favors learning while creating personally meaningful and shareable artifacts [32]. The research on programming over the last twenty years has focused on designing and researching environments and tools helping novice programmers to design their own games, tell digital stories, graphics, animations and even simulations (for a comprehensive overview see, [25]). Interest in learning programming has received renewed attention with the focus on computational thinking [43] that is now driving efforts to bring back programming into K-12 education [23]. Constructionist gaming activities play a special role because they provide a context for coding that is not about learning programming for the sake of programming but about making something that can be shared and played with others. In one of the few comparative studies that pitched playing versus making games for learning, Vos and colleagues [42] found that students who engaged in making a game that the other group of student just played, demonstrated significantly deeper engagement in their learning and strategy use which involved system analysis, decision-making, and troubleshooting. Of course this comparative study only analyzes students on the elementary level and is far from definitive in its examination of motivation, coding and content acquisition based upon the playing versus making paradigm. These positive findings are supported by numerous other studies of youth programming their own games that have shown a wide range of academic, social, and motivational benefits (for a recent overview see, [22]).

In contrast to programming activities that have mostly emphasized screen designs, maker activities have focused heavily on crafting hands-on or physical designs such as building robots, 3D printing objects or electronic circuits. The research on maker activities has concentrated on how youth can become engaged in designing, building, and sharing things and how to develop maker spaces in museums, public libraries, and community centers [16]. Maker activities are also seen as a promising context for supporting STEM learning because they provide an authentic context in which the learning of science, technology and engineering can be situated rather than being taught as an abstract context. One of the key challenges in studying making has been in understanding what and how youth learn when they make. While making on screen is often seen as distinct from making off screen, we argue that such boundaries overlook the realities where many maker activities can and should cross the lines in developing learning activities for children [17].

Having youth design augmented board games proposes to integrate coding and crafting in the context of game making activities by leveraging shared pedagogical premises of constructionist learning that value the building of artifacts, on and off the screen. Furthermore, this proposal would also connect back to largely forgotten practices of modding software, building components, and hacking code that were an integral and often encouraged part of the early days of digital gaming [40]. Yet current research on computer-based augmentation of physical games (sometimes also called tabletop games), has focused mostly on designing such modifications for players (for an overview, see [27]). Research has focused on augmenting traditional board games like Go [18] or Settlers of Cattan [9], adding 3D to Battleboard game [1], or even developing new game designs [28], to name but a few. In this context, digital augmentations have been provided in various forms and modalities such as light and sound feedback, randomly changing game board configuration, playback mechanism, and automated game setup. These different examples illustrate that augmented board games can provide a rich context for constructionist gaming by broadening the kind of games to be designed, by leveraging the informal knowledge most youth have from playing tabletop games, and by introducing new modalities for situating computational thinking.

With the advent of low-cost and accessible programming devices such as MaKey MaKey [38] and Lilypad Arduino [5] that bridge digital and physical computing, the proposal to design of augmented game boards moves into the reach of novice game programmers and designers. Some of our earlier work has focused on having youth design tangible interfaces such as joysticks and touchpads using MaKey MaKey that can connect and control to video games designed in Scratch [26]. We found that such activities gave opportunities for middle school youth to produce creative aesthetic designs while being thoughtful about functionality and provided youth the opportunity to engage with basic computational ideas through remix and get practice with game logic and usability. Other recent work has used a combination of Lego bricks and magnets as physical components and apps that interpret this information to create connections between the physical and digital [29]. In this study we introduce augmented board games as a new area of game making for learning with the following research questions in mind: (1) What are the affordances of blending coding and making in the context of game design? (2) How do youth experience the connection between coding and making? and (3) In what ways do youth engage with computational concepts and practices in the context of designing augmented board games? The hi-lo board game designs were implemented using low tech materials like foam boards, color pencil, foil and alligator clips with high tech computational tools like Scratch [34] and MaKey MaKey [38].

3. CONTEXT

3.1 Participants

We designed and taught the augmented board game workshop for 17 high school freshman (4 girls, 13 boys, ages 13-15) situated in a metropolitan city in US northeastern state. The youth in our workshop were part of a larger ongoing science immersion partnership between their high school (a science magnet) and local science center. Every four to six weeks students choose a new workshop to participate in during their freshman year by surveying short descriptions from all the available choice opportunities for a given period of time and prioritizing their top three choices. In our workshop on augmented board game designs, one main instructor (a graduate student) designed and facilitated workshop activities and was supported by two undergraduates who assisted students with their technical designs and also helped with data collection.

3.2 Workshop Design

Our approach to the workshop was to gradually introduce gaming, coding then crafting over the course of eight sessions. In the first session students received an introduction to the workshop and had a chance to play board games like Clue and Monopoly and reflect on how those games were designed. In the next two sessions, students worked to devise their own board game designs and play-test the games. In sessions four through six, students were taught the basics of Scratch programming. To facilitate their learning and comfort with Scratch, we designed simple debug'ems, or programs that are mostly complete but with some problems or bugs, which students were asked to solve in pairs. These debug'ems were directly connected to the coding and functionality necessary their augmented board games. Groups also tested digital components, like a digital dice, with their playtest boards to get a feel for how the digital components would impact game play. Then, in sessions seven and eight, students went to work on creating their final board designs, completing their Scratch code and integrating digital components aided by MaKey MaKey. In the final session, the students played their games and had the opportunity to get feedback from a range of adults that work in creative fields. A few weeks after their last session, students from the workshop set up and participated in an arcade (in an open space at their high school) where their peers came to play the games.

3.3 Data Collection and Analysis

We collected different qualitative data to address our research questions. We took field notes that described activities in each session and interactions between students. In addition, we logged videos during each workshop session to observe the processes of each group as well as the interplay of making and coding. We also collected each group's prototypes and final board games as well as their final Scratch code. Finally, we gathered students' reflections by conducting focus groups with three of the four teams. For our analysis, we examined each team's final projects by looking overall at their game designs and group interactions in making the boards and coding Scratch designs.. In this context, we also used Brennan and Resnick's framework [4] on computational thinking to more closely analyze in which ways youth engaged with computational concepts (e.g., loops, conditionals) and practices (e.g., remix, testing and debugging) in during their design. To look at the relationship between coding and crafting in the context of augmented board game design, we developed a case study that will be presented in more detail. Finally, we thematically coded youth's focus group reflections to understand how they interpreted the game design process and to more clearly understand how youth navigated coding and making. We also did a descriptive review of all the features on their board games and in their Scratch programs.

4. FINDINGS

We begin by presenting broad themes and features in the augmented board games produced in the workshop, followed by a case study of how one team of high school designers approached coding and crafting to produce their augmented board game *Cairo*, concluding with youth's overall reflections on choice of theme, work distribution, and audience consideration.

4.1 Crafting, Coding, and Collaboration

To answer our first two research questions, we examined more closely how crafting and coding were embedded in the game design process. We begin by describing the kind of augmented board games the student teams designed. All teams adopted a start-to-finish game mechanic, i.e., a particular starting space from which players had to navigate to the final destination in order to win the game. But the selected themes for the augmented board games differed, as reflected in titles like *Cairo*, *Safehouse, Get Out Alive and Mega Mountain Men* (for more detail, see Figure 1).

Safehouse: Start to finish game, digital spinner and playing cards, board used bright colors and hand-drawn graphics

Mega Mountain Men: Start to finish game, digital dice and introduction, board mirrored platform games

Get Out Alive: Start to finish game, digital dice and playing cards, board had simple two tone aesthetic

Figure 1. Board Game Designs: screens (left), boards (right)

In *Cairo*, players had to get to the treasure at the center of a tomb by surviving a variety of setbacks while in *Safehouse* a player had to get to a safe house while also dodging obstacles, whereas in *Get Out Alive*, a player had to find their way out of woods, a sort of camping trip gone-bad scenario and in *Mega Mountain Men*, the players in teams had to climb up the mountain while dodging mountain goats and other challenges while ascending. Designing the game mechanics and developing the theme provided the context of team members asking each other questions, programming on the same computer, co-drawing or coloring on the game board and in the final class sessions, assembling and composing their designs. This "in-practice" work of game design was evident in the ways the game-making and game play-testing were essential to improving the final designs.

To craft and integrate the augmented features, each team had to think about the interaction between the physical board game and the digital components. In two games, games, *Cairo* and *Mega Mountain Men*, game play was mediated by a digital dice while instructions were embedded on the board. In *Safehouse*, designers included a digital spinner and digital playing cards with riddles that the players had to solve (although they did not quite get to integrating their spinner, introduction and digital playing cards into one Scratch program). In *Get Out Alive*, the team used digital dice and playing cards that were called up each time a player landed on a certain kind of space. These augmented designs posed interesting challenges for youth, who were all comfortable thinking about and sketching a physical board game design by drawing on their personal knowledge of games. Augmenting the games added a layer of complexity that required them to think about the game play activities in a different way—they had to think about how the digital would be embedded into their game play experience, and vice versa. These crafting and gaming dimensions became even more intertwined in their coding.

To code their game designs, teams embedded a wide range of computational concepts and practices [4] connecting on-screen and off-screen interactions. Each group's final Scratch programs used computational concepts such sequences, events, operators and parallelism, while some also ventured into conditionals and loops. In terms of their Scratch programs, three groups (*Cairo, Safehouse* and *Get Out Alive*) remixed stock Scratch code we provided by changing aesthetics (e.g., the background, images, sounds) and functionality (e.g., adding new or tweaking existing features) to align with their game themes. A fourth group, *Mega Mountain Men,* opted to program an original introduction and digital dice without using stock code. In writing the rules for their games, groups utilized computational concepts such as sequences (e.g., each group numbered their rules), conditionals (e.g., rules utilized statements like *if a player rolls a 3*) and data (e.g., all games implicitly ask players to retain information like which artifacts had been collected or who had a special power) and, loops (e.g., *repeat steps 3-6*). In the chart below we illustrate some of the ways in which computational practices were taken up on the screen and in the board game designs and also overlapped (see Table 1).

To accomplish the integration of crafting and coding, all teams participated in an iterative design process; moving from playtest boards, to incorporating peer feedback to thinking about MaKey MaKey integration and then incorporating all of these things into their final designs. In the process, they had to determine what would remain the same (e.g., content, location of spaces) on the boards versus what would shift (e.g., scale) and what they needed to incorporate to finish the boards (e.g., aesthetics). While our analyses separately highlighted each crafting and coding, the following case study of the Cairo team illustrates in more detail how the integration was accomplished. More importantly, it brings to the foreground a performative aspect, the playtesting of the games, that became an integral part of the design process.

Table 1. Computational Practices in Hi-Lo Game Designs

On-Screen Designs	Board Game Designs
Being Incremental and Iterative	
• Updating code or making improvements as they bug tested and played • Making small changes during student arcade (e.g., fixing glitches in dice) to improve game for next sets of players	• Groups moved through a process of initial concept, test boards and final game boards
Testing and Debugging	
• Testing introductions to make sure things flowed in the right sequence. • Testing dice, playing cards and other digital components. • Incorporating MaKey MaKey to see if the functionality they built was working with the new interface.	• Youth had to play their games to determine if it was long enough, complex enough and if the traps and other challenges worked according to design.
Reusing and Remixing	
• Taking stock code and transforming or remixing aesthetics (e.g., using background, sprites, images, sounds) • Remixing functionality (e.g., *Safehouse* tweaked the spinner we provided to make it harder to get a 3).	• Youth borrowed or remixed ideas from popular board games like Monopoly and Clue.

4.2. Hi-Lo Tech Game Design: Cairo 's Case

The board game *Cairo* was designed by a group of five high school freshman boys (Peter, David, James, Tom and Ike—all pseudonyms) all aged 14-15. They knew each other because they shared an academic schedule and thus gravitated toward one another when it was time to select groups. We selected this group because they had the most successful augmented board game, in terms of the functionality of the board, the integration of Scratch components, and the cohesion of their aesthetics across the digital and tangible. Over the course of the eight weeks we observed each member of the group adopt and carry out a specific role: Pedro, drew the characters, Tom and James worked on the board design and Ike thought about content and the rules and David (who had taken an earlier Scratch intro workshop), took the lead on remixing the code (with occasional support from Tom). First, we will look at how the process by which they developed and tested their augmented board game idea. Second, we will look at their experiences coding in terms of what they specifically developed in their Scratch programs. Finally, we'll turn to the construction or making aspects of their board games and how they integrated the tangible and digital and the implications for the relationship between coding and crafting in a game design context.

4.2.1 Gaming

During the first workshop session, after youth spent time playing established board games (e.g. Monopoly, Clue), we asked them to gather in teams and start formulating an idea for their own games. In that initial session *Cairo* was interested in designing a game about dragons. However, in session 2, during more structured brainstorming time, new inspiration struck Peter, who was excited by Tjay the poet's new album release, *Cairo Casanova*, and the rest of the group embraced his vision. The theme of the game changed from dragons to a game about ancient Egypt, where players were meant to navigate to the bottom of a tomb inside a pyramid to find treasure. After deciding on a theme, the group sat together to sketch their playtest board on an 8 ½ x11 white paper. Their conversations were interspersed with thoughts about how each character would be different in the game, what special powers (or abilities) would be allocated and what game play should look like. By session three, the group moved from the piece of paper to creating a larger playtest board which the group played several times. As they played the game, they came across issues with the design and continued to tweak it. During week three, *Cairo* also had the opportunity for peer feedback when members of another team, *Safehouse* played their game. As *Safehouse* team members played *Cairo,* the rules and overall game logic became clear: members of *Cairo* had designed the board to have many challenges like, taking the players back to the start or skipping turns, making the game harder to win. So by watching their peers play, members of group *Cairo* were able to see what worked and what needed to be changed on their board game. Throughout these early sessions, team members made corrections in pencil onto the playtest board as they played the game. Later, in the focus groups with all the *Cairo* team members present*,* Damon and James explain how play testing the game supported their development:

> Damon: "We played it to see how the game flowed, and once we saw it flowed we were like okay so this needs to be here, this needs to be here and that needs to be here."
> James: "We played the game while creating it."
> Damon: "We were writing those setbacks [things that stopped/forwarded movement on the game board] while we were playing."

This focus group excerpt illustrates how the designers of *Cairo* had to be play their game in order to make it. As James stated, *"we played the game while creating it."* The group was also constantly playtesting because they wanted to make their game harder or more challenging for potential players.

4.2.2 Coding

In sessions four through six *Cairo* transitioned to thinking about the on-screen or digital components of the augmented board game designs by starting to work with Scratch. Team members learned how to use Scratch like movement, appearance, event-driven functionality and some basics of parallelism. Then, team members from each group worked in pairs to practice these concepts in Scratch by solving and completing debug'ems. These are Scratch programs that are almost complete but intentionally have small issues (or bugs) that help learners apply their knowledge of computational concepts. These sessions in the middle of the workshop bifurcated team member activities between those who worked on the board game and those who worked on the Scratch game. In terms of work distribution, David, occasionally supported by Tom, worked on the Scratch code while the rest of the team helped him with testing and debugging. Since youth worked on Chromebooks, only one or two people could be huddled around the screen space to resolve programming issues.

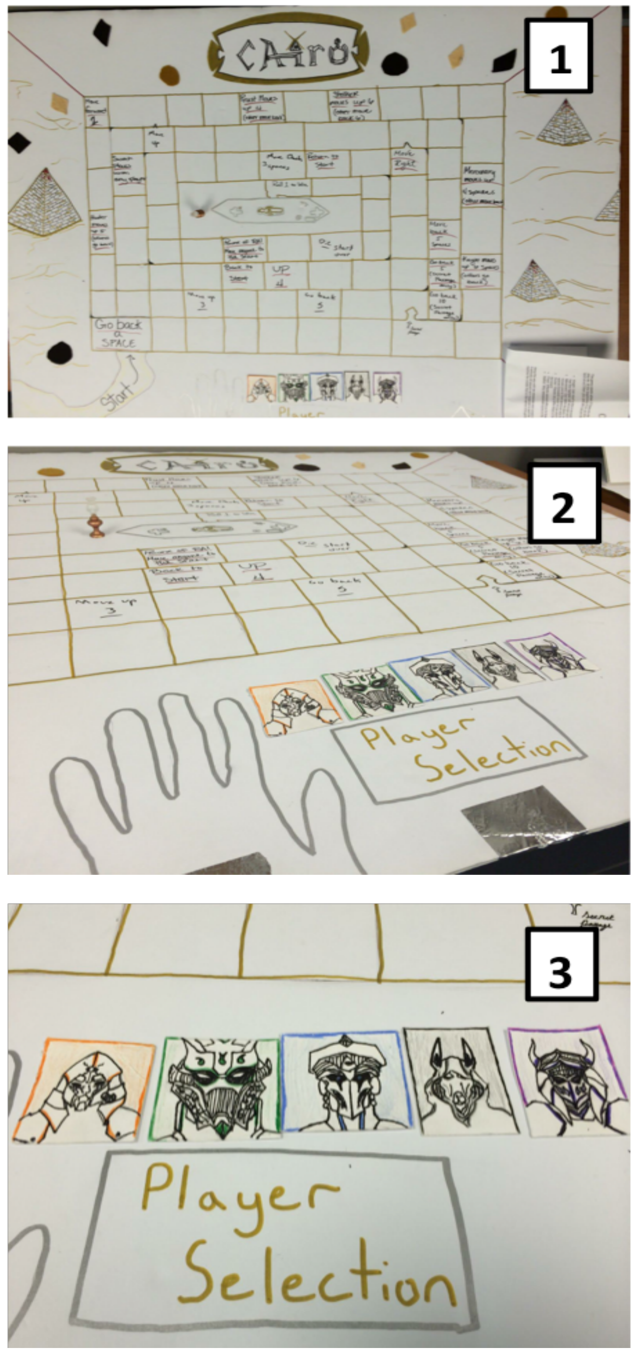

Figure 2. (1) Cairo's board, (2) Closeup of the hotspots, and (3) Hand-drawn playing pieces

Cairo decided that they were not going to have digital playing cards but did opt to incorporate a digital dice and musical introduction (see figure 2 below). In addition, they decided to use locations on the board (e.g., head back to the beginning, skip a turn) to drive the action in their game. David took the lead on developing the code because there were some team members like Peter and James who were less confident with Scratch. He remixed the sample Scratch programs we provided, working hard to match the aesthetics on screen with the physical board design and was thoughtful in considering sounds and font styles that matched the overarching theme of *Cairo*. As their game evolved, the team opted to include player and ability selection as part of their Scratch code. Thus, they took something that was originally done by rolling the dice in their original game and shifted the process to be a digital one. Player selection was an innovation they decided to digitize even though it was not part of any of the original remix code that each group was given as a way to facilitate their entry into programming.

Figure 3. Cairo's digital introductory screen (top) and home screen (bottom).

4.2.3 Crafting

In session 6, the group had to turn to the task of integrating their digital dice onto their second playtest board (a larger piece of poster board that mimicked the original design). Seeing the connection between the Scratch program, the MaKey MaKey and the board game was an important hinge point in the design process Once the team could see that they had to coordinate the interaction between the hotspot and the code, they were able to see how the digital and tangible could come together. Then, in the last two sessions, the group shifted to integrating the digital and tangible components together. To transition from their playtest board to the final foam board the team had to create a life-size version of their spaces while also integrating the digital dice, player selection, and, earth hotspots. In addition, they had to determine where to locate the MaKey MaKey and the laptop to ensure a comfortable playing experience. Members of *Cairo* also spent time refining the aesthetic elements of the board including drawing pyramids, incorporating texture with small hand cut felt stones and using metallic markers for accents (see figure 1). The last session was a frenzy of activity with the boys coloring, cutting, outlining and testing. Even though they had each taken the lead on an aspect of the project (e.g. art, Scratch, rules), each member contributed to the final construction and testing of the game.

Figure 4. *Cairo* at the arcade situated around their game.

A few weeks later, when a culminating arcade that was set up in their school, team members and other students from school played the game (see figure 4). Within minutes, *Cairo*, had gathered a crowd. Their friends and curious passersby stopped to admire the team's enthusiasm for the board game. Once others began playing they began coaching newcomers on how to use the digital dice and the general rules of the game. Soon, students were finding unique ways to complete the circuit, like high-fiving. During the arcade *Cairo* also encountered challenges for example, David observed that no one was "rolling a three." To resolve it, David took the computer for a few minutes to debug the code, only to notice there was a glitch he had not observed before. He debugged the code and the group was able to continue playing. *Cairo* was the most popular game at the end of the arcade. The case study of Cairo's team illustrated how gaming, coding and making, developed in their augmented board game design and play—connections which we also observed in the other groups.

4.3 Reflections on Hi-Lo Tech Game Design

Designing augmented board games involved youth in multiple modalities, not just in coding but also in crafting and playing their games. According to youth's interviews, these involvements aligned with their particular areas of comfort, revealed sensitivity in interaction design, and connected to their interests in pop culture. The first theme is most closely related to how game making activities promote (or not) programming activities. For example, Jordan from *Mountain Men* explained his thinking about how he chose to participate: "First I was sorta uh, the um physical uh artist. Uh, but then I wanted to do more with Scratch cause I didn't know uh, much about it. But then I tried it and it proved to be really confusing for me, and I wanted to do the dice at least but that was still pretty difficult for me. So I just went to doing the physical art." Here Jordan is explicating his lack of comfort with Scratch as a reason for gravitating toward a role where he felt comfortable. Alternatively, David, who was on team Cairo, explained of his rationale for selecting Scratch: "I gravitated towards what I knew how to do" and continued by explaining that he was not creative or artistic. Other interviewees also indicated that most of them seemed to gravitate towards roles that aligned with areas of comfort. For example, Melissa was a student who often was checking her phone and not involved with her group. When the instructor talked to her about it she explained that her lack of participation in the group was because she wasn't good at "that stuff." When the instructor pressed her on what she meant by that, she explained she wasn't comfortable with technology nor was she good at art. In moving beyond the screen, youth are challenged in how they relate to and integrate crafting and coding in their design work.

The reflections also showed youth's awareness and consideration of audience in their design process. Youth designed play test boards and then played each other's games to get feedback and perspective. This also gave youth a chance to see what worked and what did not work and make adjustments. As Bill explains, "I was designing the board and I noticed like that if it was too small and ...when we like did those...trial runs and stuff, I was able to notice, first of all like, the proportion, and also it was like a rough draft basically." Here we see Bill appreciating the process of designing a play-test (or rough draft) board where they could test out their games and had room to make mistakes. This iterative design and playtest process gave these high school designers sense of proportion and through observation, also a sense of what seemed too easy or difficult for other players. Furthermore, while these opportunities for play-testing were integrated in the overall design of the workshop, it illustrates how closely intertwined the making became with playing of the game in the process.

Finally, several statements of group members revealed that designing augmented board games can help to connect to a broad range of interests. All groups also drew on their personal interest in and knowledge of music, movies, and video games to inspire their games. For instance, Peter's personal interest in music influenced the *Cairo* group theme while two members in the *Safehouse* group drew on their understanding of the plot of the film with the same title, the first team member providing the name of the movie while the other member fleshing out the concept. For the *Mountain Men* group, Andy explained how they were trying to make their board game similar to video games: "We also wanted to make... mixing a platform video game with like a regular board game... specifically the way you move and how you jump and climb up the mountain. We also wanted...in like a video game there's...empty space you could fall so we wanted something like that, um, to put into our game as well." Such connections to popular culture are not surprising given youth' known interest in and engagement with popular media but here they highlight the potential of constructionist gaming to appeal to a broad range of personal interests.

5. DISCUSSION

In this paper, we proposed to expand game making beyond the screen by using augmented board game designs. Our analyses revealed that it is a feasible, yet complex activity that engaged youth in crafting and coding. What became quickly apparent in reviewing youth's products, processes and reflections, was the interconnectedness of different modalities: one cannot design a board game and craft interactive screen elements without thinking what and how to code them and vice versa. Likewise game making appeared to be closely intertwined with game playing as the design of the board games progressed. It was in fact an essential part of the process and suggests that the boundaries we have drawn between constructionist and instructionist gaming are more of academic nature. In the following sections, we turn our attention to affordances and limitations of hi-lo-tech game designs for constructionist gaming, then consider expansions of these designs with other materials, before concluding with thoughts on how to bring together game playing and making under the umbrella of connected gaming.

5.1. Affordances and Limitations

When we look back at this workshop and overall results, we see significant promise in getting youth involved in hi-lo tech designs like augmented board games. First, board game design, as was illustrated in our findings section, is inherently a computational thinking activity even for those parts that take place away from the screen. Constructing rules and game mechanics (e.g., how play will happen on the board) and navigating the interplay between coding and making resulted in youth being engaged with computational thinking concepts (e.g., sequences, data, loops) and practices (e.g., being incremental and iterative, remixing).

Second, we observed that even in groups that were not as collaborative as *Cairo*, the board became a space for collaboration around computation. During the final two sessions, groups hovered around their boards, coloring, pasting, adding digital components and the like. Unlike the small computer screens where youth had to collaborate to work on Scratch, the boards provided enough space for groups to adopt different tasks in service of the larger goal–refining their board designs. Such collaborative interactions can reveal interesting group dynamics. In future work we may opt to consider a framework to more closely analyze the different ways youth collaborate, code, and craft [e.g., 41]

The augmented board game designs also created opportunities for continuous design between high and low tech. For example, a character that was originally drawn on paper by one of the boys in *Mega Mountain Men*, was then recreated as a digital character on-screen. This an important hinge point as we think about design across these modalities. We found high-low tech game design provided a rich space that does require some structure and distribution of collaborative design task but has the potential for youth to take on roles where they excel and try out modalities where they don't feel as strong, while ensconced in a larger collaborative setting. Moreover, with tools like MaKey MaKey available, everyday materials like foil can give youth opportunities to make the jump from low to high tech.

We also want to also acknowledge some of the limitations or challenges that we would seek to resolve in future work. First, not all students participated equally in crafting and coding. Many students adopted roles they were comfortable with and while the augmented board game design allowed different opportunities for participation, it does not encourage all youth to partake in coding in a more involve way. So thus we wonder how we could design such a task to encourage varied participation that does not limit youth to aspects of the project where they are already comfortable, but also leads them into areas of discomfort that could potentially become rich learning opportunities for them. We also wonder how we could more cohesively integrate learning opportunities around the tangible (the board) and digital (Scratch) design so youth can see them as two parts of a larger whole. These are important pedagogical considerations because we would want all team members to benefit from learning and expanding their coding and crafting skills.

Second, we observed, particularly with the group *Cairo*, that their comfort with each other and interest in each other's ideas made it possible for them to engage in the game design process. We wonder how more rapport building activities amongst groups and more structured tasks could begin to address some of these challenges. If we think about replicating similar efforts in schools or other learning contexts, we suggest two important changes: first, facilitating more comfort amongst collaborators, and second being more thoughtful about how the design task is structured so that responsibilities are distributed and team members are able to work with modalities where they feel comfortable, but also are required to explore modalities that are less familiar, in this case, coding.

5.2 Hi-Lo Tech Game Designs and Tools

Our previous work on the design of tangible game controllers [8; 26] as well as related efforts in augmenting game designs [27] suggest that hi-lo tech game designs present a new and viable direction for interaction design and research. We can think of expanding these designs into several directions, the first involving wearable designs where controllers move freely in the physical space, the second including bi-directional designs where input from sensors can also feed back information and actions on and off the screen, and the third involving expansions into the mobile domain. We started pilot work in which students create wearable controllers with their own remixes of Flappy Bird Scratch games that they can wear, like a glove or bracelet in which they can play their game. Here we draw on work related to e-textiles and creative computing [6] that provide tools and components to allow sensors, conductive patches, and actuators to be connected with conductive thread and embedded into soft materials like clothing. We have already successful examples of such controllers designed as part of a college coding competition called StitchFest [37] in which a winning team created, crafted, and coded a wearable controller called HackyBird.

We can also connect to current efforts around bi-focal modeling [3] that increase further the complexities of designing such extension applied to gaming contexts. Unlike uni-directional designs that only interact by triggering events on the screen or use screen designs to control patches on the game board, these bi-directional designs have the capacity for a two-way interaction [36]. Further expansions could include mobile applications that take into account GPS data. Like the augmented board games discussed in this paper, such suggested expansions into wearable and bi-directional designs can widen the boundaries for computational participation [23]. There are youth who are enamored by fashion and those who are interested in video games. Thinking about a design space where these interests connect a promising context.

To realize such integrated designs, we also need more computational construction kits that bridge the online and offline worlds for beginning crafters and coders. In our current studies, we used two computational construction kits, Scratch and MaKey MaKey, that made it possible for youth to tinker, create designs and make adjustments and bridge the physical and tangible. MaKey MaKey and basic Scratch functionality were easy to understand for our novice designers but some simple modifications could even further facilitate the design work. Some of the design work concerns technical changes such as longer supplemental wires connecting to the back of the MaKey MaKey and providing more input tabs on front of the MaKey MaKey would make it easier to work with larger boards. Likewise, using Scratch on tablets rather than notebooks would make it easier to not only integrate the screen into the board game but also facilitate collaboration between more than two group members. Currently, many toolkits exist that function well in one modality but making the integrations might require new designs.

6. CONCLUSION

In this paper we used insights from a workshop on augmented board game designs by youth on how we can rethink connections between gaming, crafting and coding and develop new models, activities, and tools to promote constructionist gaming. We return to the divide between game playing and making that has dominated much of serious gaming and interaction design and research. On one hand we have researchers concerned with designing and studying educational games for learning, while on the other hand we have researchers concerned with designing tools and studying their use that allow learners to make their own games. What our work begins to suggest is that this divide is an artificial one, not just because of our particular design task, but more importantly because playing and making are seriously intertwined in the design process and artifact, even if the players are the designers themselves [22]. We need to develop a much broader range of design activities, a broader focus on how we analyze interactions around design and play, and also directives for designing tools that facilitate these more integrated perspectives. We have maintained for far too long artificial boundaries between instructionist or constructionist gaming approaches without realizing that both of them are integral or connected part of the ecology of gaming.

7. ACKNOWLEDGEMENTS

The research reported in this paper 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.

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