Designing *eBee*: A Reflection on Quilt-Based Game Design

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ABSTRACT

eBee is a game that integrates quilting and soft circuits with the goal of bridging the disparate communities of making and crafting through intergenerational play. In this paper, we describe the design process for *eBee* and our goals for bringing the social, creative, and cooperative values associated with the quilting community to a new kind of game experience. Using an affordance-driven game design process, we identify a new space of potential games that is ripe for exploration.

CCS CONCEPTS

•General and reference → Design; •Human-centered computing → Activity centered design; •Software and its engineering → Interactive games;

KEYWORDS

game design, quilting, craft games

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1 INTRODUCTION

Historically, innovation in game design has often coincided with the introduction of new technologies and new communities. The affordances, constraints, and materials [14] of the new technologies open up new areas within the landscape of games design. In fact, a number of significant early games came about as a result of a desire to play with and explore the affordances of new technology. Arguably the first computer game, *Tennis for Two* [11], emerged from a desire to showcase the abilities of the Systron-Donner analog computer. This foundational video game was heavily constrained by that machinefis abilities, which were creatively used by the game's designers based on its unique affordances. [15].

Within the Game AI community, a movement for "AI-Based Game Design" [6, 23] argues that the affordances of AI technologies open up new game design possibilities. Advances in interaction technologies, such as gestural interfaces, biometric input devices, distributed devices, and embodied interfaces, and mobility have similarly driven new kinds of game experiences and innovations in play mechanics. Affordances such as the accelerometer on mobile devices have resulted in innovative new physical interactions as seen in games such as *Bounden* and *Space Team*.

New platforms also coincide with the expansion of play audiences and communities. Diversifying the communities playing games offers up the possibility for new styles of play that coincide with the skills, interests, and preferences of new players. For example, games made on social networking platforms offer a more casual and social form of play in fitting with the modes by which players interact with the platform. The introduction of the Wii expanded the audience of console games. And mobile platforms, in which games are added to a larger repertoire of "on hand" apps, have also greatly broadened the audience for digital games.

In this paper, we present our method for developing *eBee*, a research-based electronic quilt game that blends historical technologies of quilting and the emerging technology of soft circuits in the service of an activist agenda. We approached this project through the following strategies:

(1) An intersectionally feminist social agenda to address the gender and diversity disparities in maker culture, through highlighting traditionally feminine "craft" practices and juxtaposing them with more male-gendered electronics and digital fabrication;
(2) An affordance-centered, iterative approach to game design in which the unique properties of the materials are a driver of design; and
(3) Adopting the highly accessible family activity of a board game as an activist vehicle for creating an intergenerational bridge between textiles and electronics [8]

The resulting game, *eBee*, is one of many potential "craft games": games that incorporate traditional craft practices into their design and play. *eBee* merges the social contexts of quilting bees and board games, the strategic and systems thinking of gaming and electronics, and the tangible nature of electronics and quilting to build a new kind of game experience. The project aims to bridge the generational, ethnic, and gender gaps in games and electronics through the incorporation of traditional quilting methods and practices. This paper details our design process, discusses the design tradeoffs made throughout the project, and presents *eBee* as an exemplar of a new potential design space and process for game designers to explore.

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2 METHODOLOGY: ITERATIVE, AFFORDANCE-DRIVEN DESIGN

Research-based games, that is, games that emerge from the formulation of a research question, can take a variety of different forms depending on the goals of the project. The impetus from this project emerged from a simple question: "How can we merge the traditional craft of quilting with contemporary 'maker' practices in order to bridge gender, age and ethnicity gaps between these two similar activities?" The original aim was to create an informal learning experience in the form of a workshop that would bring members of these two communities together through a common interest in generating material culture. Experientially, we envisioned an intergender, intergenerational peer-learning environment where sewing machines and soldering irons sat side-by-side, and older women might teach younger men, for instance, how to sew, while being taught electronics. In its initial vision, the game was primarily conceived of a means to an end, a bridge-building function between creative communities.

We began the process by familiarizing ourselves with the affordances of the materials with which we wanted to work, building on residence expertise in quilting within the team. Previously, two members of our team had been exploring a process of "affordance-based game design," an artistic method which places the affordances of materials at the center of the design process; concurrently, another member had been exploring "AI-based game design", a design method used to create innovative games that are uniquely suited to the technologies they are based upon. These combined approaches allowed the materials to tell us how they want to be played with, in the same way as artist's talk about working with the material properties of paint, clay, or brass. It also allowed us to ask: what can we do that is unique to these materials? In addition, our process was informed by the larger cultural practices that were at the heart of our research question. This cultural perspective was instrumental in our process as we were also referencing a set of creative conventions that emerged from quilting practices. Our work was also inspired by Gaskins's work with quilting as a culturally-situated way to engage minority youth in geometry and mathematics [9].

The result of this process was, almost by accident, a complete and polished game. In taking a hands-on, design-based approach to creating workshops that bridge "making" and "crafting", we were ourselves enacting one of these workshops in our project team. *eBee* is thus the first game to result from what is now a larger-scale research project.

3 DESIGN MOTIVATIONS

3.1 Integrating Making and Crafting

The impetus for this project arose out of our mutual interest in developing a quilt-based game using e-textiles as a means for bridging the gender and diversity disparities between the burgeoning "maker" and crafting communities. These communities are typically seen as separate from each other and tend to be diametrically opposed in terms of gender and generation, yet they share many common practices, goals and values.

The "maker" movement embraces new digital fabrication technologies and electronics to encourage public participation in engineering and manufacturing. Though the "maker" movement has exciting ramifications for informal education in a variety of STEM fields — including computation [5, 12] and biology [13, 19] — makerspaces often have a particular focus on hardware and electronics, and tend to be male-centric [10, 20]. The "maker" movement has a serious problem with the gendering of its activities, spaces, and advertising material. E-textiles pioneer Leah Buechley has advocated for looking to existing craft communities to solve this problem [4], and feminist hackerspaces that incorporate the tools and traditions of craft through acknowledging the underlying engineering and mathematics of so-called "women's work" have risen in response [7].

Alongside the growth of the "maker" movement, the rise of social media has fueled a thriving online community of hobbyist crafters, supported by local community centers and shops with workshop spaces. Within the fiber craft of quilting, the community is predominantly female and older. There are over 16 million quilters in the United States alone, and the typical dedicated quilter is a 64-year-old woman[16], though a new movement in modern quilting is increasingly bringing younger women to the craft[18]. Additionally, quilting is an ethnically-diverse craft that spans racial, age, and geographic boundaries. For example, one of the most influential quilting groups of the 20th century–the Quilters of Gee's Bend–comprises African American women from rural Alabama[2].

Quilting is thus an ideal vehicle for promoting diversification of game communities. Quilting, which itself is highly technical, also integrates well with the STEM-centric nature of more masculinized fimakingfi communities because of the need for practitioners to engage deeply in mathematical and procedural thinking [9], as well electronically enabled sewing technologies. The intergenerational and racially diverse aspect of quilting is particularly appealing in the context of board games, which conjure up imagery of families playing together. Additionally, quilting and board gaming share a common social form of people sitting around a central artifact intent on a shared activity.

3.2 Integrating Crafting and Game Design

"Crafting" in digital games typically brings to mind complex systems that provide players with an automated mechanism transforming in-game resources into useful artifacts. Games such as Minecraft or Stardew Valley adopt a utilitarian and somewhat capitalistic perspective on craft, placing value on the function of the object being made rather than the process followed to create it or aesthetic considerations for the materials. With *eBee*, we aim to more deeply explore the integration of actual "craft"–as opposed to the metaphor of craft- through-automation–including highlighting the importance of tactile aesthetics. *eBee* aims to bridge a digital/physical divide through the incorporation of e-textiles, allowing us to authentically engage with the tactile nature of crafting but retain an element of digital interaction via its game mechanics.

We also aim to integrate the values associated with craft into gameplay. Quilting communities are built around values of social interaction, cooperation, creativity, and beauty. There is a long tradition of quilting and sewing "bees", from which *eBee* derives its name, in which communities gather and work together to create a finished quilt. These quilts are often made to mark personal special

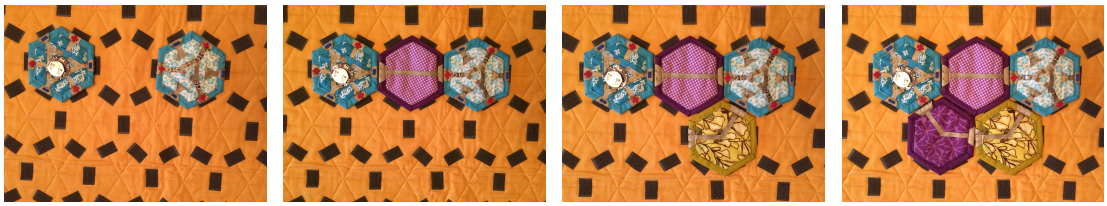

Figure 1: Players connect the hub (dark blue) and island (light blue) using game patches (purple, green).

occasions–a marriage, the birth of a child, the death of a loved one–or may be donated to others such as homeless or women's shelters, or victims of a natural or manmade disaster. During quilting bees, participants (typically women) will socialize as they ply their craft; talking about their families, current events, or social concerns. The shared creative activity of quilting frames a social space that is intimate and welcoming. Games similarly frame a social space for their players. *eBee* aims to bring the values of the social space for quilting into the game's social interactions, promoting a play environment that is cooperative, creative, and welcoming to people of all backgrounds.

4 THE *EBEE* GAME

In order to better understand our process, it is helpful to get a snapshot of the final game we produced using this method. *eBee* uses quilted hexagonal tiles outfitted with channels of conductive fabric to construct circuits that lead from a central "hub" tile, or power source, to randomly scattered "island" tiles outfitted with LEDs. The goal of the game is to create circuits to illuminate as many LEDs as possible. Connections between tiles are made via conductive Velcro that secures the tiles to a quilted board and provides the contact for the conductive fabric to form the circuit. 1 shows a sequence of steps required to build a circuit from the hub, through an island, and back.

Set Up

- Place the game board Velcro-side up on a level surface attach the hub patch to the center of the board, partially overlapping the conductive Velcro
- Distribute and attach island pieces around board (further away from the hub makes for a harder game!)

Gameplay The game can be played with two or four players. With four players, there are two teams of two players each. Each player or team choses a color. On each turn, teams/players can choose between four available actions:

- **Place** any patch into your hand next to any other patch on the game board
- **Rotate** any patch that doesn't belong to their opponent (except for the Hub)
- **Move** a patch that belongs to you by one space on the game board
- **Remove** one of your patches
- Do not use your turn to undo the last move
- The game ends when no moves are left or players agree to end the game

Game Patches

Figure 2: Completing a circuit lights the LEDs on the island patches.

- Attach the patches to the board using the conductive Velcro strips to make a connection (see Figure 1)

Objective

- **Connect** circuits from the central hub (+) to an island (-) and from the island (+) back to the hub (-)
- **Compete** to score a point when a light is illuminated next to one of your pieces

Modes of Play

- Two player competitive
- Four player team competitive
- Cooperative puzzle mode
- or make up your own!

The game has both competitive and cooperative play modes. In competitive mode, teams maximize the number of LEDs illuminated from circuits completed by tiles of their own color. This may involve teams blocking their opponents or continuing their unfinished circuits. In the co-op "puzzle mode," players aim to maximize the number of LEDs that can be lit by combining their collective tiles. By discussing, experimenting and building circuits, players collectively assemble an illuminated quilt. 2 shows an island with lit LEDs as a result of completed circuits. We have found that offering several modes of play helps broaden the appeal of the game to a wide audience, and is in keeping with our original goal of creating a "kit" or "platform" for quilting-based games. The cooperative game mode is most in keeping with the spirit of a sewing bee, where participants work together in creation.

5 *EBEE* DESIGN ITERATIONS

eBee went through five major design phases. The first *exploration* phase involved initial research into the affordances and constraints of the materials and technologies we were aiming to integrate. After this phase, we began iterating on what would eventually become the

Figure 3: Creation of a plush toy using Arduino. The user holds each hand of the toy to trigger music, using her own body to close the circuit.

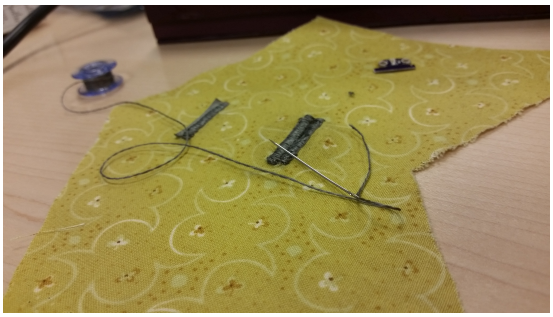

Figure 4: Experimenting with conductive fabric (left) vs. stitched (right) buttonholes.

Figure 5: Metal buttons with conductive fabric buttonholes create a connection to turn on an LED light.

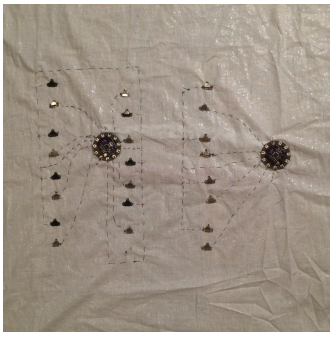

Figure 6: Our original design involved an elaborate substrate of hand-sewn conductive fabric attached to an Arduino Lilypad, using magnets and reed switches to complete circuits.

eBee game with an *experimentation* phase for prototyping potential game mechanics. The third phase involved *simplification* of the complexity inherent in the ideas that emerged from this exploratory phase into a core nugget to drive gameplay. The fourth phase was a *development* phase, where we further developed our core prototype and developed a process for creating games that are more rugged and playable by members of the general public without facilitation. The final *refinement* phase focused on improvements to usability and the visual aesthetics of the game, which are synergistic elements since the form of the game is integral to the gameplay.

5.1 Exploration

Our first phase entailed learning about the technology and familiarizing ourselves with the materials and their affordances, as well as studying games and toys that dealt with electricity, circuits, and quilts. To better understand the making processes of using soft circuits, we used instructibles to create sample projects with fabric, conductive thread and Arduinos (see 3). We also looked at a variety of different materials, including conductive fabrics and threads, snaps, magnets and metal buttons.

Games and toys we played with included *Snap Circuits*, a snap-based system that allows you to power devices by creating electrical circuits, and the board game *Patchwork* [17] where you try to orient pieces on a board to mimic a quilt. We also looked at the game *Downfall* [3] as at one point we were considering a vertically oriented board that would have been approached by players from opposing sides.

5.2 Iteration 1: Experimentation

During this phase we experimented with our own designs by creating a number of small, isolated prototypes that integrated electrical connections that triggered various effects. This included experiments using conductive thread with different types of fasteners. One approach involved using metal buttons fastened through buttonholes fashioned from conductive fabric (Figures4 and 5) . Others involved the use of snaps and magnets. We explored the properties of conductive material, such as thickness of thread, and the low resistance of conductive fabric. We also looked at various effects that could be triggered by the connections.

Our initial design involved an Arduino Lilypad (Figure 6) that would allow us to integrate computation into the game; this entailed creating an elaborate substrate out of conductive thread, that attached to various conductive components and effects on the front side of the quilt. From this process, we concluded that 1) Triggering LED lights was surprisingly satisfying as reward for successful completion of a circuit; 2) Building circuits itself created an interesting challenge; 3) Computation introduced unnecessary complexity. The result of this phase was that we decided to do away with the computational aspect of the project, and focus on the circuit-building activities which became the primary mechanic of the game.

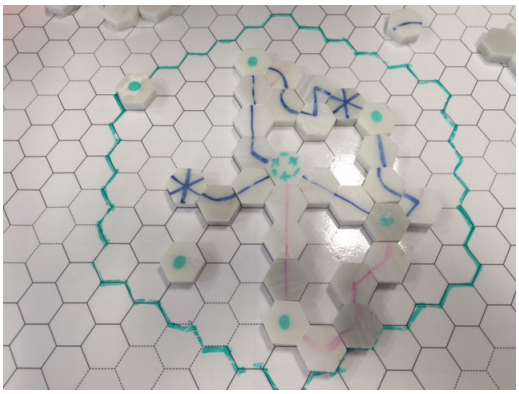

Figure 7: Gameplay prototype created with hexagonal floor tiles on a hex grid gameboard using dry erase markers.

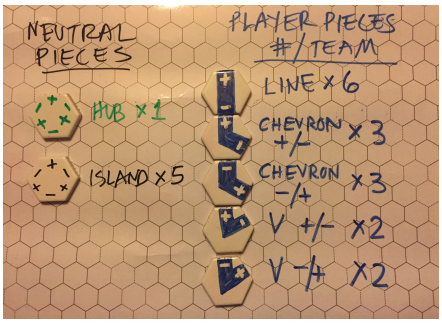

Figure 8: Gameplay prototype created with hexagonal floor tiles using dry erase markers, with different piece types.

5.3 Iteration 2: Simplification

From iteration 1, we concluded that we could use the actual properties of electricity inherent in the conductive materials as the core game mechanic. This allowed us to distill the core nugget of gameplay, bringing us closer to the conceptual intent of creating a quilt as the outcome of gameplay. At this point we began two parallel development processes. One team continued to work on developing the core technology of the game, continuing to experiment with various conductive materials and fastening strategies, while the other began to experiment with the actual game mechanic. Regular meetings and updates took place during this period, which each team building upon the work of the other.

For gameplay prototyping, the latter involved a paper and pencil prototyping process using floor tiles and dry-erase markers. The first paper and pencil prototypes used a square grid, but we found that the gameplay affordances were too limited. Eventually it was determined that a hexagonal grid would make for more interesting and complex gameplay. Introducing the hexagonal tile allowed for more tile layouts, as well as well as a much broader array of options and opportunities for emergent behavior. In the first hexagonal iteration there were four layouts: The V, the chevron, the line and the star. The star would be the most powerful piece in the game since it had a channel of fabric coming out of each side. However we quickly realized that the star piece would not work because it would result in a short-circuit. We therefore reduced it to three tile types. A number of run-throughs were done to determine the final quantity of each layout.

Figure 9: First iteration using conductive tape affixed after all the circuits are created.

An important outcome of this prototyping process was the realization that the much slower pace of quilting was at odds with the brisker pace expected of a board game. We also realized the game required a board to play on, that the pieces needed to be placed on some kind of underlying game substrate, even if the gameboard was not necessarily outfitted with electronics, as had been the case with our first iteration.

We continued iteration on the game through experimenting with different fasteners and techniques for adding conductive elements to the patches. We settled on thin hexagonal patches with conductive fabric appliqued on top. The intent was that players could choose to sew them together using conductive thread after temporarily fixing them together with conductive tape (Figure 9.

The first completed version of the game involved hexagonal tiles placed on a canvas board featuring a hexagonal grid. The fabric pieces were produced using a laser-cutter, which was required for efficiency, but also because the conductive fabric channels affixed to the pieces would have been difficult to cut by hand. We also used color-coding of base fabric to help players distinguish between the three different types of pieces, as well as slight coloration of the conductive fabric to indicate the polarities coming from the battery as well as the island tiles. Having determined that our original idea of actually sewing the pieces together to assemble a final quilt would take too long for a satisfying board game experience, we instead used conductive tape to make the connections between the pieces. In this iteration, the pieces would be lined up and the tape put on at the very end. This meant the connections did not provide immediate feedback and if the circuit was not working, pieces needed to be moved and tape re-affixed to correct the problem. We felt it would be preferable for the game to provide immediate feedback, which meant that we needed a strategy for connecting the circuit as soon as the piece was laid down on the board.

5.4 Iteration 3: Development

Our initial version of the game was first shown in the SIGGRAPH Studio in 2015, where we hosted both the game itself and a small sewing space for participants to prototype new materials. While at SIGGRAPH, our team borrowed some conductive Velcro from

Figure 10: SIGGRAPH Prototype created on-site using conductive Velcro. Note color-coding; this was added to indicate negative and positive polarities.

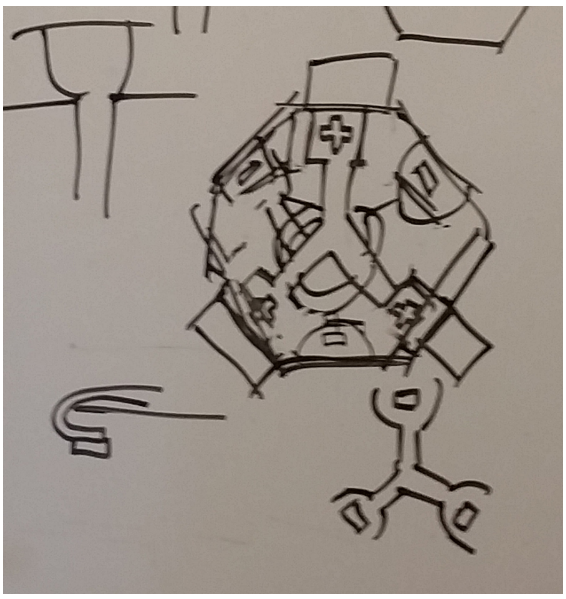

Figure 11: Mockup of the patch design for hub and island pieces.

another group that was using it in their soft circuits project to prototype what would eventually become the final version of the game patches. We sewed squares of Velcro loops to the back of each piece using conductive thread to connect it to the conductive fabric on top of the tile. We then glued squares of Velcro hooks to the canvas board. When two tiles were pressed against the Velcro hook square, it created an adequate connection to illuminate the light. This technique solved both an engineering and a gameplay problem: it at once produced an effective means to close the circuit between two pieces, while at the some time providing the instant gratification of immediate feedback to improve the player experience.

From this point we began to develop the game in its current form. We determined that the Velcro technique would work better if the fabric were wrapped around the patch, as illustrated in Figure 11. This entailed sewing a border around each piece, then folding the fabric over the edge, and attaching the Velcro piece to the back

Figure 12: Finished version of *eBee* at the end of its 3rd iteration.

with conventional (non-conductive) thread such that it made full contact with the conductive fabric.

This next iteration used more traditional QAYG (quilt-as-you-go) sewing techniques that included batting and quilting each tile so that each individual game piece was like a mini quilt unto itself. The polarities were indicated by a cut-out plus and minus shape on the battery and island pieces. We similarly created a board substrate that was also quilted using traditional quilting methods.

In summary, this iteration of the game featured:

- Fully quilted pieces with batting and binding, with fabric color coded to distinguish between players, and pattern-coded to distinguish between piece types
- Conductive fabric wrap-around with the conductive Velcro loop side sewn onto the backside of the tile
- Quilted board with conductive Velcro hook squares attached to it (note that this had to be done with glue since the hook side of the Velcro was difficult to fabricate with a sewing machine)
- Final template for the conductive fabric on the battery and island pieces, including +/- symbols out of fabric to indicate polarities to players

The subsequent iteration (Figure 12) was presented at the Boston Tech Poetics 2015, IndieCade 2015, the Smithsonian Indie Arcade 2016, and the DiGRA Blank Arcade 2016. For the most part this iteration of the game was successful in public exhibition venues; however, it still had some recurring usability issues, which will be discussed in the refinements section below.

5.5 Iteration 4: Refinement

The most notable usability issue occurred most frequently when the game was being played unsupervised by facilitators. What we found was that, although the Velcro squares on the board were laid into a hexagonal grid, it was often hard for players to cognitively recognize their relationship to the grid. As a result, we would sometimes return to the game to find that pieces were stuck in rotations that were not aligned with the quilted grid on the board. This problem was resolved by adding hexagons to the final iteration

Figure 13: The final version of *eBee* during play, modified to have a cleaner and easier to interpret game board and fresher, brighter colors.

of the board. These provided players with a guide to understand the proper positioning of the tiles.

Additionally, we decided to draw the polarities onto the battery and island pieces rather than cutting them out as the cut-out version, while aesthetically pleasing, tended to fray over time. The final iteration also included newer, fresher, brighter colors for a more compelling visual aesthetic (Figure 13).

6 DISCUSSION

6.1 Notes on Form

As the images of our iterative process indicate, we did a number formal experiments with different shapes and elements for the quilt. The final form that the game took, using a hexagonal grid, emerged directly from this affordance-centered method, as well as from the complexities of bringing together three different practices and technologies with both common and divergent properties. As the hexagon began to emerge as the favored form for the game, we found it resonated with the project goals on a number of levels. First, the hexagonal grid is a familiar motif in quilts as well as board configuration in games. When showing the game in public venues, many gamers were attracted to it due to its resemblance to the popular board game *The Settlers of Catan* [22], while quilters immediately recognized the form as a traditional quilt layout. This reasoning was also used in the game *Threadsteading*, which shares a designer with *eBee* (Smith) [1].

We also liked the form aesthetically, and the aesthetics were enhanced by the introduction of color coding used to distinguish between individual players' pieces, as well as the pattern coding which we used to distinguish between the three tile layouts. Although these changes were primarily made due to usability considerations, they ultimately served to enhance the attractiveness of the game, and give it the quilt-like aesthetic of having a variety of different styles of fabric within a recognizable quilt geometry.

It's interesting to note that in showing the game, we also encountered occasional other projects that also used this hexagonal form. One of these was AutomaTiles, a system developed by Jonathan Bobrow at the MIT Media Lab, with whom we later collaborated to develop Fracture, a game using his system. We came to think of the hexagonal grid as a kind of "golden mean" of game design.

6.2 Design Tradeoffs and Values

Throughout the design of *eBee*, we were faced with a tricky balancing act with integrating games, quilting, and soft circuits. Figure 14 depicts the common and conflicting values and properties of each of these elements. This model also reflects the interdisciplinary nature of combining the three elements of games, quilts and circuits, and the different approaches that need to be taken with each.

6.2.1 Tradeoff: Slow vs. Fast Play. Sullivan and Smith [21] suggest that the opportunity for "slow" play is a defining feature of craft games; in early iterations, we envisioned that players would literally sew the pieces together to produce a finished quilt. However, the rapid feedback that comes from building circuits to light LEDs, as well as strategic elements that require an ability to reposition game tiles, means that the game's design did not lend itself well to slow and meditative play. *eBee* attempts to strike a balance here through designing a game with parts that are pleasing to hold, touch, and play with and encourages players to strategize to move

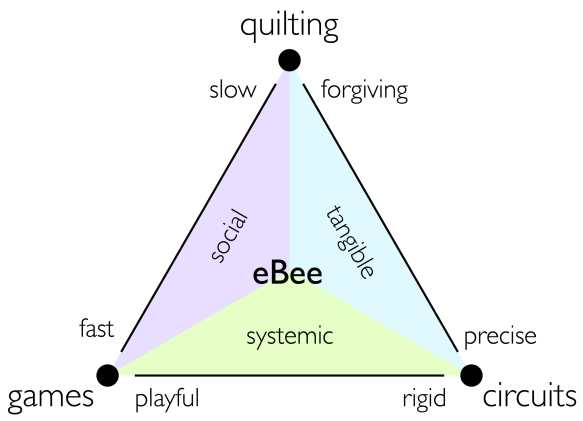

Figure 14: The design tradeoffs and shared values of games, quilting, and soft circuits.

pieces into different circuit configurations. In this way, the game's design maintains some of the slow and meditative design practice of determining the appropriate layout of pieces in a quilt, while permitting interactive play.

6.2.2 Tradeoff: Playful vs. Rigid. Circuit design conforms to rigid rules derived from the laws of physics, while board games typically permit playful exploration and bending of rules for the sake of providing a compelling and engaging player experience. With *eBee*, this conflict came to a head with designing the circuit paths on individual tiles. During iteration 2, we explored the possibility of a tile with connections on all six sides to support crossing paths, which was compelling from a play perspective and introduced new depth to the strategies players could employ. However, this design introduced too much complexity for how currents would flow through the eventual circuits: effectively, this type of tile would allow the equivalent of "crossing wires" in the completed circuit. We settled instead on an emergent complexity in circuit design, where players are provided only with tiles that can allow them to create simple circuits, but have the option to build up new circuits using powered islands as new power sources. This can lead to situations during more advanced games where players must "debug" unexpected behavior with LEDs, but still provides an entry to the game that is easy to understand and play with.

6.2.3 Tradeoff: Forgiving vs. Precise. The materials used to make quilts are soft, flexible, and forgiving. The direction that cotton fabric is cut impacts its elasticity: fabrics cut diagonally "on the bias" (as hexagons must be) are more stretchy than fabrics cut straight fion the grainfi. While some amount of precision is required in cutting fabrics for quilting, there is also some amount of leeway for imperfections and an expectation that no one piece will be exactly the same as another. With electronics, on the other hand, precision is key; currents can only flow across uninterrupted pathways, and the circuitry on the hub and island pieces must be carefully positioned to avoid overlapping conductive pathways causing a short circuit. To resolve this conflict, we took two major design decisions: 1) to cut all pieces using a laser cutter to minimize error in sewing the tiles and allow for intricate designs on the hub and islands, and 2) to use conductive Velcro to connect the tiles, so that that tiles do not need to tile perfectly on the board.

6.2.4 Value: Social. Quilting and gaming share the common value of being inherently social activities, gathering communities together in one place and fostering friendships and discussion outside of the primary activity. *eBee* aims to highlight this shared value through its team-based play, and especially in cooperative mode. Even during competitive play, having teams means that players are constantly communicating with each other. We have also found that the intergenerational and multi-dimensional appeal of the game brings together players talking about the different ways they relate to the game, from older women who quilt but don't typically play strategy games to young kids who are excited by the LEDs.

6.2.5 Value: Tangible. Quilting and electronics share the property of being physical and tangible. It was important to us during the design of *eBee* that we create a game that is satisfying to touch and handle and that reflects the warmth and weight of quilts, as well as the realtime visual feedback of building circuits. In multiple public exhibitions we were delighted at the pleasure that players derived from the tactile aspect of the game. We spent a good deal of time experimenting with the shape and size of the tiles, trying several different sizes until we found a form factor that balanced the board size, and the tile size. The final tiles were ideally sized to be comfortable for both children and adults to hold. We also padded the tiles using the traditional quilting material of batting, so they had a certain about of heft, and executed them with a high degree of craftsmanship. The tactile experience of the fabric tiles, coupled with the high quality of craftsmanship, had the desired effect of appealing to audiences that might not have ordinarily gravitated towards electronic games. In public exhibitions we repeatedly found older women, particularly crafters, drawn to the game, and received numerous compliments on the high level of craftsmanship. This attention to the efficacy of crafting gave the game credibility with one of our key target audiences.

6.2.6 Value: Systemic. Board games and circuits are both built upon systemics and require strategic thinking to understand and master. *eBee*'s core mechanic revolves around the building of circuits. Unlike many games where such systems are represented as abstracted metaphors, the game entails actually building real circuits. Players can thus experiment with the properties of electrical circuits as part of the gameplay. This opens up opportunities for emergent play within the constraints of the game system, including co-op play, and self-determined meta-goals, such as groups who tried to light up all the lights on the board with a constrained number of pieces, etc., or activating one island which then can become a power source for other islands. Thus the relatively rigid characteristics of electricity itself become one of the key affordances of the game.

7 PUBLIC RESPONSE

During the first two-year phase of the project, *eBee* has been exhibited at a number of game festivals and academic conferences,

and been played by hundreds of diverse people at a wide array of venues (Figure15)

The final, Velcro-based iteration was shown at a range of venues, beginning with Tech Poetics Boston and IndieCade in October of 2015, and in 2016 the Smithsonian Indie Arcade, Different Games, the CHI Art Show, Boston Mini Maker Faire, DiGRA Blank Arcade, Boston Festival of Independent Games (where it won the award for Most Innovative Board Game) and IndieCade's Game Tasting. These contexts provided a set of wildly different contexts and audiences for playtesting the game. The form of a board game allowed us to refine the rules with each subsequent exhibition in direct response to player emergent behavior. Based on these public showings, we found the following:

- The game had the desired result of attracting diverse audiences across gender, age, and ethnicity. In contexts where there were children present, it had particular appeal as a cross-generational game.
- As expected, women, particularly older women, were attracted to the game. This was especially the case in contexts where other games on exhibition were predominantly digital.
- A less-anticipated response occurred among people with an interest board games, who were attracted to the hexagonal form factor, and frequently commented on its resemblance to the popular board game *Settlers of Catan*.
- In public contexts, the game's innovative presentation and gameplay tended to introduce an element of novelty. While the game was less of a novelty in contexts like Tech Poetics, CHI and SIGGRAPH, all of which by design featured interactive experiences with unconventional interfaces, in more public venues and game venues, *eBee* had a novel aspect that attracted wide audience attention.
- As people played the game, they discussed the affordances of electricity as they applied to gameplay. For instance, one of the most challenging concepts of the game is that a circuit has to originate at one polarity–either plus or minus–and terminate at the opposite polarity. Thus to illuminate a light, a path of conductive fabric needs to connect at alternating polarities between the power source and the islands. When a connection failed, players would collectively analyze the path, identifying where the error occurred, essentially "debugging" their circuits. Players also discussed amongst themselves the best strategies for going about illuminating islands. This behavior pattern is illustrated in a number of photographs, in which players can be seen pointing at and discussing various tiles and connections.
- Although the game can be played in about 20 minutes, we found that players often lingered after completing a competitive game to experiment further with the affordances of the system. This emergent behavior led to the introduction of a co-op puzzle mode. In this mode, we noticed players often created their own meta-goals, attempting for instance, to light up all the lights on the board, or experimenting with the fact that once an island was illuminated, it could also serve as a power source for other islands, or daisy-chaining islands, similar to the way Christmas lights work.
- We were approached by a number of teachers and museum educators who felt the game was an excellent way to teach about electricity.
- Numerous people asked us where the game could be purchased.

One of the emergent outcomes of using the affordance-based approach is that by using the properties of electricity as core to our game's design and mechanic, we ended up accidentally making a game that teaches people about electricity. In fact, it was never our intention for the game itself to be educational. Our initial goal was to make a game system that could be created by cross-disciplinary groups of crafters and makers who would learn about electronics, soft-circuits, and textile craft through constructionist learning principles by making *eBee* games. However, because our game used the actual affordances of electricity as an integral part of its design, the gameplay itself turns out to teach people about electricity.

8 FUTURE WORK

We are currently exploring two future directions for *eBee*. First, pursuing the initial agenda for the project, we have partnered with the Boston Children's Museum and Boston Arts Academy to develop a workshop where people can collaborate to make their own *eBee* games. Our ultimate goal is to iterate on and produce a set of instuctibles that can be used within museums, classrooms, after-school programs, maker-spaces and crafting communities to create their own games using the core system we developed for *eBee*. In exploring this avenue, we have discovered that there are a number of such venues that have some of the key equipment required to create *eBee*s, such as sewing machines and laser cutters, that are in need of programming and activities. Our aim is to create a workshop package that can be facilitated by anyone with access to this type of equipment, even those with no prior experience with either electronics or sewing. The workshop format will encourage people to not only create the *eBee* game as we've designed it, but potentially to create their own games using the *eBee* system, varying for example, the effects and devices that are activated by circuits, such as triggering fans, music, etc., as well as the geometry of the quilt, and the actual gameplay.

In response to the overwhelming success of the project in public exhibition venues, we are also pursuing developing *eBee* into a commercial game. This will be challenging since the game utilizes unconventional fabrication methods, and we would like the manufacturing methods used to reflect the activist agenda of the game.

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Figure 15: eBee at the Indie Arcade hosted by the Smithsonian American Art Museum.

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