Breaking Boundaries: Mentoring with Wearable Computing

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ABSTRACT

With over 13.3 million children living below poverty line in the United States, there is a pressing need for engaging HCI research with children at the socio-economic margins. Drawing from design studio culture and art therapy literature, we explore wearable computing as a creative and tangible medium (similar to markers, paints, clays, *etc.*) for motivating 'at-risk' children in hands-on making and expressive instantiation of ideas. Working with a local outreach organization for 'at-risk' middle school girls, we conducted five weekly workshops during which participants ideated, designed and implemented personal wearable computing projects. These sessions inspired participants (age 10-12) who tend to be uninterested and uncooperative in educational activities to complete interactive projects and engage with workshop volunteers as mentors and peers. We present the challenges, merits and outcomes of our approach, proposing wearable computing as a healing outlet and a mentoring strategy for at-risk children.

Author Keywords

At-risk children, wearable computing, design studio culture

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

'At-risk' communities are defined by personal, economic or social circumstances that increase the likelihood of undesirable life outcomes, including dropping out of school, unemployment, substance abuse or pre-marital birth, among others [42]. Risk factors such as poverty, single or absent-parent homes, abuse and trauma [41] contribute to the number of at-risk children in the United States, where one in five children lives below poverty line and over 420,000 are in foster care [43]. In this paper, we explore approaches for engaging HCI research with the delicate and complex communities of 'at-risk' youths.

Drawing from prior work in art therapy and hands-on learning [23, 30, 37, 40, *etc.*], we propose wearable computing as a creative and healing outlet, as well as a mentoring strategy for at-risk children (Figure 1). Our research contributions are threefold: 1) we explore wearable computing as a creative and potentially healing medium that might extend ongoing efforts in art therapy; 2) we import principles from design studio culture [*e.g.*, 1, 2, 38] to motivate productive and expressive hands-on making in at-risk children; and 3) we apply wearable computing as a mentoring strategy to engage HCI researchers with at-risk populations.

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Art therapy

Art therapy uses materials such as paints, clays, chalk, *etc.* to help adults and children- including victims of trauma and domestic abuse- to address difficult emotional experiences through creative expression [18, 23, 37, 40]. Art therapy emphasizes "*physical involvement with the materials*" that allows children to explore and express feelings that may be difficult to explain [23]. For example, prior research has described how tangible mediums enable children to channel emotions through physical objects rather than behavioral episodes ('acting out') [44]:

> "*The physical involvement in exploring art materials appears to be of great benefit to these damaged children, as well as providing the opportunity to externalize feelings, particularly of rage and shame.*"

Working with a local organization for at-risk girls, we explore wearable electronics as a new set of *creative materials*. We argue for an alternative to the popular

Figure 1. Workshop participants paper-prototyping project ideas (top left), sewing a Lilypad Arduino onto a teddy bear (top right), programming a Lilypad Arduino (bottom left), and participants showing final projects (bottom right)

rhetoric of ‘introducing’ women and minorities to ‘computer science’, or ‘teaching’ ‘technology’ to children [*e.g.*, 24]: our work presents the adoption of electronics in ways that can be treated as parallel to how materials such as paints, crayons, and clays are incorporated into arts and crafts, studios and art therapy sessions. We explore experiences of physical placement, attachment and interaction with components such as LEDs, buttons, sensors, *etc.*, in conjunction with attendant fabrics and textiles, as an approach for facilitating creative expressions among young at-risk populations.

PRIOR WORK

Numerous efforts aim to introduce computer science to children through magic shows [8], avatar design [13], 3-D storytelling [7], as well as LEGO Mindstorms and other robotics platforms [9]. More recently, creativity and design have been emphasized as the founding principles of many computer clubhouses [*e.g.*, 33, 34, 15], for instance at the MIT Media Lab Lifelong Kindergarten[1], as well as numerous classes and workshops[2]. Scratch [35] and Modkit [27] support creative programming, while Robot Diaries facilitate creative engagement with technology [29].

Hands-on making and creative problem solving

Hands-on experience has been shown to facilitate active learning through interventions such as the Logo turtle [31] or even basic calculators [32], as well as studies in traditional subjects education [22]. Creative hands-on activities can increase engagement and learning [36] and improve problem-solving skills [30, 26, 14]. We contribute to and productively expand this body of work by exploring how creativity and problem-solving can be supported through hands-on making of wearable computing projects.

Wearable computing

Wearable (or e-textile) computing refers to the practice of embedding electronics and elements of tangible interaction into clothing and fabric. The LilyPad Arduino- a suite of low-cost electronics that can be easily sewn into textiles and fabrics has ushered a resurgence of participation and ideas within the wearable community. Developed by Leah Buechley at the MIT Media Lab, this technology includes the Arduino [3, 20]- a microcontroller that can be mounted to fabrics, fabric-friendly components such as LEDs, sensors, *etc*., and the interconnect of conductive thread. This technology has been adopted by a *milieu* of communities including (do it yourself) DIY enthusiasts, artists, small businesses and academic researchers [6]. Online DIY communities and sharing mechanisms have enabled individuals to showcase their LilyPad projects, which range from bike turn-signal jackets[3], to the ‘coin slot’ detector[4], to interactive bags, scarves, and jewelry, among others, encompassing function, craft, creativity and humor. The LilyPad Arduino has been discussed as a tool for mainstream education contexts [4, 5, 10], most notably by Ngai, *et. al*. who effectively used the technology to teach programming and circuits to middle school children [28], and EduWear [16]- a toolkit for supporting children’s wearable computing projects. In this paper, we explore how the use of the LilyPad could be expanded into the educational and mentoring practices surrounding marginal, at-risk communities. We draw inspiration from research that engages with stakeholders at the socio-economic margins: mobile computing for low-income communities in rural India [17] and PlayPower [21]- a platform empowering distributed learning through low-cost games.

RESEARCH MOTIVATION

While numerous outreach programs support young females and minorities who are interested in technology [*e.g.*, 12, 38], few efforts target children at socio-economic margins or those who are not initially cooperative or interested. We are a group of HCI researchers motivated by and passionate about reaching out to marginal groups as a matter of service. Over the past two years, we have been exploring different approaches for engaging with the children at Gwen’s Girls[5], a local outreach organization that offers gender-specific services to struggling, low-income, or ‘at-risk’ girls. Our initial efforts used traditional methods to conduct several classes including website creation, music synthesis, and basic circuits. These lecture-style sessions were mostly unsuccessful: the girls quickly lost interest and became uncooperative by refusing to listen, walking out, mocking the instructors, *etc.*

Despite the challenges of working with at-risk groups (behavior problems, lack of prior exposure and basic knowledge, lack of funding, decreased retention and success rate *etc*. [25]), our earlier classes effectively engaged the girls during a few hands-on exercises. The girls were drawn to creating their own content (music and photographs), as well as taking apart gadgets (keyboards, *etc.*) to learn about the components. These lessons as well prior art therapy approaches for [18] working with at-risk children, inspired us to pursue the physical and creative LilyPad Arduino as a new point of engagement with Gwen’s Girls. Our experiences reveal unique, (often) unexpected challenges, merits and outcomes, and we detail these in hopes of motivating future research in this area.

METHODS

Drawing from an emerging body of HCI research in design studio culture [e.g. 1, 2, 11], we organized wearable computing workshops revolving around iterative design, critique, and hands-on making practices. Our workshops were held at a university design studio- a large open space, encompassing an informal seating area (couches around a coffee table), a large (12-person) table, several smaller

[1] http://llk.media.mit.edu/

[2] Examples include Exploratorium (http://www.exploratorium.edu/), or classes by Lizabeth Arum (http://www.lizarum.com),

[3] http://www.instructables.com/id/turn-signal-biking-jacket/

[4] http://www.instructables.com/id/coin-slot-detector/

[5] http://www.gwensgirls.org/

workstations, a kitchen area, and a range of work surfaces, including desks, wall-size whiteboards, *etc*. The studio space enabled us to make a range of materials available, persistent and easily accessible throughout the sessions as emphasized in prior studio culture literature [*e.g.*, 19, 38], including electronic parts (LEDs, *etc.*), as well as fabrics, construction paper, markers, *etc.* Except for a few brief group activities, participants worked independently or with workshop volunteers (similar to a studio session).

Our five weekly sessions, lasting 1½ -2 hours each, progressed from basic circuit concepts (*e.g.,* lighting an LED during session 1) to programming the LilyPad Arduino (session 2), to brainstorming and design (session 3) and implementing a full project (sessions 4 and 5). We returned to the Gwen's Girls after our last session for follow-up interviews with two staff members and the girls.

We worked with the 10-12 age group at Gwen's Girls (7 participants total) to maximize impact at an early age. Due to doctor's visits and summer travel, attendance ranged from 4-7 participants, with 4 girls attending enough sessions to finish a final project. With the girls' and their guardians' permission, we recorded audio from each session and photographed select work. Qualitative data was transcribed and coded (themes included engagement, trust, learning, creativity, *etc.*). We reference data owing to particular participants as: S- Gwen's Girls staff, P- participants (girls), and V- workshop volunteers (authors).

ABOUT GWEN'S GIRLS

Gwen's Girls was founded in 2002 by Gwendolyn J. Elliot, one of the first female African American police officers in the United States and the first in [city name withheld]. Gwen's Girls offers support for at-risk girls, addressing the challenges and difficulties faced in early adulthood. Over the last eight years, several branches have been established in [city name], with services for afterschool hours and over the summer. The emphasis is on *prevention*- preventing girls from being removed from their (foster) homes and *re-unification*- re-uniting girls with their families. Over thirty girls attend the summer program at the branch we worked with, and nearly one hundred are involved in afterschool, foster care, and prevention/re-unification services. A staff member describes the unique Gwen's Girls population:

> *"It's one of the only places in [city name] that is a gender specific place for girls, and not only that but the population here itself is a very specific population. It's girls in the East End of [city name]… who are often dealing with some kind of emotional trauma. So that's a very specific population. 99% of our girls are African American... um and I would same the same amount is probably below poverty [line]."* (S2)

Staff also noted the social issues associated with this group:

> "*You have a higher rate of behavior issues, girls who've experienced trauma in their lives, abuse, neglect, all that kinda stuff."* (S2)

Figure 2. Gwen's Girls' computer room (left) and painted houses made during a craft session at Gwen's girls (right).

Activities and attitude

All girls are assigned a case manager who provides care at the Gwen's Girls site, as well as in the girls' (foster) homes. Many of the services are therapeutic (group therapy sessions, one-on-one support, *etc.*)*,* while others are educational (date violence prevention or career workshops), and some are recreational (craft, gardening, and weekly trips to the swimming pool, theatres, museums or a nearby theme park). Girls are either referred to Gwen's Girls by their foster home, parents or guardians, or court ordered to attend the program, and their attitudes towards the program vary:

> *"It's mixed. I would say that some of our girls are court ordered to be here. Some of them are here because they are involved in our foster care program, so in that instance too, they're sort of made to be here. Some of them are here because their parents want them to be here so whether they want to be here..."* (S2)

Recreational, off-site activities such as swimming and trips to movie theatres are most preferred by the girls. In addition, the girls enjoy arts and craft sessions where they make masks, paintings, ceramics, murals, *etc.*, while being less interested in 'traditional' lesson plans:

> "*They like painting as you can see, the crafts they're ok with, but anything that's educational they're like ahh... I don't wanna do it… usually because they find it boring and they don't want to apply themselves*" (S1)

Computer use

The Gwen's Girls branch we worked with includes a computer room with four working desktops, shared by the girls. Staff members note the popularity of computer games:

> *"The do love playing on the computer, I will say that. We only have 4 working computers right now, but they do... that's one thing that they're always* [waiting] *for a turn"* (S2)

The girls tend to use computers for online games such as y8[6] (Flash based games), some social networking sites including WeeWorld Avatars[7], as well as for music (YouTube[8], *etc.*). Besides the few courses organized by the authors prior the workshops, the only computer class offered by Gwen's Girls is on internet safety.

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[6] http://www.y8.com/
[7] http://www.weeworld.com/
[8] http://youtube.come

WORKSHOPS

Session 1: introductions, LEDs and buttons

We began by talking to the girls as a group, to introduce ourselves and gauge their comfort level and experiences with technology. Participants were shy and unengaged during this discussion: hesitating to speak, they participated only after considerable prompting. We encouraged the girls to name favorite or frequently used technologies, and answers ranged from cell phones, to laptops and computers, to ovens. When asked to describe a fun technology, the girls were hesitant to respond. After extensive prompting by the volunteers who shared a few personal favorites, participants mentioned Facebook and cameras. Only one girl described a school hands-on project where she had to light a small '*light bulb*' by connecting it to a battery. Annoying aspects of technology surfaced during the discussion including computer crashes and not being able to assemble projects from parts. Participants were reluctant to name 'fun' jobs in technology, but one girl eventually mentioned fixing broken electronics such as Nintendo Game Boys.

The girls were then shown several exemplary LilyPad projects available as images and videos on the web[9]. We also shared projects that have been made locally by the volunteers (*e.g.,* a tote bag that lit up Beyonce's eyes with two LEDs when closed). Participants showed some interest (for instance, one girl realized that "*there* [was] *something on the inside*" that made the LEDs light up), but as participants later told us, the demos were a bit intimidating:

> "*I do like seeing other projects, but I might feel more uncomfortable that theirs might be more... more sophisticated more enthusiastic than I can make.*" (P2)

LEDs and buttons

The concept of conductivity was demonstrated in a few slides illustrating electron flow between a battery and an LED. The girls then individually wired the circuit as seen in Figure 3, connecting a coin cell battery (in case) to an LED with alligator clips. Participants were visibly excited when their LEDs "*turned on*". Next, participants built an e-textile button[10] from pre-cut felt and conductive fabric and integrated it into their circuit to control an LED. During the remainder of the session, participants explored a range of materials (fabrics, construction paper, personal clothing glues, *etc.*) to create small projects with their circuit. They attached working buttons and LEDs their shirts, pants, or stand-alone objects (fabric heart or paper flower that lit up). They were excited to take home (small) working projects, except for one participant who chose an overly ambitious design and could not finish. Due to a lack of time, volunteers were unable to debug the problem and the girl was frustrated be the only one without a working project ("*I didn't think* <u>*mine*</u> *wouldn't work!*").

[9] e.g., http://www.instructables.com/id/turn-signal-biking-jacket/
[10] As shown in http://www.talk2myshirt.com/blog/archives/105

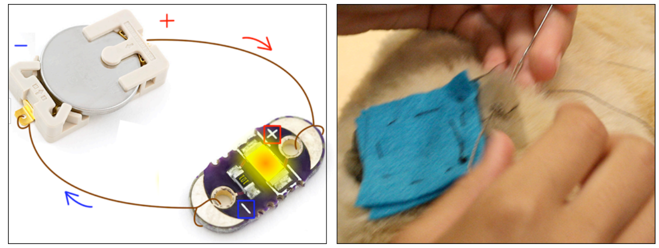

Figure 3. LED circuit (left) and an e-textile button (right).

Engagement

A staff member later told us, "*they [the girls] weren't all really totally engaged*". The session may have intimidated participants by putting them out of their comfort zones:

> *"Maybe because they didn't know what they were getting themselves into, especially because.... especially with girls who are in a high-risk population, they have a lot of walls put up. And if they're going to get into something that's like new and scary, that's going to put them in a potentially awkward situation where they seem…maybe if they seem stupid if they don't know something…"* (S2)

However, the girls became eager to participate in the hands-on part of the session. As a staff member pointed out:

> *"They love- or they respond really well to things that are hands on. I think that as much hands on things as you can incorporate is great."* (S2)

In addition, the exercises of lighting an LED and controlling electricity flow with a button helped the girls arrive at a common starting point for understanding basic circuits. A staff member later pointed out, "*I think for children who've never done anything like that before, it's really good to have a good simple base.*"

Session 2: programming the LillyPad Arduino

In this session, participants explored features of the LillyPad Arduino. In a brief (5 minute) group presentation, volunteers explained that an Arduino is a microcontroller ("*the brain*") with a "*memory*" that could be programmed to control LEDs and sensors. For simplicity, we explained that analog "*a*" pins are for input "*to read from sensors*", and digital ("*non-a*") pins- for output, "*to light LEDs*" (Figure 4). Drawing from the success of other creative environments [27, 35] we chose to use the Arduino IDE (integrated development environment), introducing it as software that *"talks to"* and "*instructs"* the Arduino.

Participants were seated around a studio table, each using a separate laptop with a pre-configured Arduino IDE. The girls followed tutorials- printouts compiled by the volunteers, to write, verify and load Arduino code onto the LilyPad. Using a template to blink a single LED, participants programmed multiple LEDs to blink in sequence. Next, the girls used another program sketch to look at values from a light sensor, experimenting with how their gestures and different light settings in the room resulted in higher and lower readings. During the remainder of the session, participants designed, connected and programmed circuits to control LEDs based on light sensor

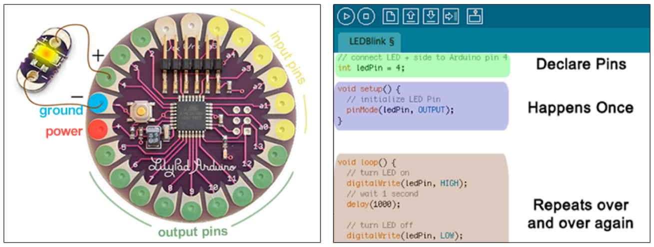

Figure 4. Images used to explain Arduino LilyPad to workshop participants: labeled diagram of board and LED circuit (left) and labeled Arduino IDE code (right).

input in a way that they liked. Although each person worked independently, the girls tended to discuss and experiment with each other's projects. For instance, one girl asked to turn off studio lights to cause another participant's LEDs to blink; several participants waved (cast shadows) over another girls' project to make LEDs turn on, *etc*.

Engagement and curiosity

Although we initially expected the programming session to be the most difficult and perhaps least exciting, the girls maintained interest and completed all exercises. Unlike the first session, during which the girls were physically seated with the staff members from Gwen's girls, who repeatedly told them to "*pay attention!"* and "*participate*", our second session separated participants from staff. The girls shared a large table, interacting only with each other and the volunteers during the session. A staff member later told us:

> "*I thought that was a good tactic because it did put the focus more on you and making it their project and their time."* (S1)

Participants became increasingly more curious about how their code translated into tangible LED and sensor behavior. They asked many questions about the LilyPad: *"So is [the Lilypad] going to remember it and keep going on?"*. The girls were also intrigued about why hand gestures affected sensor values (e.g., "*How does [the light sensor] tell you that?*"). At the end of the session, we prompted the girls for feedback (*e.g.,* "What did you think of this session?") Participants told us that they were excited to be able to control physical objects (LEDs) in software: "[*make] the light [blink] faster*". Conversely, they disliked "*when it didn't light up*", due to programming or connection errors.

Session 3: brainstorming and paper prototyping

We began by reviewing ideas from the previous sessions. The girls remembered basic concepts, for instance, *"we connected the wires to the light thing and made it light*" or, "*always connect the positive to plus and the minus to the minus."* Participants also recognized the LilyPad as the '*brain*' that can '*talk to'* sensors and LEDs (e.g., "*[The LillyPad] helped to make [the LED] blink on and off.*")

Having established a base for using LilyPad components, the third session focused on brainstorming and designing a final project. Participants were not familiar with 'brainstorming', and were not sure how to share their ideas:

V1: Does anyone know what brainstorming is?
P1: *Saying your ideas.*

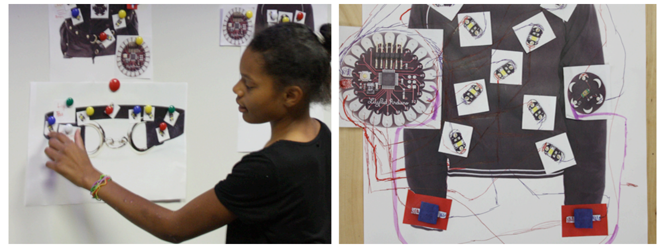

Figure 5. Participant presenting her design (left) and sweatshirt design with all pin connections drawn in (right).

V1: And is it ok to say bad ideas or silly ideas or crazy ideas?
P1: *Nah.*
P2: *Not really.*
V2: Yes, it's absolutely OK!
P3: *Cause they might compare it… and it might turn into something good.*

To help structure and facilitate ideation, we first asked participants choose an item they wanted to modify into a LilyPad project by selecting from a range of printed images, including t-shirts, sweatshirts, belts, purses, teddy bears, shoes, hats and more. Participants were also given pieces of paper (small cut-outs) with images of various electronic components: LEDs, temperature sensors, light sensors, buttons, Arduino, battery, *etc*. The girls used a whiteboard and magnets to arrange and attach ("paper-prototype") components to the item they chose for their project (Figure 5). While they were eager to visually arrange the parts on the poster, they struggled to articulate the ideas (function) behind their projects. Workshop volunteers helped each participant finalize and present their design concept to the group, as illustrated in a session excerpt below:

P6: *This is the sensor.* [pause]
V1: What does it sense?
P6: *Heat.*
V1: Heat, ok.
P6: *And this is a button, and the LilyPad goes in here. There it is.* [pointing to parts]
V1: Okay, and so what happens when it gets hot?
P6: *Oh what happens when it get hot? Oh, they all gonna turn on…* [pointing to LEDs]
V1: What happens, do they flash? Do they all turn on? [pause] Or do they do this on one, then this one on…
P6: *They all blink!*

Participants were attentive and applauded (unprompted) after each presentation, despite the back-and-forth dialogue between the workshop volunteers and presenter. The girls were encouraged to comment or suggest improvements (effectively, "critique" designs). They asked clarification questions (e.g., "*why does the buttons have to be pushed for it light?")*, and the majority of the feedback was positive, (e.g., "*cool*", "*I really like your idea*", etc.). For instance, after one presentation a girl commented:

> "*I thought it was very creative, and I like how it takes turns [blinking LEDs], and it's similar to mine actually… but I still think it's very unique in its own way like how it senses heat and stuff, and I like how it's designed."* (P2)

After finalizing their designs, the girls glued all paper components, drawing lines to represent electric connections between pins. Using different colors (red of power, blue for ground, *etc.*) participants effectively created a ‘circuit diagram’ for their projects.

Session 4 & 5: completing the final projects

During these final sessions, participants worked on their projects. Each girl brought in a personal item (teddy bear, belt, sweatshirt, *etc.*) to make into the wearable computing project they designed in session 3. The posters (‘circuit diagrams’) they made earlier were available around the studio, and participants used them to arrange all hardware parts on their item. Fabric glue secured components in place while the girls sewed (connected) pins with conductive thread. Sewing was the most time-intensive activity, as it was still new to the girls, complicated by having to avoid overlaps between thread (‘shorts’). Volunteers assisted with sewing and coated threads with hot glue to avoid shorts.

Design iteration

While working with hardware, participants continued to iterate on their designs based on perceived amounts of work and time required to complete the projects, as well as part constraints. For instance, in the following excerpt, a participant responds to the lack of an accelerometer by brainstorming alternative project behavior:

P2: *It’s going to light up when I trigger motion.*

V1: How are we going to do that?

P2: *I have no idea.*

V1: Do we have an accelerometer?

V2: No. You may not be able to do motion. We have light and temperature sensors that are easy to do.

P2: *Okay, so when it’s hot it will light up.*

V3: You might want to … [use] a button that lights the LEDs.

P2*: I’ll do that. And then I’ll be here next year then if we have time next year, I’ll come back and do [a more advanced project].*

Time, skill and part constraints resulted in micro-level problem solving and brainstorming, whereby the girls adapted their designs by scaling down components, resizing layouts and altering project interactions.

Articulating and programming project behavior

Once all components were attached and connected, participants worked with workshop volunteers to write their Arduino program. Similar to session 3, the girls at first struggled to articulate the behavior they wanted to translate into code. Prompting about specific scenarios helped participants communicate and program their ideas:

V1: So what happens when it gets dark?

P5: *They [LEDs] all turn on.*

V1: And what about the button?

P5: *And when I press this button these [LEDs] flash.*

Due to lack of time, volunteers did most of the work to debug the circuits and programs, with electrical shorts or poor connections being the most common problem.

Figure 6. Participants sewing LEDs onto a sweatshirt (top left), programming a teddy-bear project (top right), finished belt with embedded LEDs and buttons (bottom left), and participant programming her sweatshirt project (bottom right)

Enthusiasm, focus and comfort

Although participants were initially unsure how to begin their projects, they became increasingly more focused once parts of their projects were working. While components and tools were laid out and available during all sessions, session 5 (the last project session) was the only session initiated by the girls themselves, who entered the studio and immediately began working with the materials. Throughout sessions 4 and 5, participants tended to ask clarification questions about sewing, electrical connections, and programming, as well as the various gadgets they explored around our lab (soldering irons, hot glue guns, servo motors, *etc.*). Participants became more comfortable with us- workshop volunteers, asking personal questions (e.g., “*you’re from Kentucky?*”), or relating to the volunteers:

P5: *What kinda dog do you have?*

V1: She’s a chihuahua beagle!

P4: *So is mine! She’s a chihuahua and a beagle. For real, her name is Daisy. And she’s really really little and fat.*

Moreover, participants began to joke with the volunteers: for instance, one girl sang “*please, please don’t leave me”* when a volunteer momentarily turned away to help another participant; and another girl joked:

P3: *This butt right here [pointing to back of teddy bear]. She burned my butt [laughing]*

V3: I did not burn it, I put hot glue on it.

Ultimately, participants were enthusiastic to take home working or semi-working projects (*e.g.,“it’s working! I can see it! YES!”),* demoing their work in short final videos.

FEEDBACK AND FOLLOW-UP

We returned to Gwen’s Girls a week later, to conduct a group interview with the girls and individual interviews with staff members. The girls were asked to identify interesting, difficult, fun, boring, *etc.* aspects of our sessions through a card-sorting activity. In this activity the girls collectively selected cards containing images corresponding to activities such as sewing, circuits, programming, design, and others. In contrast to our last studio session, the girls were unengaged and uncooperative, refusing to talk without prompting, mocking the questions, *etc*. (see discussion below). Only one participant was enthusiastic to work on more wearable computing projects, while the others remained unsure. One girl told us the sessions changed her attitude towards technology as she realized: "*I can do more things on the computer than just download things*" (P3), and another said she would be interested to "*take a computer apart*" (P4).

Positive aspects of the workshops

Three participants agreed that they liked having a finished project, showing their work to their friends, other staff members, siblings or parents/guardians. One girl told us she liked "*connecting everything together, to see how it works*", and another enjoyed "*seeing other projects made me wanna do something similar to see how fun it would look.*" A staff member also observed the girls discussing their projects outside of the workshops:

> S1: *They did like it.*
>
> V1: And why do you say that?
>
> S1: *When we left, like they'd talk about it and they were proud of what they had made- like the finished product, and they said they told their mom or their grandma or their brother.*

The staff were positive about our workshops, because sessions were framed as a "*craft project that teaches them about electricity*"; exposed the girls to "*doing something different and challenging"*; and provided an opportunity to introduce the girls to our college campus ("*to get a feel for... that [college name omitted] even exists, because a lot of these kids wouldn't want to go there otherwise*").

Challenging aspects of the workshops

One participant was particularly unhappy because her final project did not turn out as she intended ("*I didn't like it [the workshops], 'cause mine didn't work*", P5). All participants agreed that while sewing was "*pretty fun"* at first, it became "*tiring*", "*boring*" and even "*annoying*" towards the last session. The design session was considered most difficult, as one girl explained "*designing... it takes a lot of effort to find out how you gonna do it*", and another participant agreed: "*yea cause its hard to think of... things"*. When asked to compare the paper prototyping session to arts and crafts- the most liked activity at Gwen's Girls, participants pointed out the latter was easier:

> "*It [arts and crafts class] won't be hard, because if they give you a picture to draw, then you draw it, and they'll give you the next thing"*. (P5)

Staff members also emphasized the creative aspects of our workshops as being most unusual for the girls (*e.g.,* "*I don't think they're often challenged to do creative projects like this*"). While our brainstorming session was structured by component constraints, the girls were not asked to design for a specific task, as they often were in craft sessions:

> *"We give them like a specific project to do, so this [pointing to paper flower] or these [picture frames on walls]. You pick like a specific thing to do and show them how to do it. Like these jars they made too."* (S2)

Both staff members agreed that the creative aspects posed the greatest challenge ("*the creativity piece of this project is what took them a little bit outside of their comfort zone*"), suggesting more to make the girls comfortable:

> *"If you made it like an 8 session thing for instance and say for the first 4 sessions you did: everyone does the same project and everyone gets really comfortable doing it, now you get creative, now you create your own- they probably would've been a little more comfortable."* (S2)

DISCUSSION

We now highlight the novel aspects that differentiate our work and findings from prior research:

Goals

Prior LilyPad workshops for children tend to emphasize '*the practice of education and children's crafts'* [3] and adopt the rhetoric of '*introducing electronics to children'* [5]. Alternatively, our workshops explored wearable computing as a medium for connecting with a vulnerable population: participants were shown LilyPad components as creative materials (similar to paints, *etc*.), not as technical artifacts. Although technical learning was an outcome, the novelty of our work stems from the LilyPad being a point of engagement and boundary object between that at-risk children and HCI researchers.

Participants

The majority of ongoing LilyPad research engages with children who are already interested in the subject, for instance from a program "*in which students pay to participate in science-related classes*" [4]. In contrast, our participants are from complex families and economic backgrounds that render them unable to "pay to participate". At-risk children tend to be untrusting, uncooperative and unengaged in educational activities, and thus widely overlooked by HCI research. We faced several key difficulties, including participants' lack of initial motivation, inability to articulate ideas and withdrawal from non-hands-on activities, which highlight unique challenges largely unaddressed in prior research.

Ideation

Our participants initially struggled to articulate project ideas and this challenge seems unexplored by prior LilyPad workshops (perhaps verbal ideation is more difficult for our group). The paper prototyping session of our workshop offers a novel contribution for supporting ideation among children. Our participants, who were often unable to verbalize the desired behavior of their projects, effectively expressed ideas through tangible placement and drawing of paper parts. The use of glue, markers and paper to simulate electronics helped participants adopt sensors, LEDs, *etc.* as materials that can be manipulated and actuated similar to familiar craft supplies.

ART THERAPY AND WEARABLE COMPUTING

While our workshops were not evaluated as art therapy sessions, we draw parallels between related literature and our work. Art therapy is motivated by the idea that humans may struggle to express emotions and desires within the range of verbal and written language [37, 40]. We encountered this phenomenon throughout our sessions, especially when our participants were challenged by verbal ideation. Our workshops enabled participants to successfully express ideas through paper prototyping and the physical arrangement of paper and electronic parts, fabrics and materials.

Creativity, ownership and self esteem

Art therapy research suggests that creative expression can "*increase self-esteem and self-confidence in the children by empowering them to become active participants in the direction of their own*" [23, pg. 97]. Our workshops facilitated this process by through a bottom-up teaching style, by minimizing the conventional student-instructor power structure. Our participants are not enthusiastic about group (top-down) lessons. However, they do like interacting with the other girls in the group, for instance, by listening to each others' design presentations or exploring projects made by friends. During our workshops, we too tried to assume the role of peers, assisting (helping) rather than directing the girls. Participants ideated open-ended LilyPad projects, constrained by components rather than appearance, function or intent.

During sessions 4 and 5, participants continued to 'brainstorm' and problem-solve, albeit unwittingly, re-designing their projects as they navigated time, skill, and component constraints. From altering layouts of LEDs, to changing project behavior due to absence of parts, participants took control and ownership of their work. By *asking* rather than *telling* the girls how their projects should function, we helped create instantiations of what they considered to be their ideas and their work. As '*active participants'*, the girls were in control and consequently *"proud of what they had made"*, sharing their projects with friends, families and other staff members.

Physical involvement with materials

Art therapy literature emphasizes engagement with physical objects to help children *'feel less exposed'* than during verbal interactions [45, pg. 33]. With craft and gardening being our participants' favorite activities, we see hands-on making as a core approach for engaging with this population. During our workshops, the girls' visible enthusiasm for physically connecting LEDs to batteries, gluing, drawing and attaching components during brainstorming, (initial) sewing, and finally showing off their finished projects suggest beneficial '*physical involvement*' [44] with LilyPad components.

Malchiodi focuses on '*experimentation with materials*' including non-traditional felt tips, old magazines, fabric, cardboard boxes, straw [23, pg. 107]. In our workshops, experimentation with LilyPad components inspired curiosity ("*How does it [the light sensor] tell you that?"*) and excitement ("*make it [LED] blink faster!"*), while inability to successfully manipulate parts was a source of frustration ("*I didn't like it, 'cause mine didn't work*"). The items made by the girls, ranging from small artifacts (buttons and LEDs integrated into shirts, hearts/flowers) to larger-scale final projects (interactive belts, sweatshirts, *etc.*) served as *boundary objects* to help us communicate with the girls. While we leveraged these items as materials to showcase basic electronic concepts, participants used them to showcase personal ideas and skills.

Design studio culture, space and context

Space can be crucial for art therapy sessions (*e.g.*, Waller converts "*a very formal conference room to one where many different kinds of interactions were possible*" [45, pg. 109]). We see parallels between this use of space during art therapy and our arrangement of the room as inspired by design studio culture literature. The persistence, availability and accessibility of materials throughout all sessions (rather than having to ask for permission to use the parts) enabled the girls to take charge of their projects, especially during the last session. Our participants prefer activities that take them away from their routine space (off-site trips to movie theaters, museums, and swimming pools, *etc.*). The workshops served as a productive change of context, exposing the girls not only to our studio but also to a college campus- a setting that, as a staff member explained, they may not "*want to*" or be able to experience otherwise.

During the first session, the girls were '*thrown*' into a new space, filled with unknown objects and unfamiliar people. With their '*walls put up'*, they appeared to be estranged, introverted, and unengaged. However, the following week, they returned to a semi-familiar space and session 2 altered a routine power structure by separating participants from staff members and placing the focus on them, "*making it their project and their time*" (S2). At the same time, the setting did not isolate participants from each other. As they completed individual tasks in a group setting, participants were inspired to discuss and experiment with each other's work. As sessions progressed, participants became more comfortable with the space, exploring surrounding objects and materials, such as soldering irons and inductors. In this increasingly familiar context, researchers themselves became familiar; participants frequently initiated questions about our backgrounds, pets, and everyday interests.

However, when we later returned to Gwen's Girls for our follow-up interview, it seemed as though we were strangers: intruding on *their* routine space we initiated an unfamiliar activity- the semi-formal interview and card sorting. Consequently, participants were shy, uncooperative and unsure about working on wearable computing projects in the future. As staff members previously pointed out, our participants are a marginal, low-income, and at-risk population who inherently have "*a lot of walls put up*". Our findings appear to suggest context as one of the many complex and delicate factors that contributes to participants' comfort levels, trust, and engagement.

DESIGN IMPLICATIONS

Graceful recovery from breakdowns

Participants' ability to create functional projects appeared to openly impact their moods and attitudes. While successful work inspired pride, excitement ("*YES! It works*!") and sharing with friends and family members, broken, unfinished or mal-functioning projects were a source of frustration. Unfortunately, time limitations necessitated workshop volunteers to troubleshoot the majority of electronic shorts and programming bugs. However, our participants' enthusiasm and ability to resolve problems such as time, skill, and part constraints suggest a design space for new methods that involve participants in software and hardware troubleshooting. Similar to participants' experiences of empowerment through creating working projects, novel ways to enable independent fixing of technical issues could contribute to a sense of accomplishment as well as problem-solving skills and technical knowledge. More generally, there appears to be space for developing creative and intuitive troubleshooting techniques to fluidly empower this population to resolve technical problems. For example, one instantiation could involve mystery games asking participants to design circuits with shorts and having peers 'track down' the problems, or conducing code walk–through exercises with a voltmeter.

Wearable electronics as a creative and healing 'material'

Art therapy leverages creative materials such as markers, paints, clays, *etc.*, to facilitate expressive, meaningful and, in some cases, therapeutic "*physical involvement"*. Our workshops were not explicitly modeled to be art therapy sessions. Nevertheless, there appears to be a parallel between participants' use of wearable components and what could be considered conventional craft materials: participants adopted LEDs, sensors and Arduino's as materials to be aesthetically arranged, physically attached, and creatively controlled. The greatest challenge appeared to stem not from manipulating (or programming) tangible parts, but from articulating their behaviors. This apparent disconnect between physical components (sensors, *etc.*) and their interactive behaviors reveals opportunities for making—and conceptualizing--interaction design more tangible. Stop-motion videos, storyboards, and re-enactments can enable children to create and explore concrete representations of the embedded interactions they imagine and desire. More broadly, materializing aspects of ideation could open significant opportunities to increase "*physical involvement*". This direction could catalyze future collaborations with art therapy researchers to collectively explore wearable computing as a new and tangible medium for externalizing, channeling and expressing emotions.

Breaking boundaries with LilyPad Arduino

We used the LilyPad throughout our research in an attempt to break boundaries in several ways: ***spatially***, a studio layout with collaborative work surfaces (large table, shared whiteboard *etc.*) and persistence of available materials removed participants from their routine context; ***hierarchically***, a top-down teaching structure was replaced by 'peers'- volunteers assisting rather than directing participants' work; and ***creatively***, participants designed and built projects without constraints on function, appearance, or behavior. By importing design studio culture, focusing on hands-on making and empowering participants to create and own their projects, we were able to gain trust and 'put down walls' between us (HCI researchers) and a complex 'at-risk' population. Future work can pursue this approach on a broader scale, leveraging the LilyPad to break boundaries, subvert power structures and engage HCI research with overlooked, underprivileged and marginal populations.

CONCLUSION

We presented wearable computing as an approach for engaging HCI research with a community of 'at-risk' children. Our workshops imported ideas from design studio culture, enabling participants to freely access a range of materials and work on personal projects in a shared studio space. We leverage our findings and ideas from art therapy to propose wearable electronics as *creative materials* that can motivate learning, problem-solving and expressive hands-on making. We hope that our work inspires future efforts that mentor and 'break boundaries' through the use of tangible media such as the LilyPad Arduino.

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