For Megan Boler & Matt Ratto (Eds.).
DIY Citizenship: Participatory Practices of Politics, Culture and Media

TRANSPARENCY RECONSIDERED: CREATIVE, CRITICAL, AND CONNECTED MAKING WITH E-TEXTILES

Yasmin B. Kafai & Kylie A. Peppler

The intersection of digital and physical production is quickly becoming one of the largest, and fastest-growing, DIY movements, emphasized at Maker Faires, in Craft 'zine' articles and in countless DIY forums, like Instructables.com (Frauenfelder, 2010; Gauntlett, 2011). While prior research into youths' DIY practices has explored activities at both ends of this spectrum—such as work on cosplay as well as youths' onscreen productions in the form of blogs, videos and games—the coming-together of the two has remained relatively unexamined. This area of production includes dimensions of digital media construction and design that dovetail with hands-on crafts, physical construction and design, as well as material play. An exploration of youths' tangible media texts seems especially promising in the domain of electronic textiles (e-textiles), which include young people's design of programmable garments, accessories, and costumes. Such designs incorporate elements of embedded computing which allow for controlling the behavior of fabric artifacts, novel materials that can include conductive fibers or Velcro, sensors for light and sound, and actuators such as LEDs and speakers, in addition to traditional aspects of textile crafts.

We see e-textiles as part of a larger DIY movement to promote personalized fabrication outside of traditional manufacturing that can also extend into classrooms. Indeed, today's educators and researchers see creative media production as a central component in media education (Buckingham, 2003; Guzetti, Elliot & Welsh, 2010; Knobel & Lankshear, 2010). This, however, has not always been the case. For many years, media educators have put an emphasis on "critical analyses" over creative production. Initially this resistance to creative media production could be explained by hurdles, such as the lack of portability and reliability of older media like celluloid film or older cameras. Similarly, the field of e-textiles shares a common history of inaccessibility due to the lack of novice-friendly tools. While impressive student work can happen with less technological materials (e.g., Cunningham, 2005; Perner-Wilson, 2011), current technological developments have made more complex forms of creative media production much more accessible and easy to manage in today's classroom environment (Stafford, 1994).

In this chapter, we consider how students' and teachers' work with e-textiles can expand our understanding of "transparency" — revealing power structures and constraints in the design and use of new media — a core idea promoted in participatory media (Jenkins et al., 2006) and critical design approaches (Ratto, 2011; Buechley, 2010; Peppler & Kafai, 2011). We see the additional benefit in revealing insights about the production or design of technology itself and cultural assumptions that nowadays are often hidden or "invisible" to youth. Creative production with e-textiles engages students and teachers to question their current observations and understandings of functionality and aesthetics, make explicit their gendered assumptions about crafts, and develop the conventions of writing in the language of a new field by learning the visual, aural, and technological literacies necessary to inscribe one's self into the larger DIY and fashion culture. All in all, what takes place during such creative production becomes a critical reflection on how technology design decisions are made, how they are interrelated with craft production and engineering functionality, and how they intersect with personal choices and cultural assumptions. We examine these ideas by first outlining the different perspectives, their historical antecedents and relevant research in the constructionist tradition. We then present examples from our own research with youth and adults in e-textile workshops that illustrate how the visibility of production affords opportunities for critical engagement. Finally we discuss how this type of production holds the potential to disrupt gender divides that are often ubiquitous in educational settings focused on high-tech media.

Section I

Initially, transparency was promoted in the context of critical analyses of media texts to better understand larger issues of power: Who is doing the writing? Whose voice is being heard? Who is being positioned in certain ways within a particular text and for what purposes? Our goal in using transparency as an aspect of criticality draws from approaches in media and critical design education. The most established tradition comes from the field of media literacy, which posits that when learners understand how ownership in media works, they begin to see how information is produced and positioned. Media scholars (e.g., Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006) have explicitly included creative designs, ethical considerations, and technical skills in their exploration of youths' expressive and intellectual engagement with new media. They place an emphasis on creative production because it empowers individuals to redefine their position within established power structures and learn "to see clearly the ways that media shape perceptions of the world" (2006, p. 3). Along with the necessity of developing technical skills and ethics, the understanding of power structures has been seen as a key aspect of digital citizenship. Here, transparency is a goal that learners need to accomplish in order to understand media, which can be achieved by creative media production. Educators rooted in this tradition frequently use youths' *engagement with media* to illustrate issues of power in production.

More recently, scholars engaged in the examination of critical design have expanded the notion of transparency by focusing on the connections that designers develop in the process of creative production. This work picks up on the emotional connections and relationships that people form with technology and uses them as springboards for critical reflection "to turn the relationship between technology and society from a 'matter of fact' to a 'matter of concern'" (Ratto, 2011, p. 15). This approach to critical design is aligned with the open source movement that allow users to build more complex understandings of the way things work. Classes in which students use open source software and build artifacts provide students with critical understandings of production and programming processes. Transparency in these educational settings is afforded by students' *reflection with media*.

While proponents of both approaches agree that creative production can be a valuable pathway into critical understanding of power structures and relationships, we offer a complimentary perspective on transparency as a vehicle for learning. Indeed Buechley (2010, see also Eisenberg, Eisenberg, Buechley & Elumeze, 2006) questioned whether invisibility in technology is a good design principle. Most of today's technology designs intentionally hide or make invisible what makes them work. Yet for educational purposes visibility might be more beneficial in promoting understanding and learning. In e-textiles, for example, the fabrication of stitches, circuits and codes reveals the underlying structures and processes in tangible and observable ways. This call for making the underpinnings of technology transparent for educational purposes is part of a long tradition starting with Alan Kay's open programming environments in the 70's and Ron Becker's auditory visualizations of program flow in the 80's. Like participatory media studies, we stress the importance of making media designs as way to understand the world; like critical design studies, we see programming and open source technology as a way to "look under the hood." Transparency in educational applications thus comes from learners' *building with media*.

Underpinning all of these approaches is a fundamental view that learning happens best while in the process of making shareable artifacts, which is at the heart of constructionist theory (Papert, 1980). Constructionist activities afford transparency by providing opportunities for concretizing knowledge and highlight "the reconnection of two modes of engagement with the world that are usually held separate: critical thinking, traditionally understood as conceptually and linguistic based, and physical 'making', goal-based material work" (Ratto, 2011). This "revaluation of the concrete" (Turkle & Papert, 1992) is an epistemological stance towards knowledge — the relationships that learners build with knowledge and pathways that facilitate such knowledge construction. The constructionist paradigm, by encouraging the externalization of knowledge, promotes seeing the knowledge object as a distinct "other" with which we can come into meaningful relationship. This relationship consists of questions that makers ask themselves about how the external object connects to other bodies of knowledge (Wilensky, 1991). New forms of creative interactions afforded by these connections are some of the main affordances of working with open technologies that do not hide relationships, but rather leave them open (Benkler, 2008).

It is how we come to build these knowledge relationships that is at the center of our work with e-textiles. As Turkle and Papert have argued (1992), there are preferred ways of working with technologies, the hard over the soft, that value the formal over the concrete. E-textiles complicate the relationships we have pre-established with technology in multiple ways. There is a historically gendered notion that sewing and fabric fall near-exclusively in the domain of females, while engineering and programming are traditionally seen as the domain of males. Along the same lines, there is a dichotomy between crafting and coding that come together in e-textiles, reflecting a long standing hierarchy of mind over manual work (Rose, 2005). Furthermore, there are tensions between aesthetics and functionality that, in particular, bring out the personal in e-textiles design because these artifacts are often carried close by their designers and might have a purpose in everyday life. In contrast, the corresponding domain of robotics often seems to exist for the sole purpose of competition. We argue that e-textiles are domain-crossing objects that provide fertile contexts for revisiting and remaking relationships with technology.

Section II

Our observations draw from a series of workshops with e-textiles that we organized with different groups of youth and adults over the last two years. The goal of these workshops was to engage participants in learning crafts, circuitry, and coding while making e-textile artifacts. The *LilyPad Arduino* construction kit (see Figure 1) enables novice engineers/designers to embed electronic hardware into textiles (Buechley & Eisenberg, 2008; Buechley, Eisenberg, Catchen & Crockett, 2008). It is a set of sewable electronic components, including a programmable microcontroller and an assortment of sensors and actuators that allows users to build their own soft wearable computers. Users sew LilyPad modules together with conductive thread instead of traditional tools like insulated wire and soldering techniques. To define the behaviors of the project, users employ the popular Arduino or ModKit development environments, enabling them to program the LilyPad microcontroller to manage sensor and output modules (like LEDs) employed in their designs. The LilyPad was released as a commercial product in October 2007 (Buechley & Hill, 2010). Since then, it has been widely adopted by designers and engineers of all ages from around the world. It is now sold in several countries and it has been employed in a number of universities in computer science, engineering, fine arts and design courses.

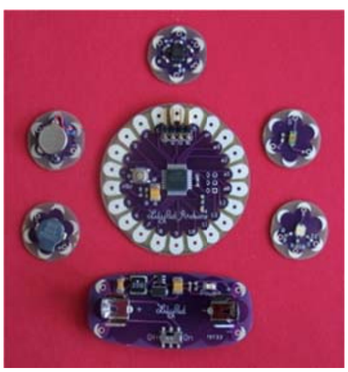

Figure 1: The LilyPad Arduino kit. The microcontroller is in the center, and the other components, clockwise from the top, are: accelerometer, light sensor, tri-color LED, power supply (requires a AAA battery), speaker, and vibrating motor. An FTDI board and USB cable are also part of the introductory kit.

The following examples are drawn from e-textile workshops with middle-school youth, women engineers, and writing teachers. Taken together, these examples illustrate how technology design decisions are made, how they are interrelated with craft production and engineering functionality, and how they intersect with personal choices and by extension promote critical reflection within locally-situated e-textiles contexts.

In a middle school, six boys and four girls signed up for the e-textile workshop, meeting twice a week in an open atrium area for one month. They gathered around three tables where LEDs, switches, batteries and holders, needles and conductive thread in addition to t-shirts, canvas bags, caps, and various decorative materials such as puffy paint, buttons, glitter were spread out. Before starting on their projects, youth were given a short overview by the facilitator that described the goals of the workshop, showed a few pictures of e-textile projects, and gave a DIY tutorial on how to sew an electronic circuit. Youth were immediately drawn to the creative possibilities of the LED assortment on the tables, though were more halting as they critically deliberated possible designs on T-shirts or bags. Over the course of the workshop, youth brought in supplementary materials to electronically enhance beyond the assortment of materials provided by the workshop. These additions provided opportunities for creativity and personalization. One of the boys, for example, brought in a pair of black canvas sneakers to sew on a three-color RGB LED with a switch. He also experimented with how to use his keychain to change colors by positioning it over different ports of the RGB light. Others decorated t-shirts with circuit designs while some created gifts for their parents that incorporated LEDs into graphic designs decorated with puffy paint (see Figure 2). The fact that some youth turned their projects into gifts demonstrated the utility that they perceived their e-textile creations would have for someone else—a reflection of the value the youth assigned to the materials, as well as the pride in their creative ideas and workmanship.

While all students initially laid out their complete and functional circuits by connecting alligator clips to batteries, switches and LEDs, the move onto fabric inevitably brought its own challenges: the polarity of LEDs was often misaligned or thread endings were not properly knotted, revealing that the youths' understanding of circuitry wasn't entirely infallible. Furthermore, the challenges of the textile materials and crafting presented new hurdles upon which to apply this information. This is to be expected, given that our students had no prior experience in working with construction kits like the LilyPad Arduino. However, the students learned through the design process and were better able to explain their final circuit designs, mentioning aspects of polarity (the direction of energy) and flow (the circular path), such as when one student accurately explained that "the two lights work...came from switch to this positive and its positive from positive and negative from negative and it goes to battery." Having to move across contexts—from initial debugging with the alligator clips to the textile materials—promoted youths' critical reflection, asking them to externalize their understandings.

Yet a certain unease became quickly apparent when the project started and the boys saw the fabric and realized they had to sew. Throughout the weeks, the unfamiliarity with sewing — threading the conductive thread as well as guiding the needle through the fabric to make stitches — remained a major hurdle for all students except for one girl whose grandmother had taught her how to sew. It was also difficult for the youth to explain to others what exactly they were working on. When other students passed by the atrium, looking curiously at the tables covered with fabric and other materials, two of the participating boys immediately shouted out "We're doing circuits!" while holding up their t-shirts, hinting at their identification with the more masculine aspects of the activity.

Figure 2: Images of completed projects from the middle school workshop.

Our second example is drawn from a recent *Women in Computing* conference in the Midwest where over 100 women ranging from undergraduate students to tenured professors gathered for a three-hour e-textiles workshop. Participants received a basic packet of materials, which included LEDs, conductive thread, a needle, a scrap of fabric and a battery pack. The objective of the workshop was to introduce a burgeoning field to an audience already steeped in the language of computing and engineering. After a brief overview presentation, the group was led through a series of steps that detailed the fundamentals of circuitry and sewing. In the process, participants utilized their e-textiles materials toward the creation of unique artifacts—circuitry-enhanced bracelets, conference bags, shirts, hats, gloves and more (see Figure 3). And, yet, the abilities of the participants to create their projects were only slightly higher than those of the participants in our early elementary school workshops, despite this audience's experience with advanced programming, robotics, computer science and engineering. Several participants worked ahead of the rest of the group, assuming that they would know what to do, only to run into hurdles down the line, and very few participants were able to complete the activity without assistance. Frequent mistakes included participants sewing through the circuit in one continuous thread, thus returning the power directly back to the battery source and shorting out the connection; underestimating the need for solid connections; misunderstanding polarity concepts when putting multiple lights in parallel; improperly threading a needle or even tying basic knots. Interestingly, the women who excelled in the activity were all older in age and more accustomed to the material science of working with fabric, needles and thread. For them, the electronics were a natural extension from their prior experiences with traditional crafts.

The experiences in this workshop call two tensions to our attention. The first concerns a lack of transparency in traditional computing: the initial explorations of well-educated scholars with these materials brought their small misconceptions of circuitry concepts, such as polarity (the direction of energy), connectivity (the stability of connections) and flow (the circular path), to the fore. However, most participants were able to connect to the wide bodies of knowledge with which they were familiar once a demonstrator made the initial parallels between the materials. The new materials thus made concepts more apparent that participants had understood before, but had some lingering misconceptions when transferring this understanding to a new domain—working with such a transparent medium underscores the importance of seeing how these engineering concepts apply across a range of media and conditions.

Figure 3: Images of completed projects from the Women and computing workshop.

The second tension touches on a larger cultural trend, concerning the role of a woman's skillset in engineering and computer science fields. The evident atrophy of a historically feminine activity (i.e., sewing) across the two youngest generations represented at the conference points to some academic females' devaluing of "women-centric" knowledge and skills. And while the vast majority of participants were drawn into the activity—especially the aura of a communal sewing circle that permeated from it—a minority of women argued that e-textiles reinforced gendered stereotypes, preferring that women get involved in more male-dominated activities, like robotics. This seems indicative that "women's skills" are something from which women in STEM fields continue to distance themselves. Though the causes for this tension are multifarious and deeply engrained, our hope for women's involvement in e-textiles is to return cultural capital to these largely undervalued skillsets, recognizing the potential of the unique perspectives and insights they could bring to STEM fields. Furthermore, while women already in computing may have adapted the dominant epistemology of computing and frown at bringing "women's skills" into the field, girls and women just entering computer science may find comfort in the bridge between their existing gendered identities and the scientific identity they are being asked to take on.

Our last example comes from a summer professional development session (part of a month-long curriculum co-development workshop) with a select group of teachers from the National Writing Project, where we presented a weeklong e-textiles unit focusing on e-fashion and e-puppetry applications in K-12 classrooms. The National Writing Project, one of the largest teacher professional development networks in the United States, has been in existence for almost 40 years and acknowledges the importance of various forms of digital composition in the conception of literacy and writing across the curriculum. The workshop participants expressed that, though they knew that they had to introduce circuitry (a core science standard) into the classroom, they didn't feel comfortable enough with the content to present it confidently. They also were interested in getting into design and hands-on activities that would tie into the curriculum, yet had not come across any amenable platforms. In professional development, teachers worked with the materials while considering how to connect to English/language arts, science and other areas through working with e-textiles. They also realized how little they knew and remembered about simple and more complicated circuits, running to basic web resources, like BrainPOP (www.brainpop.com), to supplement their understanding. Striving to know and understand the concepts and materials at a level in which they could teach them afforded teachers with the ability to make concrete their understandings about circuitry, thus reinforcing their confidence in being able to bring this content finally into the classroom.

Initially, one of the male teachers was resistant to the e-textiles materials in fear that boys would lack interest, preferring methods of construction with which he was more familiar, such as soldering and hot glue gunning. An interesting outcome of the workshop was that this same teacher left the workshop very enthusiastic about boys' engagement with e-fashion design, wanting to implement an e-textiles unit (of all the various media from the summer workshop, including game design and computer programming) in his own classroom. Being able to wear these constructions, he felt, was key to transforming the identities of the minority youth. The teacher, himself, furthermore, learned the traditional techniques of fabrication for crafting through this experience and indicated a desire to continue honing his skills.

Section III

We are just beginning to understand how youth and adults engage with e-textiles, a relatively new addition to the DIY community but one that is becoming part of a larger personal fabrication movement. With rarely an exception, most participants approach these activities with little prior knowledge or experience in sewing, circuit design, or programming, let alone having ever used the LilyPad Arduino construction kit that we use for e-textile designs. While some have argued that such tangible materials can promote transparency and aesthetic engagement with technology (e.g., Resnick, Berg & Eisenberg, 2000), these considerations have been articulated in regard to traditional construction kits aimed at robotics and scientific instrumentation. E-textile artifacts sit "betwixt and between the world of formal systems and physical things, it has the ability to make abstract concrete … by the same time it makes it visible, almost tangible and allows a sense of direct manipulation" (Turkle & Papert, 1992, p. 4). While Turkle and Papert made this reference to objects on the computer screen, the inferences apply even more so to e-textiles. Simple misconceptions become apparent that range from not understanding what insulation does for wire, and why it's needed, to what the relationships are between an energy source and its components. While each of these are valuable learning insights, one could easily classify them away under functional understandings. What's important here is that all of this happens in a context where designers want to build something of aesthetic and personal value and within this context begin to understand the coordination of design constraints. In a paradoxical way, e-textiles make it more complicated to build with technologies while making it simpler to enter relationships with technology.

Most pronounced are of course the references to the gendered nature of e-textile materials and activities that throughout the workshops slip into conversations. When middle school boys label their activities “circuit design,” then of course this is an intentional reference to engineering as more male-appropriate and more highly valued activity. These distinctions are in fact more complex since they make reference to old stereotypes that are no longer viable. Most girls and women do not know how to sew and so the seeming advantage is no longer available. Yet we also know from a recent study by Buechley and Hill (2011) that examined the participation of women in the LilyPad community, that indeed their participation is much higher here than in the more engineering-centric Arduino community. While the LilyPad is a more recent technology development, it also connects back to the foundations of modern computing, bringing us back to the longstanding historical connections between women, textiles and computing: for example, Ada Lovelace’s notes on the analytical engine that resulted in the first “computer program” in the 19th century, and the Jacquard loom (1801), which though created for weaving complex patterns in textiles, is considered the first step in the history of computing hardware.

Furthermore, more nuanced understandings of how technology works with a broader range of materials is crucial for today’s DIY citizenship, as more aspects of life have moved into the digital domain. The mind-and-hand merger of the digital and physical, additionally, is brought together through creative production with e-textiles, forcing learners to externalize knowledge and reformulate their misunderstandings. E-textiles reposition youth as active creators, rather than consumers, of knowledge. These domain-crossing objects have the potential for attracting marginalized youth that have been left out of the STEM pipeline in more subtle ways by capitalizing and affirming their interests in low-tech materials while simultaneously introducing STEM content. These opportunities are especially prescient as seen against the backdrop of larger economic and political changes with dual forces of massive concentrations of media ownership with profound influences from underground and urban cultures. This type of work cultivates a citizenry that understands, through transparency of technology, not only how things work, but how to make things themselves.

Acknowledgment

This material is based upon work supported by the National Science Foundation (CIS-0855868 and 0855886) to both authors. The views expressed are those of the authors and do not necessarily represent the views of the National Science Foundation, the University of Pennsylvania, or the Indiana University. We thank Diane Glosson, William Burke, and Michael Moore for their help with workshop coordination and Deborah Fields and Kristin Searle for comments on an earlier version of the chapter.

References

Benkler, Y. (2006). *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. New Haven and London: Yale University Press.

Buckingham, D. (2003). *Media Education: Literacy, learning and contemporary culture* Cambridge, UK: Polity Press.

Buechley, L. (2010). Questioning Invisibility. *IEEE Computer*, *43*(4), 84-86.

Buechley, L., and Eisenberg, M. (2008). *The LilyPad Arduino: Toward wearable engineering for everyone. Wearable Computing Column in IEEE Pervasive, 7*(2), 12-15.

Buechley, L., Eisenberg, M. and Elumeze, N. (2007). Towards a Curriculum for Electronic Textiles in the High School Classroom. In *Proceedings of the Conference on Innovation and Technology in Computer Science Education* (ITiCSE), Dundee, Scotland, June 2007.

Buechley, L. & Hill, B. (2010). LilyPad in the Wild: How hardware's long tail is supporting new engineering and design acommunities. *Proceedings of Designing Interactive systems (DIS)* (pp. 199-207). Aarhus: Denmark.

Cunningham, H. (1998) Digital culture - the view from the dance floor. In J. Sefton-Green (Ed.), *Digital Diversions: Youth Culture in the Age of Multimedia* (pp. 128-148). London: UCL Press.

Eisenberg, M., Eisenberg, A., Buechley, L. & Elumeze, N. (2006). Invisibility considered harmful: revisiting traditional principles of ubiquitous computing in the context of education. *Proceedings of Fourth IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology in Education (WMTE'06)* (pp. 102-110). New York: IEEE.

Frauenfelder, M. (2010). *Made by Hand: Searching for Meaning in a Throwaway World*. New York, NY: Penguin.

Gauntlett, D. (2011). *Making is Connecting*. Cambridge, UK: Polity Press.

Guzzetti, B., Elliot, K., & Welsch D. (2010). *DIY Media in the classroom: New literacies across content areas.* New York, NY: Teachers College Press.

Jenkins, H., Clinton, K., Purushotma, R., Robison, A.J., Weigel, M. (2006). *Confronting the challenges of participatory culture: media education for the 21st century*. Chicago, IL: MacArthur Foundation.

Kafai, Y. B. & Peppler, K. A (2011). Youth, Technology, and DIY: Developing Participatory Competencies in Creative Media Production. *Review of Research in Education, 35*, 89-119.

Knobel, M. & Lankshear, C. (Eds.) (2010). *DIY Media: Sharing, Creating and Learning with New Media*. New York: Peter Lang.

Papert, S. (1980). *Mindstorms*. New York: Basic Press.

Perner-Wilson, H. (2011). *A kit of no parts*. Unpublished MS Thesis. Cambridge, MA: Massachusetts Institute of Technology.

Ratto, M. (2011). Open and design and critical making. In Atkinson, P., Avital, M., Mau, B., Ramakers, R. & Hummerls, C. (Eds.), *Open design now: why design cannot remain exclusive*. BIS Publishers.

Resnick, M., Berg, R, & Eisenberg, M. (2000). Beyond black boxes: bringing transparency and aesthetics back to scientific investigation. *Journal of the Learning Sciences, 9(*1), 7-30.

Rose, M. (2005) *The Mind at Work* (London: Viking Penguin).

Turkle. S. & Papert, S. (1992). Epistemological pluralism and the revaluation of the concrete. *Journal of Mathematical Behavior, 11*(1), 3-33.

Wilensky, U. (1991). Abstract meditations on the concrete and concrete implications for mathematics education. In I. Harel & S. Papert (Eds.), *Constructionism* (pp. 193-204). Norwood, NJ: Ablex Publishing.