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Published in:
Connectivity and Creativity in times of Conflict

DOI:
10.26530/9789401496476

Published: 01.04.2023

Document Version
Publisher's PDF, also known as Version of record

Citation for pulished version (APA):
Harjuniemi, E., Jarusriboonchai, P., & Häkkilä, J. (2023). Light It Up: Designing Electronic Textile with a Light as a Design Material. In K. Vaes, & J. Verlinden (Eds.), *Connectivity and Creativity in times of Conflict: Cumulus Conference Proceedings Antwerp 2023* (pp. 304-308). Cumulus, the Global Association of Art and Design Education and Research . https://doi.org/10.26530/9789401496476

Light It Up: Designing Electronic Textile with a Light as a Design Material

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Abstract
We are living in the era where digital futures are emerging and the technological development is rapid. Digital transformation is also happening in designing with soft materials, as the digital technology is integrated with fibers, yarns and fabrics. Therefore, the role of the textile and clothing designers changing and they are dealing with e-textiles and interactive materials. This paper explores a way to support textile designers in designing interactive artefacts. The aim of the research is to study and identify characteristics of technology as a tangible design material that designers could use along with other conventional materials, even if they are not technology experts. In this research, we are interested in developing better means for designers to prototype interactive and physical artefacts, allowing them to focus on their design vision, aesthetics, and normal practices used in their specific profession. Our goal is to identify characteristics of technology as a design material. We report of two workshops with altogether 17 design student participants using a fixed functionality electronics and a non-programmable microcontroller. We present the designers' overall experiences with the process as well as the resulting interactive prototypes. We discuss on the characteristics of ready-to-use technology that ideally would support the design, as well as integration of interactive technologies from the design education point of view. Our findings show that removing the need to do the actual programming allows the participants to focus on their design and to scope their concepts more tightly. Design students had positive opinion and experiences from the workshop as they managed to produce a functional porotype within three hours. The process forced them to work with the limitations of the technology and to process the idea how to integrate technology and light in their design. The paper contributes to the understanding of adoption of technology as a design material, and adds on to HCI education discourse which typically has emphasized the programming skills.

Author keywords
Prototyping; e-textile; design material; workshops; design process; design education

Introduction
We are living in the era of interactive technology, which is intertwining in our life in all sectors. The early days of technology development focused on exploring different solutions from the engineering perspective. In the last decades, the user experience viewpoint has gained more attention in the technology development. This has opened many different design opportunities in designing interactive products. For a long time, graphical user interfaces (GUIs) have been a standard interaction paradigm for people to interact with technology. However, new form factors and interactive materials are emerging. Materials are an important factor when designing and experiencing interactive artifacts (Fernaeus & Sundström, 2012). As interactive products take new physical and tangible forms, software

and hardware can be perceived as a material for design instead of being just computational and processing units. This perception is argued to enable new opportunities towards designing interactive artefacts, including textiles (Hallnäs, Melin, & Redström, 2002). The familiar set of conventional gadgets, like smartphones and smartwatches, are being complemented with various different kinds of unconventional interactive products (Döring, Sylvester & Schmidt, 2013; Li, Häkkilä & Väänänen, 2018). Among these, textile interfaces are emerging (Cheng et al., 2017; Devendorf & Lauro, 2019; Freire, Honnet & Strohmeier, 2017; Häkkilä, Colley, Roinesalo, Lappalainen, Rantala, Väyrynen, 2017; Nilsson, Satomi, Vallgårda & Worbin, 2011; Perner-Wilson, Buechley & Satomi, 2010; Schneegass & Amft, 2017).

Electronic textiles, i.e. e-textiles, are made of textile materials with integrated electronic components. When e-textiles are developed, it is important to have knowledge on textile design process. However, to develop this further requires expertise from the field of human computer interaction (HCI) (Kettley, 2016). The designer needs to have at least some understanding of the programming and possibilities of the technology. When teaching the design of e-textiles, teachers with expertise on various fields are needed, as the domain falls in the intersection of design and technology. As a field, e-textiles need interdisciplinary development teams. Teachers with wide expertise can ideally share their methods and knowledge from applications, software and technologies, as well as learn from each other. This gives also the students a fruitful learning environment (Harjuniemi, Johansson & Pyrstöjärvi, 2019). Designing new form interactive devices requires more than just useful functions and intuitive interfaces. They need to have well-designed forms factors, be aesthetically pleasing, and fulfil cultural and social meanings (Devendorf et al., 2016).

In this research, we are interested in exploring the ways of teaching technology to textile designers. Our target was to 1) create positive experience on technology, 2) make it easy to present ideas via rapid prototyping, and 3) give the designers freedom to concentrate more on their design than to get stuck with coding problems. While we believe that learning to code could offer designers several benefits, in this paper, our focus is on enabling and supporting designers to follow their typical way of working when designing interactive artefacts, not in teaching coding to designers. We present design workshops with designers in training using microcontroller and electronics to prototype their design ideas. This paper marks the first stage in our research towards exploring technology as a design material for physical interactive artefacts.

Prototyping interactive products

The design process in a design discipline starts from researching the given problem, and then, generating concepts to solve the problem. A concept is chosen for the further development, where it matures to the production, and is finally launched to the market (Morris, 2016; Travers-Spencer & Zaman, 2008). During the recent years, we have witnessed a rapid growth in the number of microcontrollers in a form of physical and tangible computing toolkits. Microcontrollers such as Arduino or LilyPad Arduino come with an integrated development environment (IDE) and off-the-shelf electronic components, bypassing complex low-level electronic knowledge and lowering the barrier for integrating interactive technology into physical products. While designers can use these microcontrollers to create art pieces and prototypes of interactive products (e.g., Grant, 2019), it still requires skills and effort to create functional prototypes. For instance, the designer needs to consider how to embed and hide, or highlight, the conductive threads and microcontrollers in the designed object.

We have used Arduino and LilyPad in our previous courses and recognized these challenges. Because programming was new to the design students, they worried about learning and utilizing the skills which effected their ideation process. Also, the programming being an abstract, more mathematical task differs from working with the physical design materials the designers have used to, and may thus feel uncomfortable for them. In this research, we wished to further explore and identify characteristics of a prototyping technology that would allow the designers to perceive it as one material among other design materials they were working with during the design process.

Design Workshop with Design Students with Light Up board

In the workshop, we used Bare Conductive Light Up Board (Figure 1) as a probe to explore designers' preferred characteristics and expectations of technology as a design material. The Light Up Board is a microcontroller with six (6) built-in LEDs and six capacitive touch sensor electrodes. The board itself is not programmable. However, the board comes pre-programmed with six different light modes: touch on/off, dimmer, proximity, candle, spin, and dice. The behavior of the LEDs can be changed to different light modes by connecting different electrodes together.

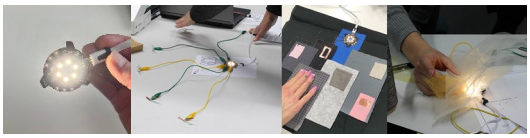

Figure 1. From the left: 1) The Light Up Board is quite small. 2) Participant P3 testing the touch sensors on the Light Up Board using copper tapes. 3) Participant P6 testing her prototype after integrating the Light Up Board with her custom-made touch sensors and other components. 4) Participant P1 testing material to create a flame-like feeling from the Light Up Board.

We chose the Light Up Board for this design workshop for several reasons. The board includes both input and output elements, i.e., capacitive touch sensing and LED outputs, offering degrees of freedom for our participants to decide on interaction and feedback of the board. Light and LEDs are one of the most common output modalities in physical computing (Devendorf et al., 2016). Turning a single LED on/off is typically the first step in designing and building physical computing. We believed that the configurable light behavior would encourage our participants to focus on the material and the physical design and, at the same time, still offers a possibility to explore interactive aspects of the technology.

Methodology and analysis

Participants

We conducted two workshops with 17 participants (15 female and 2 men, aged 24-44 years) in total. Here, 13 participants (P1-P5, P7-P14) were Master students majoring in interior and textile design, the participant P6 was an experienced textile designer, and 3 participants (P15-P17) Master students in industrial design. The recruitment was done at an e-textile course, where the teacher distributed the advertisement to her students. Eight (8/17) of the participants had studied the basics of Arduino programming before, and responded that the programming was the most challenging part when they had to work on technology-related design projects.

Workshop setup

The two workshops were both three and a half hours long and were organized as part of an e-textile courses at the university. For the course, the participants' task was to design and build interactive prototypes with the theme of well-being and happiness (P1-P5), or a delightful item in the context of dinner party (P7-P18). The themes were given to the participants before the workshops. The participants had the freedom to use any technology for their final design. Only for the course´s first technology workshop, the participants had to explore and use the Light Up Board. Information about the workshop and used technology was sent to participants beforehand. We also had a short introduction about the board and capacitive touch sensors at the workshop. The participants were provided with plenty of Light Up Boards, soft design materials (e.g., plastic sheet, felt, fur, fabrics), different wiring components (conductive thread, copper tapes, conductive ink, crocodile clips, tin foil), and electronic tools.

Workshop procedure, data collection, and analysis

First, we asked the participants to fill in an ideation form by drawing and writing down the design ideas they were planning to create. After that, we introduced the Light Up Board and gave introduction about the capacitive sensor: the techniques are as simple and

straightforward as more crafty techniques of connecting conductive ink, conductive thread, or copper tape directly to the electrodes, as introduced by Strohmayer and Meissner (Strohmayer & Meissner, 2017a; Strohmayer & Meissner, 2017b). The participants were then asked to revisit the ideation form to describe how they planned to use the Light Up Board.

After the initial introductions, the participants had two hours to work on their prototypes. They had the freedom to use all materials and tools provided and as many Light Up Board as they wished (Figure 1). We observed and took notes of how the participants used the board and problems they encountered. The participants presented their prototypes to other participants at the end of the workshop. After that, we conducted a semi-structured group interview with the participants. The interviews were recorded, transcribed, and analyzed with an inductive thematic approach (Braun & Clarke, 2006). In addition to the workshop, we also did a follow-up study on how the workshop influenced the participants' final design (P1-P5, P7-P17) for the e-textile course, which they exhibited at the university in the end of the course.

Findings

Overall, the participants had a positive opinion and experience integrating the Light Up Board into their designs. Although the board had limited features, it still helped the participants to explore and demonstrate the interactive features in their designs and functioned nicely in the rapid prototyping workshop (Figure 2).

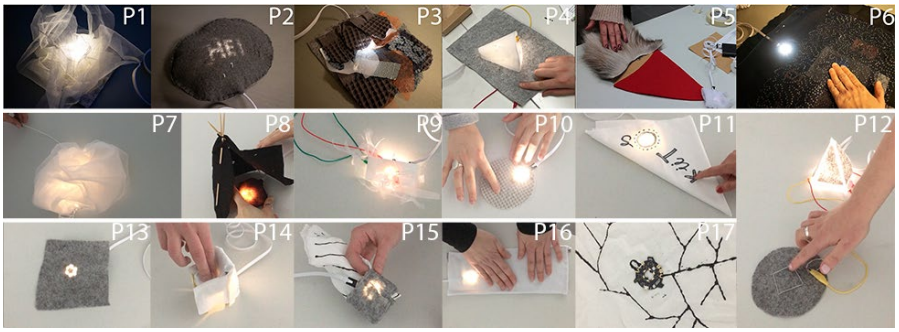

Figure 2. Interactive prototypes the participants created during the workshop.

It was a positive observation to see the participants enjoying the prototyping process. *"This was a fun experience for myself […]. That was quite simple after getting to know it a bit. And I liked it, it was fun."* - P11. Positive experiences were regarded important for the e-textile studies and future projects. *"At the starting point I didn't have any experience for this kind of e-textile things, and I felt a bit nervous. But I realized that the user interface was quite a simple and even easy, and that gave me a little sparkle for the future. So I could call this as very well working package."* - P8. *"This might give a push for those people who otherwise would see this difficult."* - P7.

Material for ideation

The participants appreciated the simplicity of the Light Up Board. The plug-and-play feature allowed a prototype to be created quickly, which was important in the ideation phase in the design process when one explores and try-outs different ideas. The used time constrained forced designers to conduct fast prototyping. Having a working prototype after a half a day was also considered to be rewarding. *"I think it was easy and especially fun. I feel like it didn't make you feel like you used a shortcut even there were something done already for you. I think was, this kind um, nice, especially for fast prototyping... And we didn't have much time but still we experienced a lot, failures and successes."* - P14. However, the limited functionality of the board could restrict the idea generation. It was seen to work the best when the technology matched with the design. Participants also saw having a tangible

prototype early in the process to ease the communication to others, and to be another benefit. The participants considered the Light Up Board and Arduino to complement each other.

Exploring materials and interaction possibilities

The participant P2 reported using the Light Up Board to test one of her ideas in practice. She also highlighted that the board helped her to realize where she should pay attention in her final design: *"I got to test my idea in practice with the board. I now know that in the final design, I need to have something to diffuse light to spread it to a wider area."* - P2. Furthermore, the board offered opportunities for the participants to explore different materials, e.g. conductive thread, and various interaction possibilities. Knowing that the board would always work allowed the participants to explore new materials to create touch sensors and to test whether they would work with the technology (Figure 1).

Focus on design and communicating the ideas

Bypassing the actual programming the Light Up Board allowed the participants to focus only on a few aspects when they created their prototype, particularly when developing a design concept and connecting the design with the board. This was considered as an advantage*: "for me, the coding part on a computer, then getting [the board] to work together with the code, put it into an actual prototype, and having functions work as they should and also [the design to] look good... this is a difficult combination of things. Working with [the Light Up Board] feels more certain. I don't have to focus on too many things... and it works more reliably"* - P1. Configuring the board to show the desired light pattern by using different wiring patterns was also considered simple and straightforward with the instructions.

The Light Up Board allowed the participants to communicate their design ideas in high fidelity, in a form that was close to a final product, without having to do any programming. The participant P2 show-cased a great example for using the board to communicate an interactive function in her design. P2 used two Light Up Boards to demonstrate remote touch between two *Secret Message Rocks* (Figure 3, left). Although the Light Up Board did not provide a wireless or a remote connection between the boards, a simple crossed wiring between two of them was enough to communicate the design idea and present the interactive feature of the rock.

Figure 3. Examples of the participants' final designs for the e-textile courses using the Light Up Board. Left: P2's Secret message. Right: P16's Spots of usage.

Problem solving

Although the Light Up Board did not require programming, it still helped if the participant had acquired knowledge and understanding about the technology. *"There was a problem with my prototype. I think the fabrics touched each other and created a short circuit. I moved it a bit and it's now working"* - P1. Thus, the participants knew how to fix the occurring problems. Our experience was that this was harder with programmable boards, where a teacher was needed more often.

Preferences for design

We observed that the participants first decided what function they would use or tested how it would looked like (Figure 1). The process then continued on to integrating the board with other materials and diving into the aesthetic details with the design (Figure 2). We also observed the participants spent a good amount of time choosing materials for their design, especially the materials to create the touch sensors, to cover the board, and to diffuse the light (Figure 1, right). The interview after the workshop revealed that it was important for the participants that their prototypes worked properly and were aesthetically pleasing. The

participants discussed the properties of the Light Up Board as a material for design from two perspectives: physical properties and interactive functions, described in the following.

Physical properties
The participants considered electronic components in general to be *ugly*. Most of the participants' comments about physical properties of the Light Up Board were directly related to aesthetics, and in particular, how the board provided them freedom in design and allowed to create nice looking prototypes. The participants were fond of the *small size* of the board, which made it easier to hide. They also preferred an organic and conventional look and feel for their prototypes. They appreciated that the board allowed them to use different materials to create touch sensors in different form factors and to place them at various locations, depending on the design idea.

Interactive functions
The participants appreciated the different light modes the board offered. The configuration to select a light mode was simple and easy to understand. The participants would have preferred to have more interaction possibilities. Currently, the Light Up Board allowed one light mode to be active at a time. The participants wished to have multiple light modes (P2), movable LEDs (P5), different LED colors, and others sensors and output actuators (P1). However, the participants' preference was not to add more sensors or actuators to the existing Light Up board, as *"adding more [sensors and actuators] to the Light Up Board would make it to lose its simplicity. You already have Arduino if you want to do all those things"* - P1.

Final art pieces for the E-textile course
The participants continued developing their prototypes for the e-textile course, where they had to present their final prototypes that demonstrated the design concept and interactive features (Figure 3). In the exhibition piece by P2, one rock showed a hidden message when the other rock was touched. P16's piece was a scale model of an interactive table cloth that lighted up from below revealing decorative pattern of spots. In total, five designers used the Light Up Board in their final design piece.

Conclusion
In this paper, we have addressed the digital futures in the area of e-textiles and design education, and presented our exploration study of technology as a design material. We conducted two workshops with design students using the non-programmable but configurable Light Up Board as the ready-to-use technology. Our findings show that removing the need to program a microcontroller allowed the participants to focus more on their design. The board also facilitated the ideation and validation of design ideas in the rapid prototyping process. Overall, the designers liked the technology and got positive experiences in the very beginning of designing and making of e-textiles. We reported on the characteristics of ready-to-use technology that would be an ideal material for design. This research contributes in making technology more accessible to designers with limited technical background, and allowing them to start building prototypes of interactive artefacts. In this research paper, our studies were limited to textile designers. However, we believe that the results can generalize over other design disciplines where the designers work with physical material and do not have technology courses as part of their education. As future work, differences and similarities between different design disciplines in prototyping interactive products should be investigated.

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