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Empowering Textile and Fashion Designers with E-Textiles for Creative Expression †

Mei Zhang [1,*], Rebecca Stewart [2] and Nick Bryan-Kinns [3]

[1] School of Electronic Engineering and Computer Science, Queen Mary University of London, London E1 4NS, UK
[2] Dyson School of Design Engineering, Imperial College London, London SW7 2DB, UK; r.stewart@imperial.ac.uk
[3] Creative Computing Institute, University of the Arts London, London WC1V 7EY, UK; n.bryankinns@arts.ac.uk
* Correspondence: mei.zhang@qmul.ac.uk
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Abstract: In the field of textile and fashion design, there is a growing desire to integrate interactive technologies into creative work. Traditional design education typically lacks support for material-oriented designers to develop electronic skills alongside their expertise in materials. There is a need to develop proper support for these designers to enter the world of electronic textiles (e-textiles). Our previous work introduced a material-centred e-textile learning approach through the development of a toolkit. This paper offers a glimpse into a design project made by our students, where digital functionality intertwines with physical design. It serves as a testament to the effectiveness of our approach in merging interactive technology concepts with material expertise, thereby aiding these designers in their creative endeavours.

Keywords: e-textiles; toolkit; creativity support; integrated interactive system; wearable; education; fashion design; textile design

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1. Introduction

In the Fourth Industrial Revolution, digital technology has significantly changed the way we live, work, and study [1]. With this impact, the boundaries between art, design, and engineering fields are blurring, and the importance of interdisciplinary education is rapidly emerging [2]. Material-oriented designers now have a growing interest in integrating interactive systems into their work. However, there are few formal higher education environments where both sets of skills are comprehensively taught.

Electronic textiles (e-textiles) are conductive filaments or yarns arranged in woven, knitted, or non-woven structures [3], offering digital features along with soft textures and composition. They present a new form of expressive materials for fashion and textile designers in their design process [4], enabling textiles and fashion items to be digitally functionalized while also remaining stylish [5]. However, expertise in e-textiles is inherently interdisciplinary as it requires the mastery of both material and of interactive technology systems, or collaboration between technologists, textile designers, and textile engineers [6].

As Jekal et al. note, "the systemic manner in which the fashion design industry operates needs critical reform, and there is a need to nurture [fashion] students' soft skills, including empathy, ethicality, as well as critical thinking, with a balance of technology-driven hard skills [7]." In order for the use of e-textiles to mature in fashion and textile disciplines, methodologies for guiding fashion and textile designers in designing with e-textiles and integrated interactive technology need to be developed. Our research examined how textile and fashion designers approach interactive textile knowledge and how

they apply this knowledge into their design practice. The results contribute to the development of tools used to support textile and fashion designers in designing with integrated interactive technology.

2. Methods

In our previous work [8], we developed an e-textile toolkit specifically for textile and fashion designers with limited electronics knowledge. It offers support for technical aspects while enabling open-ended design exploration and promotes a material-centric approach, guiding designers to view interactive textile knowledge from a material perspective. Subsequently, the toolkit was upgraded based on feedback from participants. The enhanced toolkit was then applied in an interdisciplinary wearable codesign study. A design case from this codesign study will be discussed in this paper.

In this study, interdisciplinary participants were recruited through universities. They were undergraduate students from various design and engineering programmes and were divided into codesign groups. Each group comprised at least one fashion or textile design student and one engineering student. Initially, the students were invited to participate in a full-day e-textile toolkit workshop to learn the basics of interactive textile, e-textile sensor principles, and construction. Subsequently, they were guided through open-ended material exploration to construct e-textile interfaces and interactive textile prototypes. With this foundation of knowledge, the groups began codesigning wearables over a six-week period, having the freedom to continue using the toolkit (see Section 2.1) or to choose their preferred electronic components.

Data were collected through questionnaires, design diaries, and tutorial-based interviews. In this paper, we will focus solely on the textile and fashion design participants' perceptions of interactive textile knowledge.

2.1. The E-Textile Toolkit Design

The toolkit design incorporates additional sensing functions using assembled hard sensors. Table 1 shows the input and output functions provided by the second iteration of the toolkit design.

Table 1. Toolkit functions.

	Input Functions	**Output Functions**
Existing functions	e-textile switch sensor e-textile positional sensor	movement music
Newly added functions	e-textile pressure sensor proximity sensor light dependent resistor sound detection sensor	heating

Additionally, soft connections used on the printed circuit board have been updated to offer two analogue and two digital connections. A series of e-textile wires has been designed using silver thread and covered with thin nylon rope. Furthermore, tutorial videos demonstrating step-by-step instructions have been provided. Figure 1 shows the hardware and the sensor template of the toolkit.



Figure 1. Toolkit hardware and sensor template, including templates for an e-textile pressure sensor, a switch, a positional sensor, e-textile wires with pin headers, e-textile wires with snap connections, a mainboard, a movement function module, a heating function module, a music playback module, a microphone sensor, a proximity sensor, batteries of different voltages, and a USB cable.

3. Results

Figure 2 shows the design process and a part of the wearable compositions, including stretch-sensing trousers (Figure 2(1)) and an e-textile glove (Figure 2(2,3)) that triggers touch sensing when contacting the shoulder pad on a cloak (Figure 2(4)). The project was a collaboration between four textile undergraduate students and two electronic engineering undergraduate students. The key role of the engineering students focused on technical development, including programming and circuit construction. They also participated in testing the e-textile sensing performance and provided suggestions for making design choices.

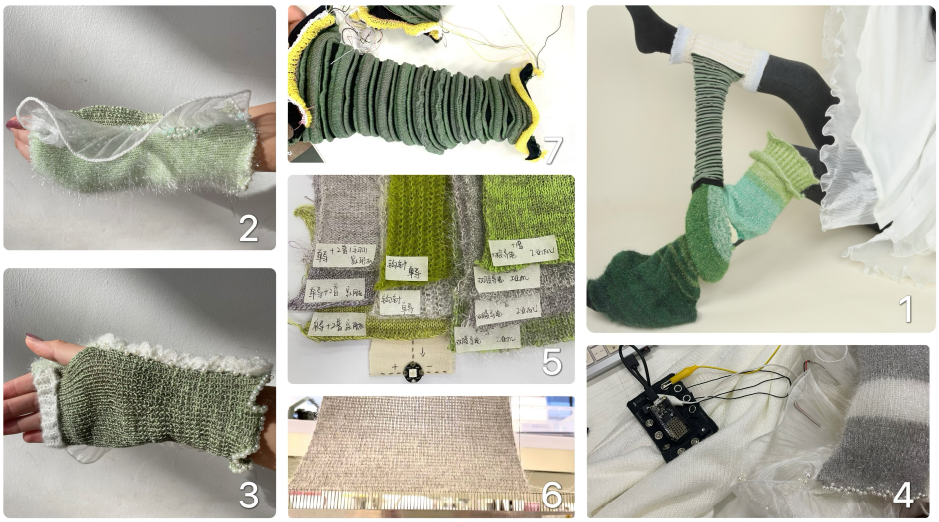


Figure 2. Participants' wearable project: design process and wearable compositions (1: Stretch-sensing trousers; 2: Upper side of the e-textile glove; 3: Palm side of the e-textile glove; 4: The e-textile shoulder pad on the clock, connected to the toolkit mainboard; 5: A part of knitting samples made with various materials and construction techniques; 6: The e-textile sample knitting process; 7: The e-textile stretch sensor).

The design process for their project began with the participants researching the colour scheme, texture, and format of the design. Following this, they selected a series of candidate materials for the physical design. To construct the e-textile touch sensing that features excellent technical feasibility while also maintaining aesthetic requirements that match the design concepts, the design participants created 12 knitting samples (Figure 2(5)) with different material combinations, knitting structures, and knitting machines including an industrial knitting machine and home knitting machine (Figure 2(6)). Twelve e-textile sam-

ples were then sent to engineer participants for testing conductivity, and then the engineer participants gave suggestions to the design participants from a technical perspective based on the testing results. Out of the candidate samples with the best technical performance, the design participants chose the sample of purple yarn knitted with a single strand of conductive thread using a hand-crank knitting machine.

For constructing the knit stretch sensor, the design students knitted a series of samples and sent them to technical participants for technical testing. After several rounds of sample making and testing, they finally reached the sample with the best sensing performance, which was knitted in the tube, and sheet geometry (Figure 2(7)).

The e-textile sensor experiment process demonstrates the effectiveness of participants' prior engagement with the toolkit in learning interactive textile knowledge and the hands-on creation of e-textile sensors using various raw materials [1]. This suggests that design students have developed a flexible understanding of interactive textile knowledge through a material perspective and are able to integrate it into their textile design process.

In the later stages, the design participants constructed the trousers (Figure 2(1)) and glove (Figure 2(2,3)) with the materials and techniques that were proposed during the experiment stage. The results demonstrate a good sensing performance, and the sensor design is fully integrated into the physical design, achieving aesthetically pleasing results and good wearability.

4. Discussion and Conclusions

We suggest that the results illustrate the effectiveness of incorporating e-textile knowledge with a material-centric approach through the toolkit [1]. Instead of treating digital functionality as a separate entity, we suggested that students integrate e-textiles into the textile structure. This integration included not only technical feasibility but also aesthetics, including the selection of materials and material construction techniques.

Approaching interactive textile knowledge through a material lens leads to a more successful balance between functionality and aesthetic appeal. Rather than rigidly applying technology to design or presenting an interactive system as a separate addition to the fashion item, our approach builds on the students' existing material expertise. For example, in the creation of wearable trousers (Figure 2(1)), students experimented with various knitting techniques and experimented with various knitting structures to optimize sensing capabilities while maintaining aesthetic quality. Additionally, in the construction of a touch sensing glove, a series of materials combined together with various knitting techniques and structures were sampled and tested. This practice, where the development of technology and design are interdependent, results in a more harmonious, functionable, fashionable, and wearable design.

We suggest that our approach makes learning electronics more effective through textile and fashion students' familiar knowledge and experiences; it enables students to explore technology during the design process and to offer unique insights into technology development through their practices in textile and fashion construction. Furthermore, this approach empowers design students to integrate e-textile knowledge into their design practices, thereby embedding interactive textiles as an integral part of their design skill sets.

Our approach appears to be effective in assisting textile and fashion designers in understanding the fundamentals of creating integrated interactive systems. The open-ended e-textile design skills acquired through the toolkit may enable designers to blend technological knowledge with their existing material expertise. This work contributes to the development of toolkits that support designers with material expertise in acquiring interaction design skills, and it benefits the development of emerging interdisciplinary education.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of Queen Mary University of London (QMERC20.114, 5 March 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The link to the publicly archived datasets of participants' design outcomes is www.mmeizhang.com, accessed on 1 November 2023.

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