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Interactive textiles

Learning e-textiles with higher education art and design students

ABSTRACT
The fusion of computing with textile materials has enhanced the interactive capabilities of textiles. Applying these electronic aspects of textile design is an evolving discipline. This study introduces a case study of teaching textile design in higher education with an interactive focus on art and design. We analysed projects and contents that appeared to be significant in the students' processes as well as findings from the point of view of art and design pedagogy. Working on design education in multidisciplinary teams together with accessible technology was found rewarding. Knowing the basics of textile design is essential, but when developing e-textiles, interdisciplinary teachers are recommended. Moreover, creating positive experiences, circumstances and possibilities to continue the design process in the future is also important.

Keywords:
design education, communication, art, craft, e-textiles.

INTRODUCTION

This case study examines the processes, implications and pedagogical issues of designing and making electronic textiles (e-textiles) in art and design at the higher education level. E-textiles, especially interactive ones, are challenging the traditional conception of textiles as a static expression. Previously, we have assumed that textiles are designed to keep their given, static appearance during their life cycle. A striped pattern, for example, was expected to keep its stripes without changing into something else after being touched (Nevay et al., 2017; Worbin, 2010). Textile designers were also previously trained to design for static expressions in which patterns and decorations were meant to last in a specific manner. Recent developments in the field of textiles, however, show how new possibilities, especially those deriving from new information technology and its application in fashion, architecture, interior design and healthcare, have redefined textiles as a uniquely multi-disciplinary field of innovation and research (Quinn, 2009; Worbin, 2010). Embedded with microcomputers, digital components or other electronic devices, textiles can, for example, provide important conversational bridges between family members and carers as well as people with dementia, particularly when visiting is found challenging (Treadaway & Kenning, 2016).

Just a few decades ago, researchers invented textiles that could change their interactive surfaces, textiles that had technical features but still felt like textile. MIT researchers explored physical computer interfaces and computational devices built into electronic fabrics and conductive threads. In 1998, Orth, Post & Cooper introduced the textile keypad, which was made from a switch matrix and a conductive embroidered keypad (see Orth et al., 1998). Nowadays, it is possible to create interactivity with all kinds of sensors and actuators embedded in textile materials, and e-textiles have become commercially available. Project Jacquard, for example, has manufactured interactive surfaces using existing textile weaving technology (Poupyrev et al., 2016). However, e-textiles are still faced with certain challenges before they can permeate the entire textile industry. In this study we promote interactivity as an inspiring context of textile design and as well as an era to develop in design education. The above-described new and more interactive-oriented identity of textiles is also promoted in STEAM projects in schools (Nugent et al., 2019; Peppler, 2013; Searle et al., 2019; Strand et al., 2020). As part of the STEAM field, applications with textiles may also dispel textile's representation as being mostly reserved for women, as men have also become active in the field (Buchholz et al., 2014; Demirbas et al., 2007). In the context of STEAM, e-textiles are also used in learning design thinking as 'explaining an idea, in words or through an artifact, requires re-organising that idea into different formats' (Peppler, 2013, p. 41). The STEAM context nowadays is of growing relevance, especially in basic craft education (Kokko et al., 2020). In this study, which focuses on design and pedagogical issues around the design process, the testing and technical training aspect of STEAM is not the main issue, as we as teachers approach e-textiles as an area of various possibilities from the point of view of design education and artistic expression. Students of art and design who create e-textiles provide a case study in this article. The students' projects we analyse concern intertwinings of arts, craft, design and technology. Hence, by combining traditional textile craftsmanship with electronics and computational knowledge, material knowledge and problem solving, we approach the field of e-textiles as a complex area that is both fascinating and challenging (Strand et al., 2020).

This study presents a thematic dialogue between two universities in Finland, as the teachers of these two institutions approach the era of e-textiles from two slightly different pedagogical standpoints. At the University of Lapland, higher education in textile design produces textile designers who usually work either as designers, artists, entrepreneurs or researchers in the field of textiles. At the University of Helsinki, the focus is on educating teachers of craft and design in various sections of education, primarily to serve the need for basic education. However, what both universities have in common is the professional desire to develop the field of (modern) textiles using an interactive focus, the fields of art, craft and design being seamlessly present in our approaches to e-textiles. It is also notable that in Finland, 'craft' has nowadays a broad meaning that does not make a clear distinction between artistic, crafting and technological approaches (Ihatsu, 2002; Kokko et al., 2020). The Finnish National Core Curriculum for Basic Education calls craft 'an exploratory, inventive, and experimental activity in which different visual, material and technical solutions as well as production methods are used creatively' (FNBE, 2014, p. 462). The nature of e-textiles as an exploratory activity fulfils this purpose well.

This article seeks to introduce and analyse design and the making of e-textiles in higher education textile design courses, and to consider the benefits as well as challenges of learning about e-textiles in higher education art and design. This study asks (i) What kind of outcomes are made when promoting interactivity through e-textiles? and (ii) What are the pedagogical challenges as well as strengths in promoting e-textiles in higher education art and design? The article is organised as follows: first, the literature in the concept and era of e-textiles is reviewed and this is followed by an overview on educational projects. The outcomes of the empirical projects are then introduced, and last, the pedagogical implications as strengths and challenges from the point of view of teaching and learning e-textiles in higher education, are presented.

E-TEXTILES: COMBINATIONS OF MATERIALISING AND AN IDEA

E-textiles are fabrics with integrated electronic circuits and components (Han et al., 2020; Strand et al., 2020). The simplest e-textile can be built using textile material, conductive yarn, LED lights and power supplies. In addition, using a microcontroller, buttons and/or sensors the product can be made interactive. This technology allows makers, hobbyists and designers to create e.g. accessories, interior decorations and furniture with expressive, interactive and functional features for playful or serious applications. Using such artefacts is a multisensory experience for the user, which can be created using e.g. LEDs, vibration motors, speakers, GPS receivers and touch sensors (Hamdan et al., 2018). When creating e-textiles a typical process has five stages: (1) designing or choosing an artwork, (2) planning the layout of electrical components and traces, (3) creating the artwork and fabric circuit on the base fabric, (4) insulating circuit traces where necessary, and (5) attaching electronic components (Lovell & Buechley, 2010; Hamdan et al., 2018). E-textile crafting labs usually contain facilities such as knitting, sewing, embroidering and weaving machines, Jacquard looms, digital printing facilities and 3D printers. Techniques for executing e-textiles are often based on traditional textile techniques, e.g. printing, weaving, knitting and embroidery (Berzowska, 2013, pp. 173–174; Coleman et al., 2011).

Conductive materials such as metals have been integrated with textiles for over a thousand years. When electricity was first harnessed, some experiments were carried out on illuminated clothes, but the development of e-textiles and wearables truly started in the 1990s when MIT researchers started to develop, as they termed it, 'wearable computers' (Buechley et al., 2013, p. 3). The first designed products were presented in the MIT Media Lab's Wearable Fashion Show in 1997, including e.g. the Musical Jacket, which had an embroidered capacitive keypad in the bodice (Orth, 2013). The technology used in e-textiles was finally commercially available for the public in 2007, when an e-textile construction kit called LilyPad Arduino was released, enabling embedded electronics to be placed in textiles (Buechley, 2013). The designs of the components are round and aesthetically pleasing. They are small, washable and the holes in the components make them easy to sew on. Their commercialisation brought them closer to consumers and the maker culture adopted them because it is not necessary to be an engineer to make e-textiles.

Nowadays, e-textiles have properties such as sensing, actuating, communicating and generating/storing power (Serzin et al., 2016). An e-textile might be designed with an ability, for example, to communicate to the environment the user's state of mind, or it can be used for interaction with the environment. This ability to interact is important, as textiles are usually thought to be passive, which in the modern world restricts their communicative value (Nevay et al., 2017). In Jutila's study (Jutila et al., 2015), for example, a wearable sensor vest with integrated wireless charging was designed to improve the security of children. The wireless charging of the vests could take place in, for example, an ordinary wardrobe or coat rack without requiring any specific actions from the user. The sensor vest provides information about the 'location and well-being of children, based on received signal strength indication, global positioning system, accelerometer, and temperature sensors' (Jutila, 2015, p. 915). The applications of e-textiles today vary depending on the context in which they are meant to be used, for example, in elderly care (Mc Cann et al., 2017; Yang et al., 2019) or for health and physical well-being (Treadaway & Kenning, 2016; Yang et al., 2019), or to express a new form of fashion design (Han et al., 2020; Pantouvaki, 2014).

E-TEXTILE DESIGN PROJECTS IN VARIOUS EDUCATIONAL CONTEXTS

Studies focusing on e-textile applications in education are nowadays published with various aims and contexts, especially in maker activities or maker education, or in the proceedings of prestigious HCI conferences. E-textiles are also promoted to increase girls' and women's enthusiasm for STEAM disciplinary contents or computing. Hence, they diminish the gender gap in which males are typically keen on technology and females on the arts (Buchholz et al., 2014; Han et al., 2020; Nugent et al., 2019; Peppler, 2013; Strand et al., 2020). Along with gender, another barrier in education is equity concerning access to the new technology that is promoted with e-textiles. The purpose of Searle, Tofel-Grehl and Breitenstein's (2019) research into multicultural education, for example, was to have 'non-dominant female students make physical and digital artefacts (e-textiles) that support expression and exploration of their intersectional identities' (Searle et al., 2019, p. 45). The study explored the phenomena around students' experiences as well as the influence of their teachers' perceptions. Their findings indicate that the personalisable nature of e-textiles created a meaningful opportunity for students to engage in a science class in a new way (Searle et al., 2019). In Fields et al.'s (2018) study of high school computer science classrooms, the students designed wearable electronic textiles with microcontrollers, sensors and in two e-textile units. This study was designed to promote equity by broadening access, diversifying the representation of makers and the objects made as well as encouraging participation so that more young people could engage in 'rich learning and expressive maker activities' (Fields et al., 2018, p. 31). In another study with high school students (Lui et al., 2020), students were examined to see how they 'navigated different tasks including coding, crafting, and circuit design through creating collaborative e-textile projects and how their social interaction supported or inhibited their collaboration' (Lui et al., 2020, p. 73).

Working with e-textiles in higher education fashion design courses, Han et al. (2020) created and tested a user-friendly graphic learning tool for university students without an engineering background to enhance the prototyping of e-textiles. The study found that the tool could be used in preliminary sessions with novice users before physical prototyping. In Karppinen et al.'s (2019) interdisciplinary study on higher education, design and invention pedagogy were applied to pre-service teacher education and were used on a course that integrated crafts, physics, drama and new information technology, such as e-textiles. After the course, the majority of students were in favour of the topic and its feasibility for implementation also in primary schools. From the pedagogical point of view, the most visible impact was a clear change in attitude towards interdisciplinary teaching and crafts designing (Karppinen et al., 2019).

METHODS: THE CASE OF TWO HIGHER EDUCATION COURSES

A case study exploring the design of e-textiles in higher education art and design courses was carried out in two universities in Finland. The courses and their implementation are opened more closely here below. In the education of future textile designers at the University of Lapland, the reason for including e-textiles in students' study programmes is to develop know-how concerning the possibilities of e-textiles, to learn the basics of electronics and programming and to build interactive prototypes. Having an e-textile project in their portfolio links designers to the intersection of design and technology and would no doubt have a favourable effect on their employment as designers (Harjuniemi & Genç, 2020). In turn, for future craft teachers at the University of Helsinki, the design and making of e-textiles can offer a new and innovative environment to 'benefit varied content areas of crafts as well as new ICT' (Karppinen et al., 2019, p. 70). The basis of the nature of craft as a subject is that 'multiple materials are used, and activities are based on craft expression, design and technology' (FNBE, 2014). In the context of design, design-based learning related to the solving of authentic problems, for example problems in our daily lives, and the shaping of environments are promoted (Kangas et al., 2013; Pöllänen 2009).

Research on students' design process helps educators understand how to develop their pedagogies for teaching the design process (Lahti, 2016). Teaching creative practices in the art, craft and design disciplines is generally based on a studio model usually emphasizing problem-based learning in where students are initiated into the process to solve open-ended design problems (Lee, 2009; Lahti, 2016). According to Cennamo (2016, p. 256) a design studio 'must be focused on design problems'. These problems are typically so-called "wicked problems," characterized by a virtually infinite number of possible solutions and are not tractable or solvable in their initially defined state. The activities, students as well as instructors, undertake in the studio depend on the discipline. The process, however, starts with the purpose of design and then moves outward to encapsulate the tools and practices for achieving that purpose (Cennamo, 2016). In this study, during a practice-led learning process students learned designing textiles with interactive qualifications under a given open-ended design assignment. The courses were separate, but the design learning process consisted of phases summarised below as five steps. The order of the steps was not necessarily linear, but each step included reflection with the teacher and/ with other participants of the course:

Step 1. Explore – a workshop exploring and learning the technology appropriate in designing e-textiles
Step 2. Define – defining the idea of the individual design project based on given design assignment
Step 3. Ideate – sketching and/ producing possible solutions for the design assignment
Step 4. Prototype – developing a prototype as a solution to design assignment
Step 5. Test/ Evaluate – testing the prototype to find the most satisfying solution as an e-textile.

We analysed the data from the courses, namely students' artefacts and reports, using qualitative content analysis and focused on identifying thematic content as significant factors that were characteristic in the full data set and highlighted the content (Drisko & Maschi, 2015). In applying our research method, we especially included examples from the full data that appeared to be representative in producing an idea through e-textiles design. We also explored contents that were significant to us as teachers, especially from the point of view of art and design pedagogy in higher education. Methodically, we were not looking for differences between the universities, but following the holistic case study idea focusing on the contents and characteristics that were common in teaching e-textiles in design education in the university context (Merriam, 2009).

The advanced studies textile course at the University of Helsinki
Students at the University of Helsinki study to become craft teachers at various levels of education, albeit mainly in basic education. In an advanced studies five-credit course, which was supervised by the author working as a University Lecturer in Craft Studies, the contents included user-centred design for interiors and the aims of user-centred design issues connected with interior design and textiles. In the first nine-week phase of the course, each student applied a probing process to an interior to learn user-centred analysis as a co-design practice (for details, see Kärnä-Behm, 2016). In spring 2018, when the data were collected, there were 16 students in the course.

The second nine-week phase that followed at the end of the same spring period consisted of an introductory lecture (2 hours) and training lessons with evaluation (22 hours). During the training lessons, the students designed and made an interior textile using materials and textile techniques of their own choice into the space probed. In their design they followed Lamb & Kallal's (1992) FEA consumer needs model. In the FEA model, the future users' needs are provided by means of establishing design criteria that are defined as 'Functional, Expressive and Aesthetic considerations' (Lamb and Kallal, 1992, p. 42). In addition to unifying the FEA model, other design criteria meant that the textile had to be somehow modifiable according to its size, colour, construction or purpose of use. According to the students' choice, this modifiability could be implemented in the form of an e-textile which was associated with interior textiles that were handled in the author's introductory lecture at the beginning of this period. Some of the students had completed a five-credit basic course on making e-textiles in their previous, optional textile design studies, but this was not a condition of participation in the course. This previous course providing basic knowledge in creating e-textiles was supervised by another teacher who specialised in interactive technology. The e-textile course contained lectures and a workshop during which students learned the basics of electronics and applied LilyPad Arduino communities as a resource in their e-textile prototypes build.

The advanced studies textile course at the University of Lapland
At the University of Lapland, higher education in textile design aims at educating textile designers usually working either as designers or as artists, entrepreneurs or researchers in the textile industry. The five-credit e-textile course in the Faculty of Art and Design at the University of Lapland was arranged with an interdisciplinary team of teachers in the 2018 autumn term. The course was for future textile designers and was part of advanced studies in interior and textile design and in Creative Technology as a minor subject. The aim of the course was to familiarise students with e-textiles in the Arctic context

and the teaching methods were lectures, workshops, guided working with the prototypes and evaluation. This was a 5-credit course (50 hours) and 9 students participated. The course started with introductory lectures on e-textiles and the course assignment was given. Students continued to do background research and ideation with the Arctic as their source of inspiration. They then attended technology workshops, where they learned about electronics and made rapid prototypes of their ideas. The technology used was the Bare Conductive Light Up Board. This is a pre-programmed board with LEDs, which can link connectors to create six different light modes. The students were also introduced to a sound-producing DIY toolkit in the second workshop. The Bare Conductive Touch Board was again pre-programmed to play 12 different sounds that the designer could choose. If any students had a further interest in the topic, they were given a LilyPad Arduino and could use Arduino communities as resources. After the workshops, students developed their own ideas and textile designs.

The technology used in e-textiles was supervised by the author, a design technology teacher, along with a postdoctoral researcher with a background in human–computer interaction. An interior and textile design lecturer supervised the textile design process. The aim of the co-taught course was that students should learn the basics of e-textiles in the context of interior and textile design and should be able to embed electronics in their design. Under the theme of Arctic design, students designed and built an interactive, working e-textile prototype. The finalised e-textiles were presented in early 2019 in an exhibition in Arctic Design Week.

FOCUSING INTERACTION AS A DESIGN CONTEXT: OUTCOMES

Techniques for executing e-textiles are often based on traditional textile techniques, e.g. sewing, weaving, knitting and embroidery (Berzowska, 2013, pp. 173–174; Coleman et al., 2011). In this section, selected students' e-textiles are introduced as representative outcomes when interaction with e-textiles is created. An interactive pillow and a room divider are from the University of Helsinki and message sending stones and a communicative wall textile from the University of Lapland.

An interactive pillow with changing expressions according to the surroundings

In designing an interactive pillow, the student wished to express the user's own craft hobby as well as cherish and promote craft culture by combining traditional vernacular embroidery with modern techniques like e-textiles. The product was also designed to fit into the present colour of the living room as well as future colours. The readjustment of the changing environment along with the craft culture emphasis was a starting point in the interactive pillow design process. The colour of the LED lights in the pillow changes when reading the colour sensor. In this way, the colour of the LED lights can also be adjusted to the changing colours in a future interior. A woollen fabric was chosen as the pillow material as it is ecological and easy to clean, and in most cases merely requires airing rather than washing.

Traditional vernacular embroidery that is typically used in sleigh quilts, was designed and sewn by hand into the pillow using woollen yarn. The traditional motifs of vernacular embroidery were then combined with electronic components. The aesthetics of the pillow thus consist of the traditional motifs of embroidery and technical-looking electronic components. The colours of the pillow itself were calm: the cloth is dark grey and the embroidery figures have been made using black, white and grey. The colourfulness of the textile comes through the LED lights, which can change their colour (Figure 1). The front of the pillow has LED lights with an Adafruit Flora microcontroller. The back of the pillow has a colour sensor which can be used to read the colour of the LED lights on the front.

FIGURE 1. An interactive pillow. The embroidered motifs change colour according to its surroundings. Images: Niina Niinimäki.

An Interactive room divider in a sailing boat

The aim of the e-textile was to divide up space in a sailing boat. According to the student, the diversity of activities as well as the unfocused nature of the space sometimes make the sailing experience a stressful one. Sailing boats are moving vehicles in which the right-timeness of functions and their chain are central. It should not be difficult to divide up the space into three areas: the bow cabin, the middle cabin and the toilet. A considerable amount of time is spent on board, especially when sailing in the summer season and holiday period, so the interior space must be safe and sufficiently organised to allow one to rest and relax. Consequently, the aim of the e-textile design was to make the boat's inner space more user-friendly by using an interactive room divider. An e-textile room divider with a fastener connects the bow and middle cabin together and also functions as a means of communication between passengers

One criterion in the design of this e-textile was that the conductive yarn as well as other components should be hidden inside the product. This was solved by using a macramé technique through which the components run inside the work. During the design and making process, experiments with macramé technique were made with the yarns of various materials (such as cotton and linen) and thicknesses. A LED light is placed at one end of the fastener. Magnet couplers are placed in the middle of the fastener as well as at the other end. The conductive yarn that connects the components goes inside the holder (Figure 2). When the divider is kept open, one of the magnet couplers is connected to the LED end of the fastener, meaning that the electric circuit is not closed and the light goes off. Should some privacy be required, the divider can be closed. When the divider is closed, the magnet couplers connect with each other, the electric circuit closes and the LED light goes on as a sign of a reserved space.

FIGURE 2. From left to right: An electric wire runs inside the fastener that is made using a macramé technique. A 3-volt battery is used as a power supply and the wires are soldered as a circuit. No board is included, but the LED, battery and wires are used. Normally, when privacy is not needed, the fastener simply keeps the room divider open between the spaces. A small press stud acts as a switch and an LED light is placed at the end of the fastener (left side, not visible in the picture). The light goes on when the switch is pressed. This indicates a reserved space when more privacy is needed. Images: Iina Mähönen.

Message-sending stones in a long-distance relationship

The design process of this e-textile began in the ideation phase when how to create happiness with textiles was considered. Inspiration came from the theme of soothing one's longings and the belief that stones have different energies. ”Secret Message” is designed for those far from their loved ones. The idea of message-sending stones was that a couple would both carry a stone. Both technology and a message are hidden in the products. The design reflects forms of Arctic nature and is associated with non-technical devices.

By touching the stone one can send a message to the other person and vice versa. The idea was tested in the workshop with a rapid prototype using a Bare Conductive Light Up Board (Figure 3). The process ended with the idea of a message-sending stone working by means of a touch sensor. The iterative process consisted of explorations with materials to guide light effectively when illuminating the hidden text in the stone. Light could pass through felt, while a blackout curtain that did not let any light through and allowed sharp letters to be formed to the surface. Inside the stones, foam was used as supporting material and wadding as filling material. Different texts and fonts were also tested.

The final product/prototype included two stones made of felt with hand-embroidered details. The chosen materials formed an interesting contrast between technology and natural elements as well as cold, hard stones and soft wool fabric. Expressing details through moss made the surfaces of the stones more interesting, supported the shape of the stone and tempted one to touch its surface. The embroidered patterns were partly made using conductive thread, which was connected to the Light Up Board working as a touch sensor. The lights could be switched on and off by gently touching the surface of the yarns. The prototype used two Light Up Boards connected under the plywood, but the idea was that they should work separately. The messages chosen for the couple to send each other were “Hi lovely” and “You're dear”.

FIGURE 3. From left to right: Testing the Light Up Board's settings of the six built-in-LEDs by connecting electrodes differently. The student´s first rapid prototype made in the workshop. Finalized artpiece of the "Secret Message", an e-textile product where text is lighted with the integrated LEDs in the Light Up Board. Images: Emmi Harjuniemi.

A communicative wall textile welcoming you home

The aim of this project was to create a communicative wall textile that interacts by means of touch. It reflects the theme of creating happiness and well-being using e-textiles by alleviating loneliness through communication. "Come Well" welcomes the homecomer. It is designed to be put in the wall of hallway and it shows its location with its glow-in-the-dark details. Touching the surface makes the textile play greetings from other family members and thus the home no longer feels so empty. The e-textile also acts as an interior detail and as an acoustic element. Its complex surface was created by a rug-weaving technique using various textile materials, such as leather and fur (Figure 4). The design and colour were inspired by Arctic nature. The surface created with various materials is attractive and pleasant to the touch. The sensation of soft materials and the voices of family members create an emotional moment for the user.

"Come Well" includes greetings from family members and selected music. The embedded speaker contains recordings of family members' laughter, wishes and piano playing. Alternative soundscapes could be of many sorts, such as voice messages, the sounds of nature or the user's favourite music. The technological elements consist of a Bare Conductive Touch Board microcontroller and a small speaker. This technology was tested in workshops, where the student made a rapid prototype and tested how the touch sensors worked when embedded in the rug elements. The microcontroller has built-in touch sensors that are conducted to the surface touch-sensing features by means of conductive threads and fabrics.

The future user of this e-textile might be someone who has a family that lives in the same apartment but comes home at different times. One could also record the voices of distant relatives or loved ones. The concept of this communicative wall textile could be transferred to different environments and contexts. It brings people closer together but at the same time it tells stories or brings back memories. The next step of this e-textile could be to test what kinds of sounds the user wants to hear coming from the interactive wall textile. The process also continued the notion of a "flying carpet", an idea which was developed after the e-textile course. In this work, storytelling and traditional and vanishing textile techniques combined to form an intriguing product. The process opened up innovative ideas and the possibility of using this kind of technology in different contexts with the goal of encouraging a sense of well-being and happiness.

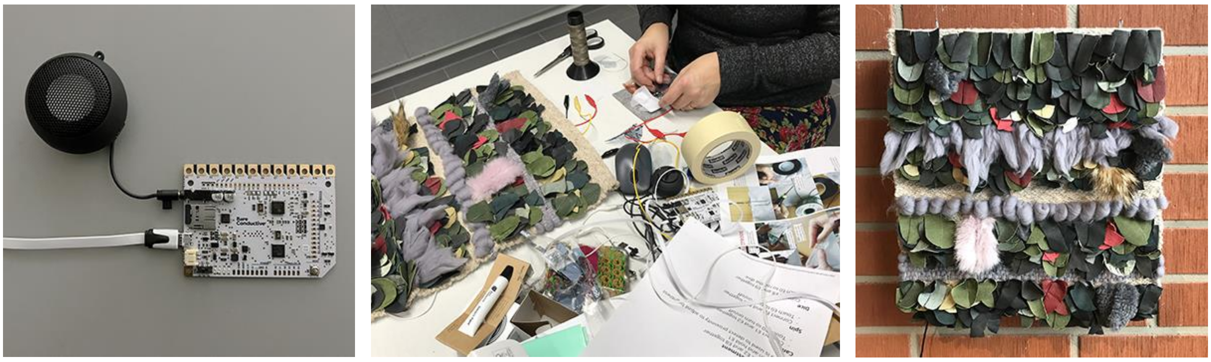

FIGURE 4. From left to right: A Bare Conductive Touch Board plays sounds and voices when touched. A student exploring textile materials and technology in the workshop where the participants were provided with Bare Conductive boards and a variety of electronic tools, soft design materials (e.g., felt, fur, fabrics), and various wiring components (conductive thread, conductive ink, copper tapes, crocodile clips, tin foil). The finalised work in the exhibition is called "Come Well", an e-textile containing an embedded touch board. Images: Emmi Harjuniemi.

THE PEDAGOGICAL FINDINGS IN TEACHING AND LEARNING E-TEXTILES

From the pedagogical point of view, the study examined the benefits as well as the challenges of applying e-textiles to art and design in higher education. These are next explored based to our experience and reflections as teachers of the courses.

In learning about e-textiles, the design process includes understanding the use of such elements as sketching circuits, hiding conductive yarns in seams and using light as a design element. Learning programming and building electronics differs from students' other studies that are connected with textiles and therefore requires a different mindset. In our teaching, the aim of applying e-textiles to design studies was to inspire students to integrate new technology into their future projects by giving them successful experiences with their first experiments. Keeping this in mind, one of the challenges is in *defining the right level of skills and knowledge needed in using the required technology* for e-textiles. In this study, bringing together technology and textiles aimed at promoting interactivity in textile product design. Programming was a totally, or an almost, new aspect of textile design for all the participants. In the University of Lapland´s course, the challenge of using programmable microcontrols was earlier tested with several groups of students and as a result, non-programmable Bare Conductive Boards were used with the students who were training to be textile designers. Before this, it was noticed that students encountered problems with programming and needed a great deal of support from teachers. Others felt that it was frustrating when such problems were merely the result of a missed comma or an incorrectly written letter. The pre-programmed boards made it possible for students to focus on the design of the artwork, whereas more user-friendly technology gave them positive experiences and more finished outcomes. Preventing students' potential frustration by keeping the technology accessible a teacher should, however, be aware that there is always a risk of failure in the process of programming. Hence, Peppler (2013, p. 42) underlines the importance of celebrating successes as well as failures as 'learning experiences'. This celebration of success was realised in an exhibition in Arctic Design Week 2019, where the results were arranged and in which 'Secret Message' was especially appreciated by the exhibition visitors, including experts from the field of e-textiles.

Learning to team up with experts from multidisciplinary fields of design, e.g. textile design, industrial design and interaction design is a strength that broadens students' as well as teachers' know-how in combining design and the technology recommended for making e-textiles (see also Kettley, 2016). Teachers from various fields of expertise can share their methods and knowledge of applications, software and technologies as well as learn from each other (Harjuniemi et al., 2019). Considering this teaming up from the point of view of design students or future entrepreneurs, it is important for them to learn to communicate with HCI specialists as well as develop their future designs in cooperation with interdisciplinary teams. However, certain *preconditions as challenges*, especially in teamwork, still need to be addressed. These are, for example, *the financial resources* to supply the software and other material needed in teaching, *adequate time resources in the planning* of the teaching as well as *agreeing upon the division of work between the educating participants*. The sooner the planning and agreements begin, the better. The need for and benefits of teamwork between teachers, as well as sharing expertise, was also brought out by the students. Students from the University of Helsinki mentioned that especially in basic craft education, where a craft teacher usually works alone in a classroom, some kind of technical support in applying suitable technology might be needed. It is also possible that the more experienced students could teach other students about their knowledge of technology (Fields et al., 2018). The final responsibility for the learning process, however, rests with the teacher and not with the student.

The chosen e-textile products and artworks in this study represent the outcomes that meet the cross-disciplinary goals in the intersection of art, craft, design, technology and education. Equally important is the process itself, namely what the students as designers learned in creating e-textiles. Looking at the results from the students' point of view, after taking the course a student's knowledge of what can be done with electronics, for example, embedding wires into seams or using conductive thread, was increased. In a practice-led learning process, students learned the basics of building electronics, designing textiles with interactive qualifications, taking into account the user experience in the design process as well as gaining encouraging experiences in creating a working prototype, possibly their first e-textile, by themselves. As higher education teachers, we learned that the design process in e-textiles can *promote new ideas and the possibility of using technology* in other or different contexts than in the task just completed. Along with learning ICT by designing e-textiles, students can connect themselves with current or important themes concerning the design assignment given and learn about design thinking that requires reorganising one's ideas into different formats (see also Peppler, 2013, p. 41). The results that evolve from such explorations could lead to unexpected combinations that create new meanings. The opportunities to ask later about the technology or components needed in new projects that would be available in the near future, are valuable aspects of the learning process. This kind of a continuing design process is well aligned with the iterative nature of the creative process (Han et al., 2020) and also *breaks down the boundaries between the research lab, the classroom and the design studio* (Berzowska, 2013, p. 171; Lidwell et al., 2003).

Textiles and computing are understood to be quite different gendered domains (Searle et al., 2019, p. 45). In dissolving the borders between these gendered domains, e-textiles can 'disrupt students' previously-held stereotypes of computing and making' (Fields et al., 2018, p. 24), as well as art and technology (Han et al., 2020; Peppler, 2013). Despite the fact that our emphasis in this study was not on gender issues, it is nevertheless important as teachers of art, craft and design to be conscious of such issues. In appealing especially to girls and women, e-textiles' strength is that *they can be a significant medium for broadening participation in computing* (see also Peppler, 2013, p. 40). This is especially notable in basic craft education. As a school subject and before the Basic Education Act of 1998, craft was divided into technical work and textile work. As an optional school subject in the upper level of comprehensive schools, technical work was mostly preferred by boys and textile work by girls. The tradition and image of learning craft contents divided by gender might still, unfortunately, be alive in our culture today and even among teachers (Kokko et al., 2020). We believe that diminishing this gender gap in craft education by using e-textiles in design tasks could play an important role.

CONCLUSION

From the viewpoint of design education, it is important that students practise various kinds of design tasks during their education in scaffolding their design learning (Yang et al., 2022). In this practice-based case study, we as teachers introduced and analysed design and the making of e-textiles in two higher education courses. As a starting point, we were aware that e-textiles are both fascinating and unusual due to their ability to blend physical objects with digital processes and the visible with the invisible (Nevay et al., 2017). Their significance in materialising ideas and creating an interaction between a space and its user, or between several users, is a valuable resource in design education at the higher education level.

On the basis of our case study as well as the congruent findings of Demiskas and Demirkan (2007, p. 345), we conclude that higher education art and design students benefit from applying e-textiles in their studies in many ways. In creating interactive designs with textiles, students have learned to combine textiles with technology, enabling them to cross traditional disciplinary boundaries (Peppler, 2013). This is a useful skill for future craft teachers who will be expected to teach multi-material craft that combines craft, design and technology (Kokko et al., 2020). Designing and making e-textiles demands creativity and as such these kinds of tasks can channel personal and aesthetic expression that is useful for future designers and entrepreneurs in the textile (and fashion) era (Han et al., 2020; Pantouvaki, 2014; Peppler, 2013). In general, cross-disciplinary teaching that involves experts from different fields can create better circumstances for the development of e-textiles. At its best, this is a fruitful learning experience not only for students, but also for teachers (see Harjuniemi et al., 2019). The teaching methods, lectures and workshops in both courses, as well the technologies used, were successful as far as the results were concerned, as the students were successful in creating working interactive prototypes.

Cross-disciplinary teaching, however, demands careful planning and adequate time resources for curriculum planning processes along with equal division of responsibilities and financial resources in order to make the teaching material available (Fields, 2018). Another challenge is to prevent students' potential frustration by keeping the technology accessible, especially when they make their first prototypes using e-textiles. Despite the challenges of learning and using the new technology connected with e-textiles, considerable pleasure, fun and playfulness is connected with creating interactivity through textiles (Treadaway & Kenning, 2016). In the future, it is to be hoped that the kinds of courses that were introduced in our study will be used when educating future designers as well as future teachers in the field of art, craft and design.

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