A Review of E-Textiles in Learning Environments

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Abstract

The field of electronic textiles (e-textiles) combines digital technology with textile objects, and has applications in fields such as wearable computing, theatrical design, and medicine. Prior work has examined deploying this technology in educational settings, to teach such skills as circuit design, computer programming, and iterative design. However, e-textile-based learning materials are still not commonly used, and more validated examples of such interventions would be valuable. The aim of this project is to investigate the state of the art in e-textile technology, especially in educational contexts, and to develop and evaluate an e-textiles intervention which could be deployed in a classroom or extra-curricular setting to teach introductory programming skills. So far, we have conducted a literature review examining applications of e-textiles in learning environments. For example, in one study [9], the researchers provided a safe environment for children with ASD (Autism Spectrum Disorder) to create their own sensory haptic toy. We found that many of the studies targeted middle and high school age children as a way to gauge and increase their knowledge of electricity and sewing techniques, but not many examined undergraduates. Therefore, in future work, we plan to conduct an experiment investigating the effectiveness of e-textiles in undergraduate learning.

CCS Concepts

• **Applied computing** → **Education**; Electronics; Arts and humanities; • **Hardware** → *Integrated circuits*; • **Human-centered computing**;

Keywords

E-textiles, Education, Review

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1 Introduction

Electronic textiles (e-textiles) are textiles that combine technology with fabric based materials. The applications of e-textiles are vast and can be used in many fields such as theater, wearable computing, healthcare, and education. Our project focuses mainly on the use of e-textiles in educational settings, where their integration displays a unique bond between technology and learning.

Prior work (e.g., [2]) has examined deploying this technology in educational settings, to teach such skills as circuit design, computer programming, and iterative design. This approach is supported by educational theory such as embodied learning [10] and constructionist learning [4]. However, e-textile-based learning materials are still not commonly used, and more validated examples of such interventions would be valuable. The aim of this project is to investigate the state of the art in e-textile technology, especially in educational contexts, and ultimately to develop and evaluate an e-textiles intervention which could be deployed in a classroom or extra-curricular setting to teach introductory programming skills.

In this paper, we describe a review of the existing literature on e-textiles in education. We were particularly interested in identifying trends in contexts of use, learning objectives, and measures used in this body of work, to find areas that would benefit from further research and experimentation.

During this review, we primarily found papers that provided e-textile workshops for students ranging from middle to high school. These workshops offered an excellent opportunity for teaching children skills such as circuit design, computer programming, and problem solving. The researchers also were able to include many different children from the communities who had learning disabilities or who came from struggling areas. We noticed throughout our literature review that most of the projects conducted were aimed towards a younger audience. Therefore, in our future work, we will address this gap by conducting a study examining undergraduate students learning with e-textiles.

This paper contributes an investigation into the state of e-textile technology with a focus on its applications in education. E-textiles is a field that anyone can be a part of, and we believe that the broader adoption of e-textiles into learning could enhance outcomes and experiences in both classroom and extra curricular settings.

2 Background

E-textiles, or electronic textiles, represent a fusion of fabric and technology that allows for a greater range of use than ever before. E-textiles integrate various materials such as sensors, wires, and power sources directly into fabrics to enable detection and transmission of various forms of data. The evolution of e-textiles blends together innovations from several fields including computer science, electrical engineering, medical science, and textile manufacturing. The potential applications for electronic and smart textiles are near endless, including fine arts, medical assistance, fashion, and education. The number of possible uses will only increase as e-textile technology increases in complexity.

Although the concept of e-textiles may seem very modern, one of the earliest examples of electronic textiles dates back to the ballet

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La Farandole in 1883 in which illuminated headbands were used. One of the first patents for an e-textile was created in 1910 for an electronically heated glove. [7]. In 1990, a research project conducted at MIT introduced the idea of wearable computers. Their "Wearable Motherboard" project proposed a shirt that could monitor life signs of the wearer. This idea led to the development of methods that allowed for embedding electronic components into fabrics. These efforts paved the way for contemporary e-textiles that now merge technology with wearables to create interactive and functional garments.

Educational applications of this technology offer advantages over more traditional, less tactile methods for teaching programming and electronics by making more visible the connections between physical actions and hardware and related theoretical concepts [8]. These benefits may be increasingly important in the current era of expanding generative AI use, where students may be tempted to delegate potentially tedious tasks like programming to these tools without truly learning if they are not sufficiently engaged in the process.

Another strength of e-textiles is that they have the opportunity to engage students belonging to groups that have been historically underrepresented in CS. For example, many textile crafts such as sewing are practiced primarily by women, while CS is currently a male-dominated field. By including e-textile-based assignments in an introductory course to help teach programming, it may be more possible to recruit and retain women students by creating connections to an activity in which they are already interested. Similarly, e-textiles could allow students of different cultural backgrounds to preserve and celebrate their traditions in ways that are often non-obvious in CS teaching and learning. In this paper we contribute to the existing body of literature by identifying existing themes within the field and by discovering the need for areas of future research.

3 Research Questions

This paper addresses the following research questions:

(1) What contexts of use have prior e-textile studies examined?
(2) What learning objectives have prior e-textile studies examined?
(3) What measures have prior e-textile studies examined?

Answering these questions will clarify the effectiveness of e-textiles for education and identify areas of potential contribution to this literature, guiding the design of our future work in this area.

4 Methodology and Scope

In this review, we survey the existing literature to understand current applications of e-textiles in education, specifically focusing on attributes such as contexts of use (e.g., classroom vs. extracurricular activities, grade level), learning objectives (e.g., teaching circuit design, programming with variables/conditionals, etc.), measures studied (e.g., student learning, satisfaction), and the exact design of the e-textile interventions. The results of this review will identify areas of possible contribution for future research, including later phases of this project.

We began by pursuing higher-level knowledge on the topic of e-textiles through edited volumes(namely [1]) and prior literature reviews (e.g., [5, 6]). We then searched for papers on more recent work in the area, focusing mainly on papers published in the proceedings of *Creativity & Cognition* as indexed in the ACM Digital Library. The decision to limit the scope of papers considered for the review in this manner was based mainly in a need to ensure it could be feasibly completed as a semester-long project, and also because the theme of the conference closely aligned with our research interests and plans for future work.

5 Review of Selected Literature

Our main objective when starting the literature review was to figure out whether or not e-textiles were actually useful in an educational setting. While conducting the review for this project we came across several prior studies that have been performed using middle and high school age students as subjects. Although they were all conducted by separate groups of researchers, their research goals were similar. Their objective was mainly to test e-textiles projects as learning tools to increase understanding of certain skills such as coding, sewing, and problem solving. These studies provided students with a well equipped learning environment that allowed them to work together and create their own e-textiles. Over the course of the projects, researchers interviewed the students to test their knowledge of the required skills for completing their tasks. By using the data collected from these interviews, the researchers were able to visualize the learning growth that the students displayed. All of the studies found that the students' knowledge increased by a large amount at the end of the study.

An important topic in our research is the use of e-textiles in educational contexts. An interesting study we reviewed was conducted by Cristyne Hébert and Jennifer Jenson [5] and examined the use of e-textiles as a learning tool. They began their study by offering both an in school unit, and an after school maker space for elementary school children, and the information included in their paper focuses mainly on the educational growth that the students displayed. In their workshop sessions they instructed the children to create their own wearable e-textile hat. In order to construct the hats, the students would be using a special circuit board called a LilyPad Arduino, in addition to various other components such as sensors and LEDs. Over the course of the project, students would gain experience in multiple skills and ideas such as, constructing circuits, sewing, coding, and problem solving. Throughout the sessions the researchers taught the students by showing them the processes and providing hints that allowed them to successfully create a wearable e-textile. At the end of the 12 sessions, the researchers used student interviews and questionnaires to assess student learning. Their findings showed that student scores increased for both in-school and after school learning groups. "Overall, scores increased by an average of 9.74% (or 2.23 points) between the pre- and post-questionnaire. Students in the after school workshops had higher change scores, with scores increasing by an average of 11.63% (2.76 points) compared to an average of 7.69% (1.76 points) for the in-class group." ([5]) Additionally, students were interviewed about their interest in coding after the experiment concluded. After experiencing the e-textiles project, student interest in coding almost doubled. It was quite clear that students who participated in the projects wanted to see more coding education in their curriculum.

A common theme throughout several of the reviewed studies was diversity and equal opportunities for all participants. Researchers Janette Hughes and Laura Morrison conducted a study regarding the use of e-textiles in education ([6]. In their paper they held workshops for several different demographics of children. Over the course of their study Hughes and Morrison held four workshops, making efforts to improve with each iteration. One of their workshop groups consisted of 5 students who were tasked with creating an e-textile bookmark. Of the 5 students, one was legally blind, one had attention defecit disorder (ADD), and one student was a part of an Individualized Education Program (IEP), the rest were considered mainstream students. Hughes and Morrison made sure to choose students from all areas of the community for each workshop, despite the fact that some students had learning disabilities or mental health concerns. This proved to be no problem for the workshop groups as they were all able to finish their projects and learn while doing so. The aforementioned study conducted by Hébert and Jenson [5] also tackled topics of diversity. "The study took place at a large, K-8 elementary school in a rapidly gentrifying urban neighborhood in a city in Ontario. The school is situated in a community with families from a range of socio-economic backgrounds." [5] Both of these studies (as well as others discussed in this paper (e.g., [3, 9]) took into account concepts about diversity and implemented them into their work. Their findings show that the field of e-textiles is open to anyone who wishes to learn.

During our review we also came across a study conducted by Emilie Giles and Janet van der Linden, in which the participants were blind or visually impaired [3]. This study explored the idea of e-textiles creating accessible projects for persons with blindness. Rather than focusing on the visual aspect of the participants' final products, the researchers instead provided materials that each had their own distinct physical feel. This was done to shift the focus away from the technological aspect of creating an e-textile and instead focus on a more tactile interaction experience. At the beginning of the workshop the participants were apprehensive and anxious about the task laid before them. They were unsure of how to begin creating a textile without sight, and the extra steps required in order to form an e-textile only added to these feelings. One participant named Liv was extremely suspicious of e-textiles at first and shared her thoughts about its possible nefarious uses: "…. you could put in people's number, you can give them a number 649786, and press a button, and then they die…"[3] . However as each participant selected the material they liked the most and began the weaving process their anxieties gradually diminished. As Liv began to work she appeared to relax and enjoy herself. She explained to the researchers that her work reminded of tapestry work she had been unable to do for many years. Other participants had similar reactions to their work as they progressed. By the end of the workshop the participants showed enjoyment and pride in their work. The results of this research study continue to show that e-textiles can be enjoyed by anyone who is willing to learn.

In 2017 a group of researchers from Texas A&M University published their paper regarding the use of e-textiles as a way to provide support to children with ASD (Autism Spectrum Disorder) [9]. The study explored the use of haptic toys as a way to help children with ASD regulate their senses and engage in creative expression. Many children with ASD experience issues related to overstimulation and sensory development, which can lead to challenges regulating emotions, interacting socially, and focusing. There are existing support options such as weighted blankets and stuffed toys, but children with ASD are rarely given the opportunity to create these items themselves. This study aimed to address the gap by involving children with ASD alongside their caretakers in the design of toys. Five children with ASD and their caretakers were invited to participate in the study. Similar to the other papers we have reviewed, the children were given workshop sessions, materials, and help from the researchers to start them on their projects. Each participant engaged in a hands-on process in which they would sew a stuffed toy and incorporate electronic components to allow it to vibrate. The children were given a high degree of personal choice and customization in their creation process as the researchers allowed them to draw faces on the toys and select different vibration patterns. Throughout the process the children displayed deep interest and high levels of engagement, often times requiring little help from researchers and caretakers. At the end of the study the children showed pride and personal connections with their toys, with some children even expressing the desire to create more. "One child put a seat belt on for the soft toy because she wanted him to be safe and the other child took him around town and showed him to all her friends and sister." [9] The findings of this study add more weight to the idea that e-textiles are great tools for many things. Boosting knowledge, mental health support, and increasing human connection are all positive benefits that e-textiles provide.

6 Discussion

To answer our first research question, we searched for information that could tell us where e-textile studies have been conducted in the past. Our review showed us that after school programs and maker spaces provided the best environment for e-textile learning with after school students, showing a greater increase in knowledge versus in school students. For our second research question we examined the learning objectives that prior studies have tested. We found that when using hands-on learning to teach children concepts such as sewing, electrical currents, programming, and problem solving, they are able to experience the information in a way that is personal to each of them. Allowing children to physically interact with the learning material helps them figure out for themselves how each aspect functions and supports the larger project. For our third research question examining measures, we found that some studies used pre- and post-workshop questionnaires to test knowledge related to the projects. Many of the reviewed studies also examined participant enjoyment and satisfaction with the results. While answering our research questions, we noticed that a significant research gap exists in utilizing e-textiles in undergraduate education, where their potential for teaching introductory programming has yet to be fully explored.

A key theme we discovered while conducting our research was the emphasis on diversity and inclusion. In the reviewed papers, researchers deliberately chose participants from diverse areas of life and backgrounds to ensure that e-textiles were accessible to all learners. These studies included students from various socio-economic backgrounds, students with cognitive developmental disabilities, and students with behavioral disabilities, providing

them with equal opportunities to engage with activities related to STEM. E-textiles proved to be highly accessible to all learners, even including visually impaired persons and children with Autism Spectrum Disorder (ASD). It became clear to us that e-textiles are also more than educational tools. E-textiles can be used to provide other benefits to people such as emotional connections, sensory relief, and improved creativity.

7 Future Work

Based on our results, we will design an educational e-textiles intervention to use either in a course or dedicated extra-curricular event. The intention is to provide another validated example of an e-textiles application addressing a context that has not yet been sufficiently studied. For example, students in an Introduction to Computer Science course could create an accessory or art object containing LED lights and sensors, and program it to activate the lights in different patterns according to sensor readings, with the goal of learning about parameters, return values and conditional execution in programming. Upper-level students in a course such as Human-Computer Interaction could use e-textiles to learn concepts related to user-centered design. We will select appropriate techniques and measures for evaluating its effectiveness, such as pre-and post-surveys to evaluate students' knowledge of the learning content the intervention is intended to convey as well as their attitudes towards the topic and the experience they had with the intervention.

8 Conclusion

The use of e-textiles as educational tools shows their potential to transform traditional learning environments by combining technology with hands-on learning. Our literature review has provided evidence that e-textiles can teach a variety of valuable skills including, circuit design, programming, sewing, and problem solving. Studies have shown that introducing middle and high school students to e-textiles leads to increases in knowledge and interest in STEM related fields. E-textiles are also highly inclusive and demonstrate academic success across diverse demographics. We are confident that the use of e-textiles in education is a positive choice that greatly benefits everyone who is involved.

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