



Figure 1. Student sewing an electrical circuit for a wearable device using conductive thread and E-textiles.

# integrating computational thinking through wearable technologies and programmable e-textiles

*This article will provide an example instructional activity for fostering computational thinking while also addressing core engineering concepts in electronics using programmable E-textiles.*

## Introduction

Computational thinking is a problem-solving technique traditionally employed by computer scientists to develop computer applications. However, computational thinking practices are now believed to be applicable to other fields (Google for Education, 2018), specifically those related to engineering and technology. Accordingly, the Advancing Excellence in P-12 Engineering Education (AEEE) (2018) project identified computational thinking as a core engineering concept to create a foundation for students to conduct the quantitative analyses that engineers and other related professionals perform. Likewise, the Committee for the Workshops on Computational Thinking contends that

computational thinking is necessary for people to develop efficient and automated physical design solutions as well as visualizations of design concepts and computational scientific models (NRC, 2011). These abilities, which also include thinking critically about complex problems, generating creative solutions, and communicating solutions effectively, are now considered necessary at all levels of scholarship.

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While the demands in the computer science workforce continue to grow (Qian & Lehman, 2016), computational thinking skills are also considered valuable for multiple career fields (Kelleher, 2009). In response to the demand, interest in computer science education has increased and introductory courses have been developed for students at the elementary and secondary levels (Qian & Lehman, 2016). However, too few students are given the opportunity to develop these skills within engaging physical settings (Google & Gallup, 2016) provided through the hands-on and design-based learning environments afforded in engineering and technology classrooms. This article will provide an example instructional activity for fostering computational thinking while also addressing core engineering concepts in electronics using programmable e-textiles (electronic textiles). Specifically, the instructional context of wearable technologies will be used to provide a physical connection to developing computational thinking skills and electrical engineering capabilities while also enhancing the rigor of engineering design and providing socially-connected relevance to learning.

## Computational Thinking in Engineering

Computational thinking is a problem-solving technique that dissects complex problems and generates solutions that humans and machines can understand (Aho, 2012). Everyone can apply computational thinking in any career field—one does not need to be a computer scientist (Wing, 2006). Typically, the computational thinking technique can be separated into four elements: (1) decomposition, (2) pattern recognition, (3) abstraction, and (4) formation of algorithms. **Decomposition** is the process of dissecting a problem into smaller, more manageable tasks. **Pattern recognition** looks for solutions or similarities within problems. **Abstraction** ignores irrelevant data while solving problems. Finally, **formation of algorithms** is the creation of a step-by-step solution to be carried out by a computer program (BBC, 2018). These four elements are now considered essential skills to be taught across all grade levels in order to set a foundation for success in a technological society, increase interest in the information technology professions, maintain and enhance U.S. economic competitiveness, support inquiry in other disciplines, and enable personal empowerment (NRC, 2011c).

The importance of computational thinking practices has been stressed in engineering education, as individuals in engineering fields regularly rely on computational models and automated systems as design solutions. Additionally, *Next Generation Science Standards* lists computational thinking as one of eight science and engineering practices (NGSS Lead States, 2013), and the *Engineering in K-12 Education* report (NAE & NRC, 2009) states computational and visualization tools should be used, as appropriate, to support engineering design, particularly at the high school level. Consequently, the AEEE (2018) project established an engineering content taxonomy that included the

practice of Quantitative Analysis with a core concept of Computational Thinking. This core concept is comprised of the following subconcepts: (a) Programming and Algorithms, (b) Programming Languages, and (c) Software Design, Implementation, and Testing. In addition, a sample progression of learning is provided in Table 1 ([www.iteea.org/TETMayJune19AEEE.aspx](http://www.iteea.org/TETMayJune19AEEE.aspx)) to help integrate computational thinking into future or existing engineering coursework to (1) deepen students' engineering design practices and (2) increase their abilities to produce optimized solutions to authentic problems.

## Engineering Concepts Through Wearable Technology and Programmable E-Textiles

Wearable technologies are devices that can be worn to extend one's capabilities to achieve a task or meet a need/desire. Park and Jayaraman (2003) describe as examples devices that enable more "hands free" capabilities or devices that use interconnecting sensors to monitor a person's health vitals. Popular wearable technology today includes: smartwatches, like Samsung's Galaxy Gear or Apple's iWatch; augmented reality headsets, like Google Glass; and virtual reality headsets, like the Oculus Rift.

While these wearable devices have become more physically flexible and adaptable to individuals, they are often viewed as rigid technologies. However, E-Textiles (electronic textiles) have provided a way for flexible circuits that can enable electronics to be more agile when used in society. E-textiles, also known as smart textiles or intelligent textiles, is a name for fabrics that are converged with electronics so they can transform, collect, and transmit data; store and transfer energy; and house small computers (Pailes-Friedman, 2016) while interacting with the environment or user (Stoppa & Chiolerio, 2014). These components can offer an engaging medium for designing and physically prototyping wearable and flexible solutions to societal problems or creating novel products relating to fields like fashion, medicine, and athletics. Low-power wireless communications, such as bluetooth and wi-fi, and small vital sensors have advanced exponentially, reshaping how we use wearable technology and E-textiles in healthcare and preventive care (Suzuki, Tanaka, Minami, Yamada, Miyata, 2013). The wearable technology market is growing rapidly, and the Scalar Market Research firm states that this market is expected to grow 18.9% from 2016 to 2021, more than doubling its revenue from roughly 29 billion dollars to 71 billion. This data emphasizes the need for more computational-thinking-skilled employees in the workforce.

Wearable technology and programmable E-textiles can also provide authentic contexts for teaching important core concepts in engineering related to electronics and computer architecture. For example, the physical components of these technologies can address the sample progressions of learning provided in Tables 2 and 3 ([www.iteea.org/TETMayJune19AEEE.aspx](http://www.iteea.org/TETMayJune19AEEE.aspx)).



**Figure 2.** Student threading a sewing needle with conductive thread to make a wearable electronic device.

## Wearable Technologies: A Socially Relevant Context

In engineering education, there have been discussions that using programmable E-textiles in the classroom can help students to simultaneously develop making skills related to textiles (such as cutting, measuring, and stitching) and creative thinking while also providing connections to socially relevant contexts for learning in-depth knowledge of electronic circuits and components (Davies & Hardy, 2016). For example, wearable technology contexts can highlight engineering's influence on people and society while addressing students' desires to engage in fields that make a difference in people's lives (e.g., healthcare, physical therapy, veterinary care, athletics, fashion, assistive technologies, or virtual reality). Additionally, these examples can connect to the schools' cultural backgrounds and communities.

Several studies have focused on using E-textiles to provide opportunities for students to experience electronics and computer programming. Peppler and Glosson (2013) found that engaging children in E-textile design activities can help them to understand concepts around electricity, such as circuit analysis, current flow, polarity, and electrical connections. Qiu, et al. (2013) proposed a curriculum with programmable textiles and reported that these learning activities can improve students' comfort with, enjoyment of, and interest in working with electronics and programming. Also, Kafai, et al. (2014) explain that E-textile design activities can influence high school students' understanding of concepts, practices, and perceptions of computing. Buchholz, et

al. (2014) focused on the effectiveness of E-textiles toward enhancing girls' interest in STEM activities and found that replacing traditional circuitry toolkits with E-textiles can encourage more girls to participate in design practices. Therefore, the authors believe that aligning engineering with the socially relevant contexts provided through wearable technologies and E-textiles can help broaden participation in STEM fields and help achieve engineering literacy for all students. The lesson plan detailed in Tables 4, 5, and 6 ([www.iteea.org/TETMayJune19AEEE.aspx](http://www.iteea.org/TETMayJune19AEEE.aspx)) provides a start for teaching engineering content through the context of wearable technologies.

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