The E-Textiles Bracelet Hack: Bringing Making to Middle School Classrooms

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ABSTRACT
In this paper, we present an electronic textiles project called the "bracelet hack" that is intended to facilitate the introduction of making activities into classrooms. The project's design significantly decreases the costs and amount of classroom time that must be spent on the construction aspects of the project while still engaging students in design challenges. To test our hypothesis that the bracelet hack would allow just as much introduction to coding as more complicated, sewn LilyPad Arduino projects, we introduced the bracelet hack in the context of a professional development workshop for middle school science teachers. We analyzed teachers' audio recorded interactions while completing the bracelet hack and found that teachers were able to learn computational concepts, practices, and perspectives through the activity.

CCS Concepts
• Social and professional topics • Computing education

• computational thinking

Keywords
Electronic textiles, K-12 STEM education, professional development

1. INTRODUCTION
The Maker Movement and making more broadly have received widespread attention for the role they might play in engaging youth in authentic STEM learning, driven by personal interests and real-world design challenges. Yet, if the promise of making is to be truly realized, it must find its way into our public school classrooms, requiring explicit connections between making activities and the STEM content and disciplinary practices valued in national and state-level educational standards like the Next Generation Science Standards (NGSS). Connecting to educational standards and developing activities that will be successful within the constraints of a school classroom, all without losing the interest-driven, problem-solving nature of out-of-school making activities, presents a unique challenge.Introductory classroom making activities connected to STEM standards need to be cost- and time-effective in classroom spaces, but they also need to appeal to a broad range of students and provide space for personalization.

Electronic textiles activities are one promising avenue for bringing making to school [7]. Rather than the wires and breadboards typically used to teach students about electricity, electronic textiles (e-textiles) combine sewable actuators and sensors (e.g., LED lights, sound buzzers, and temperature sensors), a power source, and special, conductive thread. Students must first design their circuit blueprint, then construct the circuit using needle and conductive thread rather than wire and solder. Projects can be personalized through the kind of wearable created, the aesthetic design, and the circuitry design [7]. More complex projects introduce a sewable, programmable microcontroller such as the LilyPad Arduino [2]. E-textiles have been shown to engage students from a wide variety of backgrounds through the unique combination of craft, circuitry, and computing [6, 9]. However, e-textiles projects are time intensive and require expensive materials for each student, many are not reusable without cutting them out of an existing project.

We propose the development of a more affordable, less time intensive way to engage students and teachers in authentic STEM learning and design processes through the "hacking" of simple circuit e-textile bracelets intended for use in a middle school science unit on energy. In this paper, we discuss the design and initial testing of the "bracelet hack," a way to scale-up from cost- and time-effective simple circuit bracelets to programmable circuits using the LilyPad Arduino construction kit [2] and alligator clips. In designing the bracelet hack, we drew upon existing e-textiles curricular sequences that build from paper circuits to e-textiles bracelets to programmable projects. Knowing that the programmable project was the most time-consuming and the most expensive, we wanted to devise a way for students and teachers to engage with the scientific and programming concepts afforded by using a programmable microcontroller while cutting down on classroom time and costs. In addition, we wanted to devise an intermediate step between sewing circuits and then sewing programmable circuits. The bracelet hack removes many of the confusing debugging issues associated with sewing programmable circuits because we know that the bracelet circuitry works before we hook it up to a computer.

We audio-recorded eleven teachers in a professional development setting as they constructed simple circuit e-textiles bracelets and

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then worked with a partner to connect their bracelets to a LilyPad Arduino to make their bracelets blink and fade in various patterns. While the overall professional development goal was for teachers to be able to use e-textiles in the context of a middle school science unit on energy, our analyses focused on the extent to which teachers employed computational thinking during the bracelet hack activity. Findings highlight how teachers engaged with computational concepts, practices, and perspectives [1] and, perhaps more importantly, each other [4], as they learned to code in Arduino. In the discussion, we highlight how some of the principles used in designing the bracelet hack might be utilized to develop additional classroom-based making activities connected to STEM content standards.

2. BACKGROUND

In designing the bracelet hack, we built upon existing e-textiles research. Research highlights students' rich learning experiences as they engaged with e-textiles materials for the first time and then persisted in making and programming e-textiles artifacts. Paramount to these rich learning experiences are the interweaving of craft, circuitry, and computing as youth created personalized projects. Such projects not only captured learners' attention in thinking through authentic problems like circuitry design and debugging, but also tended to attract students other than your typical White, male computer geek. For these reasons and because middle school science standards often have a unit on energy, we felt that e-textiles could have a compelling place in middle school science classrooms. However, we also knew from our own experiences about the time-consuming nature of e-textiles. Even when classroom teachers gave us many weeks to implement e-textiles in their classrooms, we often ended up holding special lunch time sessions to provide students with additional time to work on their projects. While this was acceptable for early research efforts aimed at understanding how e-textiles assisted or hindered learning of STEM content, it is not realistic for widespread classroom implementation.

In devising a way to transform a simple circuit bracelet with a snap switch into a programmable project, our primary goal was to maximize the learning outcomes of using e-textiles materials in the science classroom while minimizing students' and teachers' frustrations. A secondary goal was to address practical concerns about the amount of time required to create a meaningful e-textiles project and the costs associated with the materials. In existing e-textiles curricula, the a bracelet project has often served as a bridge between paper circuits and LilyPad Arduino projects. The bracelet project introduces metal snaps that act as a switch in the circuit [3].When the bracelet is snapped to someone's wrist, the circuit is completed and it lights up. When it is unsnapped, it is not a complete circuit and does not light up. For many learners, having the snaps act as a switch is their first introduction to the challenges of spatial circuitry. That is, what you draw on a flat piece of paper is often a poor representation of the felt bracelet you want to create. In working through these challenges, learners develop not only their understanding of spatial circuitry but also their sense of the affordances and constraints of working with certain craft materials and e-textiles materials. Upon completing a functional bracelet project, the next step is typically to move onto a completely new, sewn project using the LilyPad Arduino. However, having students develop a completely new project requires an investment of time, materials, and teacher resources. What would happen, we wondered, if rather than developing new projects, students and teachers connected their bracelet projects to a LilyPad Arduino using alligator clips and learned to program with these projects before moving onto developing other LilyPad Arduino projects appropriate for the middle school science classroom?

The bracelet hack, as we have come to call the concept of alligator clipping simple circuit bracelets to a LilyPad Arduino to create a programmable project (see Figure 1), addressed the issue of debugging a more complicated project. Historically, a non-functioning programmable project had problems with the circuitry, the code, or both. To solve these kinds of problems requires substantial knowledge of how circuitry and coding are interrelated, as well as how craft and circuitry are interrelated within the specific domain of e-textiles [5], since it is challenging to transfer content knowledge about circuitry across different materials [8] Many novices do not possess this level of knowledge and must rely upon the help of a more knowledgeable individual like a teacher. By ensuring functional circuitry, we hypothesized that the bracelet hack would focus learners' attention on learning to code in the Arduino development environment and allow them to experiment with the same kinds of computational thinking as a stand-alone LilyPad Arduino project.

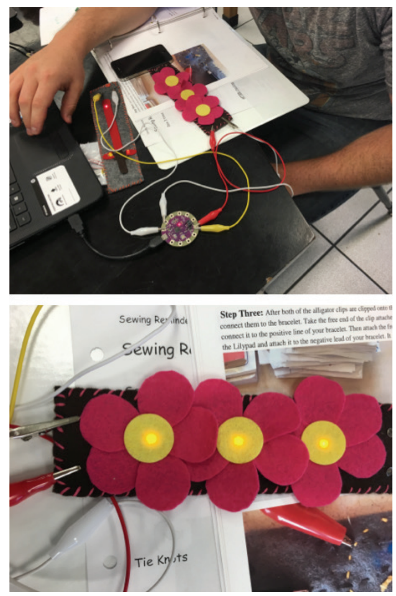

Figure 1: The e-textiles bracelet hack

3. METHODS

3.1Context & Participants

The eleven teachers whose experiences with learning how to code in Arduino are reported in this paper were participants in the STEM Teaching Integrating Textiles and Computing Holistically project (STITCH). The STITCH curriculum and professional development provides students and teachers with a personally relevant context for learning the foundational scientific and programming concepts. Specifically, it focuses on developing the skills to engage in data collection and analyses to solve real-world problems. This is aligned with NGSS's emphases on measurement and modeling as vehicles for engaging core concepts. STITCH also introduces students to science and engineering practices that align directly with careers in electrical engineering and computer science.

STITCH participants in the professional development described in this paper hailed from three participating school districts across two states in the intermountain west. Each of the districts targeted for inclusion was in a predominantly rural area with high numbers of students receiving free and reduced lunch, so as to reach teachers serving both culturally and economically diverse populations. Districts also needed to demonstrate an acute need for professional development efforts. Within these districts, participating teachers were recommended by their school administrator either as an eager first adopter of technology or as a teacher who needed additional support to engage meaningfully with technology. Some teachers sought out the research team upon learning about STITCH. Eleven teachers participated in this first professional development experience. They spanned a wide range of disciplines ranging from home economics to robotics. Prior experience with coding as well as e-textiles varied greatly by teachers. Only one teacher had previously worked with e-textiles in her classroom, but she had never explored coding projects with her class; instead she completed the bracelet and LilyTiny projects. Additionally, only one teacher noted prior coding or computer science experience; his work as a robotics teacher made him particularly enthusiastic and provided him a novel context from which to learn about these projects. The remaining 9 teachers reported no e-textiles or coding experience and one teacher stated she had “never even cut and pasted on a word processor” before entering the professional development workshop.

The professional development workshop took place over four days. During that time, teachers were provided with little direct instruction and instead were asked to work through the same projects their students would work through, including a paper circuit, a simple circuit snap bracelet, and a temperature sensing lunchbox with the LilyPad Arduino. In this paper, we focus on activities connected to the simple circuit snap bracelet portion of the professional development.

3.2 Data Collection & Analyses

In order to examine the experiences and development of a group of teachers with little prior experience coding, a wide range of data were collected. Pre- and post-tests focused on scientific content around energy and electricity were given to teachers in addition to surveys of their current computing knowledge and desired knowledge. Teachers were also engaged in clinical interviews regarding their content knowledge and participated in several reflective journaling activities throughout the professional development. Observational data was collected by multiple members of the research team and recorded in field notes written at the end of each day. Individual teacher's circuit blueprints, in process projects, and completed artifacts were also photographed to document their design processes and the challenges they encountered along the way. Finally, two audio recorders were strategically positioned to record whole group conversations and pair conversations between teachers seated at the same tables. For the bracelet hack activity, we focused on two pairs of teachers. Lloyd, the robotics teacher, and Katrina, the science teacher who had previously used e-textiles materials with her class, comprised one pair. The other pair was comprised of Jeanine, the teacher who had never used the cut and paste functions in a word processing application, and Arlene, a sixth grade physical science teacher.

Audio recordings were logged (a close but not word-for-word transcription) and examined for thematic trends across teachers, with a particular focus on how teachers engaged in computational thinking. In seeking to understand what kinds of computational thinking experiences the bracelet hack afforded, we found Brennan and Resnick’s [1] framework for assessing computational thinking to be of value. Brennan and Resnick’s framework breaks computational thinking down into three categories. Computational concepts encompasses fundamental programming ideas like sequences, loops, operators, and data. Computational practices deals with the kinds of practices individuals engage in when programming, such as being incremental and iterative, testing and debugging, and reusing and remixing. Finally, computational perspectives focuses on how learners come to see what computer code can do in the world.

4. FINDINGS

In developing the bracelet hack, we wanted to know if we could minimize the cost and time involved in making a programmable e-textiles project while maintaining the benefits of creating a programmable project connected to personal interests. Preliminary analyses suggest that teachers’ initial bracelet designs served as badges of personal interest and accomplishment. Figure 2 shows several bracelet designs, including a bicycle, a fossil, and the logo for a favorite sports team. Rather than detracting from the personal nature of the bracelet designs, teachers’ explorations of code led to further personalization.

As a class, we walked teachers through how to hook up an individual bracelet to a LilyPad Arduino using alligator clips. We then used Arduino in Codebender and had teachers upload the “basic blink” from the examples library. After talking through how to read the code, we asked teachers to experiment with the delay function and to use cut and paste to create variations of the basic blink pattern. Some teachers, remembering that there was a built-in LED on the Arduino board also experimented with how to make two lights blink. In this most basic introduction, teachers were introduced to loops and to working iteratively and remixing existing code. Then, we asked teachers to work in pairs to experiment with more complex blinking patterns.

Figure 2: Three examples of e-Textiles bracelet designs

During the experimentation phase, teachers delved into more complicated computational concepts and practices. They also refined their understandings of circuitry. Jeanine and Arlene, two teachers with no experience with e-textiles or coding, worked together to make their bracelets light up. Knowing that the initial blink code we worked with as a class was functional, they simply copied and pasted the code so that it was repeated twice. In and of itself, copying and pasting was a new skill for Arlene. However, when Jeanine and Arlene uploaded the code, only one of their bracelets would blink. With the help of one of the instructors, the teachers realized that they failed to alter the second block of code to reflect that the second bracelet was hooked up to pin 10 on the LilyPad. In coming to this realization, the teachers practiced remixing existing code and testing and debugging. They also reinforced their developing understandings of the connections between how the circuit is wired and how the circuit can be programmed. Because we knew that teachers' bracelets were functional circuits before we ever programmed them, the bracelet hack activity provided Jeanine and Arlene an opportunity to learn the same basic computational concepts we would expect them to learn from making their own programmable e-textiles projects without some of the additional frustration entailed in sewing, programming, and debugging a completely new project.

At the same time the bracelet hack provided teachers who were more experienced with an opportunity to explore more complicated computational concepts and practices. Working together, Lloyd and Katrina used the resources available to them on the Internet to find code that would allow them to create a fade effect by varying the voltage of the lights. With Lloyd's help as someone who had experience with code, Katrina was able to read the code and the pair explored the difference between analog and digital control of the lights. Lloyd later explained to the class:

> So, digitalWrite, there are really only two options. It's all on or all off. AnalogWrite has unlimited value instead of a fixed number. Analog, you can just tell it how bright you want it. So, every time through the loop, we told our [LilyPad] board we would like it this bright, so we scaled it up, and just made the number bigger and bigger and bigger until we hit the peak and then came back down. So, it's getting brighter and then it's getting dimmer (professional development transcript, 7/10/16, p.35).

While Lloyd had the coding background that allowed him to read code he found on the Internet and clearly explain it to the class, Katrina benefited from partnering with Lloyd and was also able to provide an explanation to the class. In the class share out, she articulated:

> We dimmed the lights and played around with the brightness that they dim at. So [the lights] were either pretty bright and they get brighter or they're really dim and they just get a little bit bright so you play around with that, the brightness. We also played around with the speed that they fade" (professional development transcript, 7/10/16, p.34).

In addition to exploring the differences between digitalWrite and analogWrite in Arduino, Lloyd and Katrina also had to play around with a variable called "brightness" in order to vary the brightness of the LEDs. Variables are a more advanced computational concept that move beyond sequencing and loops. In this way, the bracelet hack afforded both novices and those more experienced with e-textiles an opportunity to further their knowledge of computational concepts and practices.

Finally, playing with code during the bracelet hack activity helped teachers develop computational perspectives. Asked to explain coding in the clinical pre-interviews, most teachers said things like, "I don't know" or "it has something to do with zeros and ones." In contrast, the bracelet hack provided teachers with opportunities to see how coding could be used to express themselves. For instance, one teacher explored making his lights blink in time to Jingle Bells so that he could later make his lights blink in time to his school's fight song. The activity also allowed teachers to use code as a way of connecting with others through working on a shared goal, such as learning to fade lights.

5. DISCUSSION

When we conceptualized the bracelet hack as a cost- and time-effective solution to doing e-textiles within a middle school science unit on energy, we were uncertain if we would be able to maintain the affordances of working with e-textiles materials, namely the creative aspects and the authentic design challenges, and create enough complexity for novices to explore computing. However, in watching teachers engage the bracelet hack, not only were the benefits of e-textiles projects clearly possible, but the teachers demonstrated significant coding skill development and enthusiasm for their future work teaching those same skills to their students.

6. ACKNOWLEDGMENTS

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