Snappable Sensors: Empowering Future Scientists

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Abstract

Snappable Sensors is an e-textile toolkit designed to support student engagement with math and science learning in public school classrooms. Our design focuses on combining real-world materials, such as felt and conductive thread, with inexpensive microprocessors and sensors to strike a critical balance—enabling students to build their own sensing system and collect their own data for subsequent analysis while meeting the pragmatic economic constraints of public middle and high schools in the United States. Initial testing shows that our prototype instigates strong interest in learning. Snappable Sensors is a low cost, durable, and engaging solution that can help build students' math and science skills.

Author Keywords

e-textile; snaps; sensors; STEM education

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Middle and High School STEM curricula can sometimes elicit disinterest and frustration. Numerical manipulation and analysis can form a learning obstacle, causing withdrawal by students who are apprehensive of math. We envision a solution to these problems by incorporating data collected by the students into STEM curricula, and creating a system that invites students to explore numeracy and data analysis in the specific contexts of their local classroom environments.

The ubiquity of sensors has led to a wide range of low-cost "maker"-style electronics kits, but these advancements have not yet reached many conventional classrooms due to technological and financial constraints of public school systems. In response, we designed and prototyped sensors that enable students to learn about their school environments through interaction with real-time data collection and visualizations. In our current prototype, *Snappable Sensors*, students are provided with inexpensive and durable snap sensors and microcontrollers that they can combine to visualize *temperature* in real time as part of numeracy and data analysis curricula. Our prototype is easily extensible to new sensors and use cases (e.g., noise, light, humidity, or acceleration).

Related Work

We focused on two main threads of inquiry when looking for inspiration for the design of our classroom sensing platform: *grounding scientific inquiry in the students' environment* and *developing hands-on and customizable activities*. By exploring the intersection of these ideas, we aimed to develop a sensor system that appeals to students who may not be well served by traditional classroom activities; our goal for this work was to make *every* student feel like a scientist.

Grounding inquiry in the exploration of the environment
Frequently, schools teach science by forcing students through lab materials without clear explanation of which natural phenomena are being observed [1]. Using sensors in the classroom allows students to examine aspects of their environment and tell their own stories about the data that they collect. From this pedagogical perspective, students no longer complete the same lab assignment; instead, they have the opportunity to explore phenomena of interest and educate the rest of their classmates about their findings. Exploring the school environment empowers students to develop a unique understanding of the locale in which they spend so much of their time [8]. Furthermore, the diversity of experiments designed and run in this style of classroom and the subsequent sharing of the empirical results within a class enables the students to develop their own participatory scientific community in which they can share ideas [4].

Hands-on and customizable computational activities
Advancements in technology has made the space of individual scientific inquiry accessible to K–12 education; a classic example includes the Programmable LEGO Brick [2]. Hands-on, practical approaches have been shown to motivate student engagement, serving to develop increased interest and confidence in STEM fields [7]. BodyVis [5] is another example of using wearable sensor technologies to understand and visualize body data. We believe that building applications to facilitate the collaborative analysis of sensor data in school environments will stimulate students' interest in learning engineering and teach self-confidence and problem-solving skills.

Peppler and Glosson argue that "learning happens best when toolkits afford a sense of transparency by providing opportunities for concretizing knowledge through tinkering with the materials" [6]. The ability to

Figure 1: Informal sketches enumerating design options for incorporating different sensing platforms and form factors into various STEM classroom data collection and analysis activities.

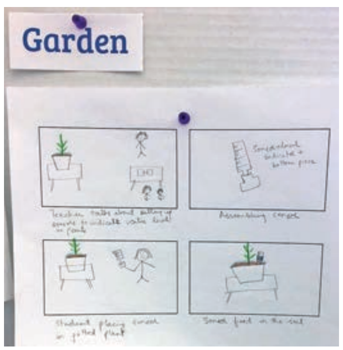

Figure 2: Detail view of one of our proposed sensor-enhanced curriculum scenarios—collecting data from a class garden. We created very informal early-stage sketches to elicit open-ended (and relatively uncensored) feedback from colleagues at our institution and educators and students at our field site.

tinker and customize a sensor system to explore specific phenomena of interest allows students to take ownership of their sensing system—and their learning.

Method

We conducted *formative qualitative field work* at a nearby public middle school to gain a deeper understanding of how our target classroom functions: *How is technology used in the classroom? What teaching methodologies are the teachers employing? To what extent are students engaged in their daily learning activities? What are some of the difficulties that students face while learning?* We conducted interviews with three teachers and observed a classroom. The interviews helped us to understand which STEM concepts students struggle with most and determine the feasibility of introducing ubicomp technologies into these classrooms.

Next, we conducted a *design exploration* of possible usage scenarios inspired by our classroom observations (Figure 1). These scenarios featured integration with a classroom setting (e.g., a plant observation device fit for instructional gardens, Figure 2), and our sketches demonstrated ideas of sensor modularization—in some cases, incorporating modeling compound as a flexible medium for connecting and protecting sensitive components. We consolidated our product designs after conducting a design review of our preliminary sketches, honing our focus around concerns of durability, modularity, and student engagement. We iterated upon these findings to create the physical prototype presented here: a fabric-based system using conductive thread and physical snaps to connect modules together.

Before eliciting summative feedback from teachers, we wanted to develop a *higher-fidelity physical prototype* to more accurately depict the look, feel, and potential usage of such a system. We chose to use LilyPad microcontrollers and sensors along with conductive thread, felt, and metal snaps to construct our prototype because it illustrated the ease of assembling the sensor and microcontroller and highlighted the durability of the product, which was a major concern shared by teachers during our initial fieldwork. We sewed the microcontroller into one piece of felt (see Figure 3a) and the temperature sensor and LED into another (see Figure 3b). With this prototype, a student can then snap the two pieces of felt together and trace the connections visually by examining the conductive thread. When students connect the microcontroller "module" to a laptop, their connections are validated — correct assembly results in illumination of the LED on the sensor "module." Using the Serial Plotter in the Arduino IDE (a placeholder for a future, more fully-featured data visualization tool), the student can see real-time temperature data read from the sensor.

Results

We presented our prototype to teachers and students in the same U.S. public middle school where we conducted our initial fieldwork. STEM teachers (n = 3) saw a short demo of our prototype and participated in an interview. A class of middle school engineering students were also shown the prototype and walked through a sample lesson plan using the kit. The students thought the prototype was engaging, with several commenting that the system was "really cool." They paid close attention to the demo, and asked thought-provoking questions about the sensors' design such as "Does the temperature sensor change

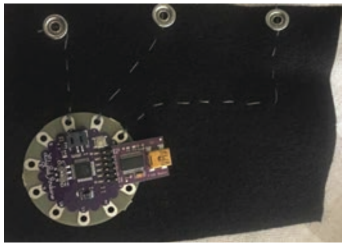

Figure 3a: LilyPad microcontroller sewn into felt. The snap on the left is power, the snap in the middle is ground, and the snap on the left is for data transfer from the sensor.

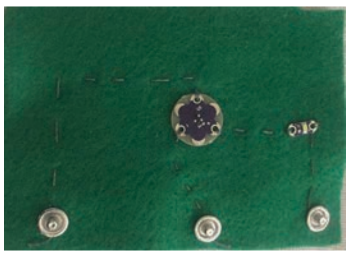

Figure 3b: LilyPad temperature sensor sewn into felt with an LED to indicate correct circuit configuration when snapped to (powered) microcontroller.

resistance or voltage?" Teachers liked the simplicity of the snaps and the durability of the fabric, discussed how the layout and tactile form factor of Snappable Sensors might foster collaborative design and creativity in their classrooms, and appreciated the systems' real-time data visualization capabilities. The engineering teacher mentioned that "these would be perfect" for a project where the students investigate temperature change of miniature solar houses. They recommended the creation of more kinds of sensors—accelerometer being the most requested—and the alternate/additional use of silicone as a base for future prototypes, in order to create a water-resistant data-collection platform.

Conclusion and Future Work

The overall response to Snappable Sensors was positive. Our biggest takeaway was identification of educators' desire for cheap, durable, and simple STEM-oriented classroom tools—especially those that enable students to independently collect, analyze, and discuss real-world data of interest. Moving forward, we plan on interviewing both STEM and non-STEM teachers, exploring the scope of sensor adoption across multiple learning contexts, including art and art therapy classes.

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References

1. Stamatina Anastopoulou, Mike Sharples, Shaaron Ainsworth, Charles Crook, Claire O'Malley, and Michael Wright. 2012. Creating personal meaning through technology-supported science inquiry learning across formal and informal settings. *International Journal of Science Education* 34, 2: 251–273. https://doi.org/10.1080/09500693.2011.569958
2. Paulo Blikstein. 2013, June. Gears of our childhood: Constructionist toolkits, robotics, and physical computing, past and future. In *Proceedings of the 12th International Conference on Interaction Design and Children* (IDC '13), 173–182. https://doi.org/10.1145/2485760.2485786
3. Leah Buechley, Nwanua Elumeze, and Michael Eisenberg. 2006. Electronic/computational textiles and children's crafts. In *Proceedings of the 2006 conference on Interaction Design and Children* (IDC '06), 49–56. https://doi.org/10.1145/1139073.1139091
4. Yasmin B. Kafai. 2016. From computational thinking to computational participation in K–12 education. *Communications of the ACM* 59, 8: 26–27. https://doi.org/10.1145/2955114
5. Leyla Norooz, Matthew L. Mauriello, Anita Jorgensen, Brenna McNally, and Jon E. Froehlich. 2015. BodyVis: A new approach to body learning through wearable sensing and visualization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 1025–1034). ACM. https://doi.org/10.1145/2702123.2702299
6. Kylie Peppler and Diane Glosson. 2013, October. Stitching circuits: Learning about circuitry through e-textile materials. *Journal of Science Education and Technology* 22,5: 751–763. https://doi.org/10.1007/s10956-012-9428-2
7. Chris Rogers and Merredith Portsmore. 2004. Bringing engineering to elementary school. *Journal of STEM Education: Innovations and Research* 5, 3: 17.
8. Katie H. Taylor and Rogers Hall. 2013, July. Counter-mapping the neighborhood on bicycles: Mobilizing youth to reimagine the city. *Technology, Knowledge and Learning* 18, 1: 65–93. https://doi.org/10.1007/s10758-013-9201-5