Supporting making online: the role of artifact, teacher and peer interactions in crafting electronic textiles

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Abstract

Purpose – The purpose of this paper is to report changes when a classroom-based makerspace moved from face-to-face to an online setting.

Design/methodology/approach – To better understand changes in teaching maker activities, as they move from face-to-face to online contexts, the authors analyzed video and interview data from six weeks of an introductory computer science high school classroom (38 youth) that was implementing an electronic textiles unit, shifting to asynchronous online teaching and learning during the March 2020 state-wide school closure because of the pandemic. The authors analyzed field notes and videos of face-to-face and online interactions between the teacher and his students in learning to craft and code their electronic textiles projects.

Findings – The analysis revealed changes in the role of physical and code artifacts, in improvising teaching, and channels for communication between the teacher and students.

Research limitations/implications – This study discusses the implications for future pedagogical design and research efforts, as the authors continue to engage youth and work toward designing equitable learning opportunities with maker activities online.

This work was supported by a grant from the National Science Foundation (NSF) to Yasmin Kafai (#1742140). Any opinions, findings and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of NSF, the University of Pennsylvania, Utah State University, or California State University, Northridge.

This article is part of the special issue, “A Response to Emergency Transitions to Remote Online Education in K-12 and Higher Education” which contains shorter, rapid-turnaround invited works, not subject to double blind peer review. The issue was called, managed and produced on short timeline in Summer 2020 toward pragmatic instructional application in the Fall 2020 semester.
Introduction

Makerspaces in libraries and schools now support learning among youth with a variety of computing-related activities (Halverson and Peppler, 2018; Lee and Phillips, 2018). Particularly popular are maker activities that involve robotic construction kits that allow youth to design and build robots (Blikstein, 2013a), Makey Makey that let youth realize physical interfaces for screen-based programs (Lee et al., 2014) and electronic textiles (e-textiles) that let learners connect microcontrollers to sensors and actuators by sewing them onto fabric and programming them to make interactive toys and artwork (Buechley et al., 2013). These maker activities help youth to connect with computing in new ways by integrating practices such as sewing and crafting and by using everyday materials such as paper and textiles that can diversify participation in making and computing activities (Halverson and Peppler, 2018; Jayathirtha and Kafai, 2019).

Research on making and makerspaces has extended our understanding of learning by emphasizing the role of materials, tools, mentors, and peers that differ from formal learning settings (Halverson and Peppler, 2018). Making activities and makerspaces provide a learning context with a focus on physical artifacts, running parallel to a constructionist philosophy of learning (Papert, 1980) and learning distributed across tools and people (Halverson and Peppler, 2018; Hutchins, 1995). Novice makers need a wide variety of support to realize products with different materials and electronic tools, an educational process, which, for the most part, has taken place face-to-face in physical makerspaces located in libraries, schools or community centers. Here, teachers, mentors, and peers have helped youth to learn circuitry, crafting, and computing (Ananthanarayan and Boll, 2020; Ball and Tofel-Grehl, 2020), while making personally relevant projects—an aspect crucial to supporting diverse youth interests and backgrounds (Blikstein, 2013b). Realizing physical artifacts—central to learning while making (Horn, 2018; Papert, 1980)—is often supported by shared physical spaces where youth, mentors, and teachers can see each other’s work, creating opportunities for teachers to help youth and for peers to collaborate (Fields et al., 2019). However, there have been far fewer investigations of making these physical computing artifacts online (Halverson and Peppler, 2018). Although online communities such as Instructables and DIY.org are a part of the maker culture (Martin, 2015), they do not provide the kind of scaffolded, social support for which educational settings have been designed (Margolis and Goode, 2016).

In this paper, we examine what happened when a classroom making e-textiles moved online and many of the affordances of physical makerspaces—access to physical artifacts, teaching in the moment and peer proximity—changed in not only format but also quality. Moving beyond the issue of access to internet and online platforms (not a given for many youth (Warschauer, 2004), though not an issue for the classroom in this study), several other concerns motivated our study such as students’ immediate access to support from either teachers or peers (Sawyer, 2011; Vossoughi et al., 2013). Furthermore, there are questions about how to translate the multi-modality of three-dimensional physical artifacts into the two-dimensional online screens, as youth seek support within these online spaces. As a case
in point to examine these issues of supporting making online, we analyzed six weeks of observational data from a classroom-based makerspace. In February 2020, a high school class with 38 students and their teacher began implementing an e-textile unit with four maker projects. The following month of March 2020, after two introductory projects in which students learned making and stitching circuits, the school closed in response to the COVID-19 pandemic and continued e-textile projects online. Our comparative analysis focused on understanding three key aspects in supporting maker activities: the role of artifacts, teachers, and peers. In the discussion, we suggest next steps for design and research to support making within online spaces.

Methods

Context
The study was conducted in a high school class at a public charter school located in a large city on the US west coast. The teacher, Ben, who has over ten years of teaching experience, was teaching an e-textile curriculum for the sixth year for a class of 38 youth (19 males, 13 females and 6 declined to state gender; 21 belonging to ethnic groups underrepresented in computing: African-American, Hispanic, Native-American, Pacific Islander or combinations of these; 35 consented to participate in this study).

This class was implementing the e-textile unit (Kafai et al., 2019) within the Exploring Computer Science curriculum (Goode et al., 2012) during March 2020 when the school suddenly moved classes online in response to the COVID-19-related district-wide school closure. For the initial three weeks online, the youth participation was optional and the workload was no more than 3 h per week to provide them with enough time to adjust to this new mode of teaching and learning. Ben, with no extra time to specifically prepare for online instruction, chose to organize his classes asynchronously during these three weeks.

Data collection
The data includes field notes, teaching videos and video-recorded debriefing interviews with the teacher across three weeks of face-to-face teaching (5 days per week, about 50 min each day) before moving online, as well as weekly teacher interviews, teaching materials (e.g. worksheets and instructional videos; about 30 min videos each) and student work from the first three weeks of online classes.

Data analysis
In the first phase of analysis, field notes from face-to-face classes were compared with the online teaching materials to identify days when Ben taught similar concepts. In the second phase, the first author generated multimodal, annotated transcriptions of all the lessons selected in Phase I to holistically capture “the social and material embeddedness of human interaction and meaning-making” (p. 286, Pea, 1994). This included enriching textual transcripts with relevant screenshots and annotations with details regarding teacher practices such as gestures, visibility of teacher work, and other contextual information. The third phase of analysis entailed generating descriptive cases (Yin, 2017) of teaching episodes within each context and comparing them to identify changes in how the teacher and youth interacted with each other across the contexts. Findings from this comparative analysis were iteratively shared and discussed with the three authors until consensus was reached. In the final phase of analysis, the findings were member-checked by Ben, the participant teacher.
Findings
Our analysis revealed how moving making online changed interactions between Ben and the youth by shifting the role of physical and code artifacts, opportunities for improvisation within teaching, channels for providing student feedback, and encouraging learning from peers.

Physical and code artifacts in maker activities
One important shift was in the availability of whole e-textile artifacts (i.e. both circuits and associated code) as centers of joint learning and problem-solving during student–teacher interactions around comprehending code and solving errors. Within the face-to-face setting, these interactions were mediated by entire physical computing objects (circuitry, craft and code as a part of a single system), but in isolated online interactions, text-based computer code took center stage. For instance, in the face-to-face setting, Ben and his students jointly observed the code execution in e-textile artifacts, e.g. comparing the different parts of the code with lighting patterns as demonstrated by the physical artifact. As an example, a pair of students requested Ben’s help in understanding the functionality of certain starter code. The shared physical space and synchronicity allowed Ben to stand by their side asking questions, guiding their attention to specific lines of the code and encouraging them to run the code and observe the artifact behavior to explain the role of that particular line of code (Plate 1). This allowed both Ben and the students to engage in conversations about code with respect to the physical artifact behavior.

In contrast, most online asynchronous interactions focused entirely on code text and circuit drawings, with the teacher struggling to support students with hardware-related concerns. With respect to debugging projects, Ben left comments in Google Docs asynchronously and students responded with revisions. One advantage to this mode was that student struggles with programming constructs were more pronounced to Ben as compared to the face-to-face context (discussed more further). However, the invisibility of physical projects and the lack of synchronicity limited Ben’s ability to support students as they reported hardware-related struggles, which continued to hamper student participation.

Plate 1.
Ben, guiding Nole and Leah to understand aspects of the code in relation to the artifact during one of the face-to-face classes.
online for weeks (e.g. dysfunctional circuitry). In other words, the asynchronous online interaction limited the mediating devices between the teacher and students to static circuit drawings and code and made physical artifacts less openly available for shared learning (Hutchins, 1995).

These constraints in sharing entire e-textile artifacts further influenced the depth of inquiry in which Ben could engage students. Face-to-face, student questions or struggles led to inquiry-driven teaching practices around code execution. Ben often encouraged students to run the code and observe the artifact, guiding them to relate specific parts of the code to artifact behavior. Such joint attention between Ben and his students to the relationship between code and the tangible artifact provided opportunities for students to understand the dynamic nature of code by iteratively tinkering certain parts of programs and observing their implications on artifact behavior – an important phase of learning while making (Papert, 1980). In contrast, although asynchronous online engagement increased visibility of programs and brought to the fore student struggles with writing code, it led to fewer conversations related to the whole artifact: either the crafting, circuitry, or the runtime behavior of code in terms of the artifact. Lack of physical artifacts alongside code in addition to the asynchronicity online led Ben to suggest procedural changes to code (Figure 1) in comparison to engaging students in inquiry around code execution face-to-face.

Opportunities for improvising explanations
Yet another revelation with moving maker activities online was the qualitative difference in opportunities to improvise teaching, a key equitable teaching practice within making (Sawyer, 2011; Vossoughi et al., 2013). In face-to-face interactions, Ben generated explanations loaded with gestures and explanations co-developed with students, in addition to highlighting corresponding parts of code while live coding on the projector visible to the whole class. For instance, taking a cue from a student referring to LED lights as outputs, Ben built on it and introduced the concept of inputs and outputs. He positioned himself at the center of the classroom, soliciting definitions for output and input devices, projecting relevant a part of a starter code and zooming in on the relevant lines to show the code underlying input and output devices. Based on a few students’ explanations of the code on the projector, he enacted electric signals and gestured “reading” and “writing” signals (Plate 2).

Online, Ben had qualitatively different opportunities to improvise, as he was limited to on-screen tools and text-based, asynchronous interactions with students. Introducing a new concept online often took the form of pre-recorded videos with circuit drawings and static code texts. A lack of shared space and time further constrained opportunities to
spontaneously build on student ideas to improvise or develop explanations. Instead, as in one of the videos, he drew on analogies – printers as output devices, keyboards as input devices – to make connections with the input/output concept. This was based on his prior knowledge of student understanding and experiences, an attempt to make up for the lack of feedback from student responses. Overall, though the face-to-face space allowed the teacher to improvise in the moment with just-in-time ideas (Vossoughi et al., 2013), the online space drastically constrained his ability to observe and respond immediately to the class.

Identifying naive ideas and structuring feedback

Online, the archived, individual submissions increased visibility of the students’ development of programming concepts but restricted avenues for feedback from both the teacher and fellow students. In the face-to-face setting, opportunities to identify student struggles were distributed across space and time; they emerged either when students came to Ben for clarifications or when he noticed their struggles while walking around the class, especially when similar misconceptions surfaced across a sizable proportion of students. For instance, Ben once repeatedly observed students’ ineffective use of variables – using an excess number of variables in the place of constant values while programming light patterns – when they walked to his desk for clarifications. Noticing this, he asked for the whole class’ attention and live programmed on the projector, making his work and thinking visible for the entire class at once. Further, the distributed nature of the physical space allowed students to get feedback and learn from each other. Ben directly facilitated this peer feedback by providing opportunities for students to interact with and learn from each other, for instance, allocating time and structuring the same for student pairs to view each other’s code and discuss their observations.

In contrast, although the online context afforded higher visibility of patterns across students’ code, all the feedback students received were limited to Ben’s comments, hardly allowing him opportunities to structure peer interaction and learning. From version histories of student programs, Ben identified student struggles with specific programming concepts as well as observed patterns across students. For instance, he noticed that most of the students used the actual alphanumeric pin numbers as printed on the microcontroller board in the place of numbers or variable names in their code. Despite this visibility of individual understanding across students, Ben’s written feedback was individualized to students. Ben

Plate 2.
Ben stretches his arms out and enacts “reading signal” while highlighting the corresponding line of code on the projector.
repeated himself frequently across students and bemoaned missing opportunities for the whole class to learn together as a community. There were few (if any) opportunities for peers to see each other’s work or to learn from and support each other, a core pedagogical practice used across many e-textile teachers (Fields et al., 2019). Overall, the online environment increased the visibility of conceptual learning across students over time, but constrained Ben to providing individual student feedback in comparison to opportunities afforded by face-to-face interactions for whole class conversations and peer interactions.

Discussion
Moving online from face-to-face revealed changes in ways we can engage youth in maker activities. On the positive side, the online environment made text (i.e. computer code) more visible and provided opportunities for the teacher to better learn about student conceptions and give individual, iterative feedback. However, such text-mediated interactions simultaneously reduced one-on-one communication to issues around coding ideas more easily accessible through computer screens and static program texts. The lack of shared physical space, time, and artifacts limited opportunities for emergent, improvised teacher–student interaction and learning from peers, practices key to promoting equity in maker education (Fields et al., 2019). Based on these observations, we suggest directions for future design and research efforts, as extended closure of face-to-face learning settings pushes teaching and learning making online.

Designing for integration of physical artifacts
For electronic maker activities, physical artifacts are as important as the corresponding computer code. Though sharing and discussing physical artifacts and their code together is easier in face-to-face settings, there is a need to design environments to better support joint attention on whole artifacts online. One approach could be to invite youth to make videos of working artifacts to accompany their code. Other approaches might include block-based programming to shift attention away from syntax errors or representations that show code outputs on simulated artifacts (i.e. online applications showing digital representations of circuit and code outputs). Such practices can better use the innate dynamicity of maker activities and, at the same time, bring greater visibility to the personal connections and stories embodied in students’ artifacts—a key aspects integral to creating equitable learning opportunities within making activities (Blikstein, 2013b; Fields et al., 2018).

Designing for equitable teaching and learning
In addition to foregrounding artifacts, making room for improvisations while teaching and supporting peer learning are needed to further equity while making online (Vossoughi et al., 2013). Online teaching centered around screen-shares of code limit opportunities for joint attention and teacher improvisation. Designing dynamic, multimodal media for asynchronous online learning can support teaching and learning during difficult times by allowing flexibility and accommodating personal situations. Further, providing opportunities for peer collaboration is key to supporting diverse learners (Fields et al., 2019); however, platforms currently used for online teaching and learning in the K-12 system (e.g. the Google Education Suite) lack features to engage learners collaboratively. Intentional designing for collaboration within asynchronous online environments should include features that support dialogic communication such as live notifications that minimize time between postings and that make room for collaborative work by providing joint annotating or note-taking spaces—difficult to realize when environments are designed for more individualistic communication. Further, designs can draw lessons from existing online
communities such as Scratch that make individual ideas visible and invite participation while building an ethos of respect, creativity, and communal learning within the asynchronous online environment (Resnick et al., 2009).

**Researching within online spaces during a pandemic**

In addition to shifts in teaching and learning, our experience of suddenly moving research online required redesigning data collection methods to strike a balance between research needs and the ethical and political concerns around the usage of various online tools and platforms. Unlike face-to-face settings that allowed for capturing a broad variety of data using traditional instruments such as videos from multiple perspectives and repeated conversations with the youth and the teacher, collecting data online requires reimagining to account for the affordances and constraints of online environments. In many instances, safety and privacy concerns limit students’ ability to speak or show themselves online through live audio and video (i.e. limited by school and the teacher union policies). In these situations, data collection must shift, as casual conversations about students’ conceptual understanding in the moment are not possible. Strategies such as introducing journal entries, integration of process-based portfolios, or frequent but short quizzes on student understanding may help to better integrate data collection instruments with existing practices within the learning space (Seylar, 2020). The response to the COVID-19 pandemic – even as we write – continues to be in flux; teachers across the world are adjusting every week to the fully online mode of teaching and learning. This provides new opportunities to develop modes of teaching, learning, and researching that may have broad influence in future years.

**Conclusion**

Moving maker activities from face-to-face to online spaces challenges teaching practices that rely on easy access to tangible artifacts, improvised teaching, and casual peer interactions. To support maker activities online, we need to rethink online tools and teaching practices to support multimodal views of artifacts, teacher and student improvisation, and to better facilitate peer interactions.

**Note**

1. This was complicated further by the inability of many students to run their code with incomplete e-textile artifacts that took longer to create and debug without the co-presence of the teacher and peers.

**References**


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