Blended Making: Multi-Interface Designs and E-Crafting with Elementary and Middle School Youth

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Abstract
Past efforts have demonstrated efficacy in broadening maker learning and participation by leveraging the material affordances and implicit presumptions associated with content creation tools. Past work has found that the purposeful integration of activities that blend multiple toolkits to create integrated designs [17;19;20] can both broaden the understanding of these affordances and demonstrate equitable and inclusive outcomes for adolescent youth. We illustrate early stage findings from an interaction analysis of the micro- and meso-level learning and collaborative processes that children and early adolescent learners engaged in throughout purposefully arranged multi-interface design projects to understand their agency and engagement over time and across activities.

Author Keywords
Multi-Interface Design; Integrated Systems; Making; E-Crafting; Paper Circuits; Electronic Textiles; Scratch; Coding; Physical Computing; Youth; Children; Collaboration; Equity; Inclusivity; Computational Thinking; Creativity; Interaction Analysis.

ACM Classification Keywords
• CCS ~ Social and professional topics ~ Professional topics ~ Computing education • CCS ~ Applied computing ~ Education ~ Collaborative learning; • CCS ~ Human-centered computing ~ Interaction design

IDC '18, June 19–22, 2018, Trondheim, Norway

ACM ISBN 978-1-4503-5152-2/18/06 $15.00
https://doi.org/10.1145/3202185.3210798

High School Curriculum iterated upon for this group of younger learners.

1	basic circuits, sewing; making buildable model 1 (BM1), basic e-textile game controller with the MakeyMakey & Scratch
2	Scratch remixing & coding (customizing BM1)
3	Lilypad Arduino (and coding with ModKit) to create standalone e-textile circuits (BM2)
4	Creating multi-interface (physically and digitally interactive) games with all tools (BM3), part 1
5	Prior Activity continued
	Design thinking, collaborative ideation of final projects; final projects and showcase (lessons 6-8)

Table 1: Lesson Breakdown of High School Workshop with buildable model curriculum [see, 19;20].

Introduction

Early efforts on making and learning focused on the promises of DIY and content creation for STEM innovation and creativity, particularly for youth learners [e.g., 2;10]. In recent years, the field has widened its focus to include its relevance to the arts and other forms of expression [16]. Drawing on the constructionism, researchers have been drawn to the democratization of content creation for both youth expression and increased diversity in computing [2;11]. In particular, researchers have focused on both the material and spatial ways we can broaden participation for underrepresented groups, such as women and people of color [3;12;13;18] and discussed the necessity of culturally-responsive and culturally-sustainable approaches as instrumental to formal, informal and interest driven education [15;21]. While some have proposed novel ways to integrate toolkits with different affordances, such as e-textile microcontrollers and content creation tools, to both engage and disrupt sociocultural preconceptions, and diversify arrangements of toolkits provided to create meaningful, collaboratively designed projects [17;19;20], many questions remain about the ways learners engage at different stages of the design process, and the affordances and limitations of different collaborative learning opportunities with different design practices. Moreover, we still have a limited understanding of the age applicability of different kinds of proposed learning activities. This iterative study sought to answer some of these lingering questions through a workshop designed to engage elementary and middle school learners in bidirectionally responsive making [17;19] facilitated through multi-interface design. The curriculum has shown tremendous potential, through its purposeful arrangement of maker tools, materials and activities to engage diverse interests and provide multiple entry points to different design practices and efficacies related to making [17;19].

This study helps us to better understand the individual learning processes and collaborative arrangements with different maker tools with different affordances on their own, and when implemented together for collaborative learning and design. We engage in the following research questions: How do age-blended elementary and middle school learners demonstrate individual and collaborative learning with multimodal tools and affordances? How do they engage STEM and non-STEM interests through the curriculum?

Methods

Participants and setting

Participants were 22 elementary (5th grade) and middle school (6th-8th grade) youth aged 10-13 participating in a making workshop offered over 3 days during an informal summer STEM camp in a rural part of the Northeastern United States. One student did not consent for research and 2 students did not return after the first day. The consenting students (N=21) were diverse in gender (12 boys, 9 girls), age (five aged 13, five aged 12, five aged 11, and six aged 10), and cultural background (13 White; 5 Asian; 1 African American; 1 Hispanic; 1 Multiracial). The summer camp was organized by a local science discovery center and facilitated by a librarian from the middle school where the camp was held. The camp had 4 adult volunteers who were there to assist with facilitation of activities but varied in their daily attendance. The activities occurred in a connected computer lab and crafting/hobby space. The camp occurred over one week at the end of the summer, 2 weeks before the school year began, and the workshop was a more structured activity during the last 3 days.

Curricular design and activity

The maker workshop had been taught twice before as part of an out-of-school learning experience for diverse early high school youth (aged 14-15) in a large city in the same state [17;19;20]. It was iteratively designed and taught by Richard (author 1) to purposefully blend content creation tools and activities so that learners were encouraged to engage in different crafting, coding, design and engineering activities, and collaboratively work together to create an artifact that is physically and digitally responsive [17;19;20] (see table 1). The

Revised Curriculum for Middle School Learners.

1	(Day 1) Expanded circuit lesson with child-friendly videos on circuits. Human circuit activity; groups of 4-5 embody different parts of a simple circuit. Learners draw paper circuits with *CircuitScribe* (n.d.)
2	(Day 1 / Day 2) Creating BM1 and Remixing and Coding in Scratch to customize
3	(Day 2) Lilypad Arduino (and coding with ModKit) to create standalone e-textile circuit (BM2)
4	(Day 2 / Day 3) Multi-interface, bidirectionally responsive games with all tools (BM3)

Table 2: Lesson Breakdown of Middle School Workshop.

Case Demographics.

CJ	M	11	Black
Corey	M	10	White
Hope	F	10	White
Rebecca	F	13	White

Table 3: Demographics.

foundational curriculum remained the same but was redesigned for the intended middle school audience. It should be noted that 27% of the actual camp consisted of 5th graders as part of a last-minute accommodation. The researchers found that the activities and tools helped implicitly scaffold team generation and role responsibilities with the group [19]. This updated curriculum was structured similarly, including the number of hours (16-18), which would occur over 3 days at 5-6 hours each day (see table 2). The paper circuit activity served to both reinforce how sensors, actuators, power sources and loads connect, and teach them how conductive inks and threads act like live wires without insulation (i.e., cannot cross traces without shorting the circuit). Further, the handouts were redesigned to contain easy-to-follow visual references for each part of the activity. Finally, we attempted to bridge buildable models 2 and 3 so learners could easily move from a standalone e-textile to a bidirectional design.

Data sources
We video taped observations, using wide-angle and close-up cameras operated primarily by two team members. We also utilized think aloud protocols to elicit learners' reflections scaffold their problem solving. In addition, we collected pre- and post-surveys of (1) demographics, (2) experiences with activities and tools before/after the workshop, (3) attitudes/perceptions toward careers and school subjects, teamwork, "making," and (4) self-efficacy toward computing, crafting, coding, and circuits. We report on early stage analyses of 2 case study groups.

Methodology
This is part of a longitudinal design-based research project on the affordances of purposeful, collaborative multi-interface design. For analyzing the observational data, we utilized micro-analytic techniques [1;8] to understand individual and team engagement in activities temporally. Specifically, we looked for themes around microgenetic (e.g., specific activities) and mesogenetic (activities over time) systems that learners engaged with [14]. Team members reviewed the corpus of video collected over the 3-day workshop and negotiated cases utilizing analytic induction [1] with close attention to the research questions. We focused on salient pairings that serve both as our first point of progressive hypothesis refinement [8] and as a point of comparison with the overall descriptive processes at work [9] (e.g., same gender dyad teams, age variability in groupings). We focus on the "thick descriptions" of interactions, and our first cycle [8] themes. We further reflect on our own practices, including ourselves in the data as follows: LWF, lead workshop facilitator, (Richard); and MWF1-3, (Giri, Ashley, McKinley) Male Workshop Facilitators 1-3.

Cases
Hope and Rebecca: Paper Circuits
The following vignette follows detailed interactions between Hope and Rebecca as they collaboratively engaged in paper circuits with conductive ink (early lesson activity). Rebecca did not have prior experience with circuits and Hope may have worked with circuits before but she could not recall the experience, as indicated in her survey and during think alouds. This particular interaction segment was chosen because it provided a closer look at agency and resiliency during collaborative learning activities, and individual and shared computational thinking processes, such as experimenting and iterating. It also provides a deeper observation of the kind of mentor-mentee relationships that can ensue with child/adolescent pairings (aged 10 and 13). As the campers divide up into groups to work with Circuit-Scribe, Hope and Rebecca can be found in a pair working closely together on their designs. Rebecca is leaning over, angled close to Hope while Hope is performing the actions. Hope positions the last piece - the battery (fig 1a). When Hope finishes adding all of the components and turns on the switch, they look closely, trying to figure out why it isn't working. Rebecca points to the battery that now has a red light glowing and quietly exclaims, "Oh," while her body remains positioned toward Hope, and she speaks to her calmly, "Oh something went wrong… there is a short circuit

Figure 1: Hope (left) and Rachel (right)working on paper circuits; a-f, top to bottom.

right now…" Hope acknowledges softly, "oh," and mirrors Rebecca, touching the red light on the battery (fig 1b). "…So what do we do about that?" Rebecca prompts, staying by her side, leaned in close. "Do you know what we do about that?" Rebecca prompts again encouragingly. "Wait, wait, wait let's try switching them around," Hope suggests, picking up the battery and flipping it around, then moving the battery to where the switch is and vice versa. However, the red light goes on again. After a few moments of quietly observing as they troubleshoot, MWF2 comes over and probes gently, "so, walk me through how it's supposed to be working." Hope starts softly, "Ummm…" Rebecca jumps in, her voice now more assertive as she addresses the facilitator, "How it's supposed to be working is - it goes through the battery and stops at the switch and when I turn the switch on it lights up the LED." She demonstrates by turning the switch off and on to which the battery's red short circuit light turns off and on. The facilitator probes deeper, "How does the electricity move through the battery to the switch?" Rebecca thinks for a moment while Hope looks at the circuit then quickly at her and then MWF2, and back to the circuit. Rebecca reasons, "It moves through the - um - conductive pen ink that was in the pen and we draw the lines." MWF2 probes again, inquisitively, "Did you draw all the lines?" Hope responds, "We drew three of them… but it didn't go to here." Hope points to the other side of the LED, which does not have a conductive trace connecting it to the rest of the circuit (fig 1c). Rebecca interjects, suggesting, "We didn't put it here because it would only circle around itself and not to the LED." She picks up the LED and traces a line with her finger between the two dots under the LED (fig 1d). MWF2 acknowledges but also indicates hesitation, ("Umm… Okay") and pauses while they troubleshoot. Hope thinks deeply, holding her chin with her hand, "So…." (fig 1e). Rebecca suggests that it may just need to be lined up better, attempting to realign the connections with Hope (fig 1f). After a pause, the facilitator nudges, "so…you might try that extra line there." Hope pauses then responds affirmatively. Rebecca asks her quietly, "should we?" Hope responds assertively, "…Let's see if it works." When MWF2 leaves, Hope starts drawing the additional line while Rebecca observes.

CJ and Corey

During the second day of the workshop, the learners have stared modifying BM2 into BM3. The following vignette follows the interaction of CJ and Corey as they engaged in making buildable model 3, a bidirectionally responsive wearable game and controller. In this group, CJ had prior experience with Scratch and basic circuits from a prior camp but did not have prior experience with the other activities and tools. Corey had previously worked with circuits at his "dad's job" (in engineering) and had prior experience with java coding; he had also learned how to sew from his godmother. Like CJ, he had not worked with other activities and tools, such as e-textiles and the MakeyMakey. This particular segment was chosen because it showed the individual learning processes and group dynamics of similar aged learners (11 and 10). CJ has taken on the role of Arduino coder, showing strong perseverance and computational thinking processes. He has engaged in extensive troubleshooting, feeling it is ready to bring to Corey, who has taken on the role of sewer and crafter for the project. Corey has demonstrated prowess in sewing, proudly taking a central position in the crafting room where many other campers have come to him for help. CJ brings LWF over to the crafting room, where he has assembled the project so they can build the final design. LWF inquires, "Okay and what ... what's it supposed to be doing according to your program?" LWF is sitting back while CJ leans in to look closely at his project, "shouldn't the buzzer be buzzing?" He starts touching the conductive tape connected to one of the pins. LWF affirms, "Yeah, well remember when we were playing with the MakeyMakey? What did we have to do to make both… work?" She opens her arms to the side to emphasize an action but does not complete it. CJ is touching the vibration actuator for the Lilypad, leaning in closely to the microcontroller and circuit (fig 2a). "Wouldn't I need to hold something?" CJ asks. LWF

Figure 2: CJ (right) and Corey (left) working on Buildable Model 3 (BM3); a-e, top to bottom.

confirms, extending her response as if to signal another question. Corey comes over during the exchange, "It would need to be conductive." LWF affirms and probes, "So it's conductive, but… Remember when we were doing the collaborative gloves [BM1], what did you do?" She again holds out her arms. Corey is still looking closely at the circuit, "And this also needs to be on." He touches the conductive tape again. LWF touches the pieces of conductive tape, "Yeah, that's a good point. It's still not working... but I'm going to give you a hint." Corey looks up from his sewing, his mouth open (fig 2b): "Oh, you need a ground." LWF smiles and whispers, "Yeah." She nods her head slowly at Corey and looks back and forth at the two of them, "connected with an alligator clip to ground." Corey is still looking intently at the connections, "But how do we…? But where's ground on the Arduino?" As he is asking, CJ is already starting to point (fig 2c). LWF mirrors his actions pointing at the negative port on the Arduino. Corey has a moment of realization (fig 2d), "Oh, that makes sense!" LWF and MWF3 start helping them consider the next steps. CJ is thinking deeply with his hand still on his chin (fig 2d), "So I need ... so I need three buttons?" LWF realizes the problem he is trying to solve, and prompts, "Well these are two buttons but we need to close the circuit." She touches each of the buttons and starts mimicking the action of the wearable controller, touching where each piece would be, as had been shown to them in the handouts: "When you looked at the mitten pattern and then you go like this…" CJ is looking where she is directing her actions, and has a moment of realization (figure 5e), "Oh yeah." He heads over to the computer room to get the supplies and Corey continues sewing.

Discussions and Conclusions

In our analyses, we see that different activities have different effects on learning and collaboration. For example, Hope, one of the youngest learners, engaged deeply with paper circuits in ways that we did not see later with e-textiles, though this did not hold true for Corey, who was highly invested in crafting. Hope was originally perceived as disconnected from the activities, but the close examination of their work with paper circuits demonstrates that she was strongly engaged in resilient practices and computational thinking. In particular, she demonstrated strong conceptual and procedural understanding of circuits and conductive traces, though she hesitated to correct her more vocal teammate, Rebecca. Conversely and by delving deeply, we were able to see that Rebecca's extroversion was protective as opposed to supervisory. Hope often shied away from a direct spotlight, and Rebecca served as an engaged mentor who encouraged Hope's centrality in the activities, even deferring to her direction while also guiding through inquiry-based questions. On the other hand, CJ and Corey, though working apart most of the time, were persistent in honing their skills and interests, and contributing meaningfully to their aspect of the design. Corey was the most versatile in his gendered expressions of interests. He came from a strong family of coding and engineering professionals, but he demonstrated primary interests in sewing, particularly once working on a multi-interface project. By looking at micro and meso interactions, we have a snapshot of the possibilities fostered through bidirectionally responsive projects. We also find that, for some learners, peripheral participation with certain activities in isolation can help them traverse social and developmental complexities or develop agency and identity to assist with more sustained learning efforts. This work extends previous work by providing a framework to help better understand the learning and collaborative practices at play as learners purposefully integrate various maker tools to create civically-minded or personally meaningful designs [20]. Future directions will expand on learners' trajectories over time to have a more nuanced and holistic understanding of these processes as fostered through different toolkits, activities and arrangements.

Acknowledgements

This study was approved under STUDY00007092 (PI, G.T. Richard), and has been partially supported by Penn State and NSF under #DGE1255832. Any opinions, findings or recommendations are the author(s) and do not necessarily represent the funders or university.

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