Collaborative Maker Activities in the Classroom: Case Studies of High School Student Pairs' Interactions in Designing Electronic Textiles

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ABSTRACT

The majority of electronic textile (e-textile) activities for beginners focus on making and coding individual projects rather than collaborative designs, which often excludes potentially fruitful collaborations. In this paper, we report on findings from an e-textile workshop in which high school youth (16-17 years old) worked in pairs to design interactive display pieces using LilyPad Arduino, LEDs, sensors, conductive thread and fabric. Drawing on artifacts, fieldnotes, and interviews, we report on the range of work approaches that students took toward collaborative e-crafting. Specifically, we examine key aspects of this collaboration: pairs' role negotiations and communication strategies. Finally, we discuss the challenges and opportunities of adopting collaborative e-crafting when introducing coding and making activities in classrooms.

CCS Concepts

K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer science education*; K.8.0 [**Computers and Education**]: General – Tangibles.

General Terms

Human Factors

Keywords

Electronic Textiles, Novice Programmers, Collaboration, LilyPad Arduino

1. INTRODUCTION

The maker movement in education has begun to transform the ways in which we conceive of learning and pedagogy [5]. While much of this work is generally focused on out-of-school learning sites [10], there is a growing interest in integrating maker activities into formal learning environments [4]. One example of a maker technology that holds promise within formal educational settings is electronic textiles (hereafter e-textiles) wherein circuits are sewn with conductive thread instead of wires [2]. Several studies document how students engage with multimodal learning through design, craft, circuitry, and computation practices within e-textiles activities [6, 7].

While studies of learning with e-textiles have generally emphasized individual, rather than group, designs, we posit that this underdeveloped field could benefit from more collaborative approaches, including the pair programming model drawn from computer science education [9]. Building on previous work [8] in which we investigated less successful collaborative arrangements of small teams of three to five, in this paper, we focus on pair arrangements of two students for e-textiles designs within a high school workshop. We report on these findings here, and discuss potential opportunities and challenges in setting up pair e-crafting arrangements within classroom setting.

2. BACKGROUND

Maker activities in out-of-school contexts draw heavily on collaborations between participants to support their learning and completion of designs [10]. However, these collaborative designs, often interdisciplinary and multi-modal, are usually exceptionally complex. As such, they introduce a host of new challenges as well as opportunities for learning. While we previously adopted the team-based learning arrangement successful in robotics learning [1,9] within an e-textiles workshop [8], that study indicated how these teams of 3-4 students were not a particularly productive learning arrangement despite role distribution being modeled by instructors.

One possible alternative to these team collaborations is the pair programming model, drawn from computer science education, which involves smaller teams of two students [9]. Here, student interactions are highly structured by outlining specific roles and tasks, modeling communication, and prescribing role-sharing techniques. While first introduced on the college level [for review, see 9], pair programming has also been found successful in K-12 settings [3, 11].

Given these documented successes, we adopted the pair programming approach for e-textiles, calling it pair e-crafting. As a first step to understand how this arrangement can function in a hybrid design space, which involves coordination across different domains including design, crafting, circuitry and coding, our research focuses on the different role distribution and communication strategies observed within student pairs. Particularly, we investigated not only how pairs negotiated their roles but also what communication strategies they employed throughout this process. This investigation is therefore guided by two research questions: (1) What are the features of a pair e-crafting learning arrangement? (2) Which of these might lead to

DOI: http://dx.doi.org/10.1145/3003397.3003408

more productive collaborations and learning within the multi-modal context of e-textiles?

3. CONTEXT

3.1 Site and Participants

We conducted this study with 23 high school juniors (4 boys, 19 girls, 16-17 years old), who were STEM majors, at a charter school in a northeastern metropolitan city. The class represented the demographics of the school: 44% Black, 35% White, 13% Hispanic, and 3% Asian and 3% Multi. Most students (n=18) had completed an introductory e-textiles project in the previous academic year [8], but six were new to the major and encountering e-textiles for the first time. The classroom teacher and graduate research assistants acted as the joint instructors for the workshop.

3.2 Design of e-Textiles Workshop

This collaborative e-textiles workshop was held in Fall 2015. Over fifteen 90-minute class periods, students collaboratively constructed an interactive sign that would be exhibited within the school. Before the workshop, the teacher put students in pairs aiming to balance skills and expertise, personality traits, and existing friendships. As we aimed to capture their naturalistic responses to working in pairs, we gave minimal guidance and structure for how students should work together.

During the workshop, each pair was assigned a canvas print design of a letter, which was created by an art major peer at the same school. Collectively the letters spelled out the school's name. Pairs were additionally provided with e-textiles components including a LilyPad Arduino (a sewable microcontroller), LEDs (or lights), sensors, switches, and conductive thread. The assignment was to make their design interactive, such that observers could trigger four different light patterns, activated through interactions with the switch and sensor sewn onto the canvas.

Through the workshop, student pairs were guided through a multi-step design process. In Phase One, pairs primarily dealt with *design* and *circuitry*. This included decisions about the concept, usability, and aesthetics of their projects, as well as the construction of their circuit diagrams (i.e., connections between components). During Phase Two, pairs executed their design ideas. This included *coding* the Arduino program that controlled the light patterns and interactions, and *crafting* the physical object by using conductive thread to sew components into the circuits.

3.3 Data Collection and Analysis

We collected a range of qualitative data focused on how pairs interacted as they were collaboratively designing and constructing their e-textile projects. In addition to photo documentation of the pairs' artifacts over time, we also video recorded four of the twelve pairs over the course of the nine sessions. Two instructors and one research assistant also took fieldnotes for each day. Before and after, we also conducted individual interviews with all the students. Drawing from our understanding of peer programming collaborations, we sought to explore pairs' different approaches toward role distribution and communication through the project. We thematically coded the post-interviews, fieldnotes, and artifact photos and also wrote analytic memos based on these two themes. Below, we report on the different approaches that we identified, as well as how these generally impacted their productivity and progress.

4. FINDINGS

Because we did not explicitly model ways of working collaboratively within the workshop, different student pairs within the class ended up having differing approaches toward role and task assignment, as well as communication with their partners. As we illustrate, these factors seemed to influence the productivity of the pairs in terms of how well they were able make decisions, troubleshoot, and complete their projects.

4.1 Role and Task Assignment Approaches

Here, we report on the divergent approaches toward role and task distribution that we observed within the class. Within e-textiles, there are four distinct domains of activity that are required for the construction of a functional project, including design, circuitry, coding, and crafting. These domains not only require different skills and knowledge, but also involve different activities. As such, each pair was required to organize and divide these different tasks amongst the partners. Different pairs took on different approaches to this distribution. Similar to our prior study [8], these ranged from *individualistic*, wherein each member primarily focused on a single role (and hence, domain), to *collectivistic*, wherein pair members were involved in multiple roles and domains simultaneously. As described below, most pairs ended up moving from more collectivistic to individualistic approaches over the course of the workshop, though to differing degrees.

During the first phase of the workshop focused on aesthetic and circuit design, almost all the student pairs adopted more collectivistic approaches, consulting with each other on both the visual and functional aspects of the design. In some sense, this is due to the inherent nature of e-textiles design; that is, when considering the placement of electrical components (lights, switches, sensors, LilyPad Arduino) based on aesthetics, it is also necessary to consider if this allows for functional circuit connections. Thus, pairs generally worked collaboratively to make these decisions, working to balance aesthetics alongside functionality, as well as ease of construction.

During the second phase of the workshop focused on crafting and coding, student pairs generally shifted toward more individualistic approaches. The one exception was Joy and Caroline, who adopted an explicitly collectivistic approach, with each partner working on half the required sewing and programming. All other pairs, however, began with one partner acting as the 'sewer,' and the other as the 'programmer.' As with phase one, this individualistic approach was likely based the inherently distinct nature of coding and crafting: while the former is based 'on the screen' interactions, the latter involves tangible materials. As described by students, decisions about who would take on a role was not only based on prior experience, but also personal interest.

The degree to which pairs stuck to this individualistic approach, however, varied over time. While a few pairs never engaged with their partner's efforts, others had a more active involvement with the project as a whole, as well as the different domains and tasks required. Adam and Evonne, for instance, generally stuck with their initial roles (as programmer or sewer, respectively), but also enthusiastically engaged with each other's efforts. For instance, whenever Adam would code a new light pattern, he would show it Evonne and ask for approval. Because of this collectivistic approach, both partners became comfortable dealing with the multiple domains of e-textiles, something that enabled them to more successfully troubleshoot their project. An illustration of this came toward the end of the workshop, when we noticed that they had not yet added touch sensors to their project. They were

immediately able to address this issue, though, because of their joint familiarity with circuitry, coding, and crafting.

Conversely, pairs that maintained a more individualistic approach toward the work generally lacked this multi-domain comfort, and thus tended to have more issues. One such pair was Jasmine and Melanie. While Jasmine was well versed in coding and Melanie in crafting (both assisted others pairs in the class with these skills), they often ran into problems within their own project, which neither could solve with their isolated knowledge or abilities. These included incorrectly connected LEDs, and a program that did not match with the existing circuit. Because of this, they generally required extra assistance from instructors in order to complete the project.

Thus, while almost all the student pairs moved from more collectivistic to individualistic approaches over time based on the inherent nature of e-textiles activities (i.e., design and circuitry as more naturally integrated, and crafting and coding as not), those that actively worked to maintain collectivistic tendencies throughout the workshop tended to be more productive. Not only were they able to produce more effective designs because of their multi-domain familiarity, but also to recognize and respond to problems more swiftly. On the other hand, pairs that adopted more individualistic approaches had much more difficulty adjusting to in-the-moment issues, suggestions and/or changes because of their siloed base of knowledge and skills. As will be discussed below however, sometimes these issues could be mitigated by a more supportive communication style.

4.2 Communication Style Approaches

Of equal importance as role negotiation and distribution are the communication strategies employed by pairs throughout the e-textiles design process. Though the teacher attempted to match students by personality and existing friendships, the resulting communication levels between pairs—ranging from *supportive* to *inhibitive*—varied widely.

As is perhaps expected, pairs that adopted more collectivistic strategies toward roles and tasks tended to adopt more supportive communication styles. Within our characterization, this strategy describes partners who actively informed and consulted one another about their individual work, as well as the overall progress and design of the project. This does not necessarily mean, however, that teams with these supportive communication styles were always harmoniously engaged. Adam and Evonne both mentioned how their constant communication and interaction would often lead to disagreements and fights. In describing this, Adam stated: "It was challenging because sometimes your idea wasn't fully being respected". However, he added: " But the good side of it was that you had someone to help you, you weren't alone, you didn't have to stress." (Interview, 12/1/15). Thus, while constant consultation and decision-making could lead to tension, both partners generally considered to as necessary to the work of collaboration and overall productivity.

Along with assisting more collectivistic-oriented partners, the supportive style of communication also worked to mitigate the potential issues within more individualistic pairs. This can clearly by seen by comparing Melanie and Jasmine, with Mia and Matt. While both pairs maintained very distinct roles, they significantly differed in terms of their communication styles. Melanie and Jasmine generally adopted a more inhibitive approach toward communication, both in and out of class. While both were present, they often would work independently, sitting on opposite ends of the table, wearing headphones. Additionally, one partner would occasionally leave to chat with friends, or even put her head down for a 'nap'. This lack of communication also continued during Melanie's repeated absences. While numerous other pairs actively dealt with class absences by calling or even Facetiming their missing partner, Jasmine made no attempts to keep in touch with Melanie. When asked about how she would update Melanie on the progress of the project, Jasmine responded: "She figured that out on her own when she come back, because each time she'd come back something is improved" (Interview, 12/4/15). Likewise, Melanie was not interested in consulting with Jasmine after returning. This was something that actively caused problems, for example, when Melanie did not ask Jasmine about changes in the circuit diagram and consequently incorrectly attached lights to the canvas. In general, this exacerbated their ongoing productivity problems, and led to feelings of disengagement surrounding the project, as well as resentment toward each other, despite the fact that they were friends.

Mia and Matt, on the other hand, had a more supportive style of communication, even though that they maintained their separate roles throughout the project (respectively, sewer and programmer). This pair also dealt with regular absences. However, both made efforts to keep their partners up-to-date on the project, whether communicating "as soon as we saw each other… in the hallways (Matt, Interview, 12/3/15), or right "before class started" (Mia, Interview, 12/4/15). Generally, this high level of interaction enabled them to stay on track when constructing their project; they were one of the first pairs to complete the assignment. Additionally, rather than actively sharing their separate domain knowledge with each other, Mia and Matt tended to trust the individual expertise of the other. For instance, at one point, the pair ran into an issue with a potential short circuit in the project (i.e., conductive thread touching on the back of the canvas). Instead of working together on the problem, Mia dutifully came up with a solution on her own (using a piece of felt to isolate the thread), while Matt continued with programming. In this sense, the pair saw each other as a resource in terms of "ideas" – something that both partners mentioned within their interviews. As opposed to Melanie and Jasmine then, Mia and Matthew spoke positively both about their collaboration and each other as partners.

In sum, the supportive style of communication generally seems to fit naturally with more collectivistic work approaches. In other words, the work of sharing tasks and roles, and engaging with one another's work necessarily involves active communication and social engagement. However, these more supportive communication styles could also enhance the productivity of an individualistically minded pair, by creating the basis of mutual trust and support. When considering the features of pair e-crafting then, it is important to note not only these differing approaches towards role and task distribution and communication, but also the ways that these strategies can intersect to influence the productivity and ultimate success of a pair.

5. DISCUSSION

Our goal in this paper was to examine how partner collaborations could work for high school students constructing e-textiles designs. Modeled after pair programming, which emphasizes highly structured ways of interacting within a single domain (coding), our approach toward pair e-crafting allowed to pursue their own work styles when navigating across the multiple domains of design, circuitry, coding, and crafting. In this discussion, we share what we learned about collaborative e-crafting and how this can inform the design of future collaborative maker activities and learning arrangements.

5.1 Promises & Challenges of Pair E-Crafting

Through this paper, we gained valuable insights into role distribution and partner communication strategies within the structure of pair e-crafting. Based on these models, it seems that pairs can successfully and unsuccessfully manage the complexity of collaborative e-textiles designs through these particular strategies and approaches. We found that adopting a more collectivistic approach to roles and tasks resulted in a key benefit with regard to troubleshooting and decision-making, that is, greater familiarity with the integrated domains of e-crafting, and hence, a more holistic sense of the project. Conversely, students that adopted a more individualistic approach risked isolating their knowledge and skills, thus hindering with the pairs ability to deal potential issues and complete the project. Interestingly, communication strategies appear to be a potentially mitigating factor in terms of these role distribution strategies. Generally, this smaller pair arrangement can more easily allow for constant communication surrounding a project and an individual's work, something that seems to keep students both accountable to and invested in their project. Likewise, more inhibitive communication strategies and individualistic approaches might lead to higher feelings of disengagement and frustration – something which additionally influences the productivity and progress of a pair.

5.2 Collaborative Making in Formal Spaces

In light of our findings, we identify two key design considerations for future designers of collaborative making in formal spaces. First, this study points to the need to actively configure collaborations for learning. As we detailed, approaches toward role distribution and communication styles are important factors that seem to influence the productivity of a pair. However, collaborative making in out-of-school spaces is typically voluntary and unstructured. Within formal settings, how might these more defined approaches toward collaboration be modeled? Furthermore, what additional factors, whether attitudes toward e-textiles practices and projects in general, might further intersect and/or impacts the productivity of a pair, moving into the future? This needs to be answered through further research.

Second, the rich, interdisciplinary space of e-textiles seems to challenge us to consider the tradeoffs that might be required here between depth and breadth in learning. While we detailed students' different approaches toward the multiple domains of e-textiles, the question that remains is how to best assess the learning that occurs not only through these activities, but through these collaborations themselves. Within this study, the teacher required pairs to submit an in-depth and comprehensive design portfolio outlining their design processes, challenges, successes, and contributions. It remains to be seen, however, how well these capture the process of collaboration as well as learning in this complex, multi-modal context. Thus, as these collaborative maker arrangements enter formal settings over time, further investigation into these questions of assessment, learning, and collaboration is certainly warranted.

6. CONCLUSION

Collaborative e-crafting, like the e-textile designs in this workshop, highlight the promises and challenges related to bringing maker activities into formal learning spaces. We see multiple benefits of promoting and developing such collaborative arrangements for classroom maker activities: for one, there are possible learning advantages that student collaborations can contribute to process and outcomes; second there is the economic advantage of reducing significant material costs often associated with maker activities, and finally, there are teaching advantages when teachers have to attend to fewer students with requests for help as they are focusing on pairs rather than individuals. Leveraging a do-it-together approach to making in formal learning environments is an arduous yet worthwhile design challenge that compels further examination.

7. ACKNOWLEDGMENTS

This work was supported by a grant (#1509245) from the National Science Foundation to Yasmin Kafai, Jane Margolis and Joanna Goode. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation, the University of Pennsylvania, or Utah State University.

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