Scaffolding Inclusivity Through Making: A Preliminary Analysis of Diverse Learners' Meaning Making Through Complex Systems

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Abstract: This project builds upon a body of work that interrogates the socio-material affordances of maker tools and integrates socioculturally responsive approaches for the inclusion of diverse learners in makerspaces. We provide a preliminary interaction analysis, which explores how racially and linguistically diverse learners engage in learning with complex systems through tools and language during bidirectionally responsive design activities.

Introduction and background

This project builds upon a body of work that interrogates the socio-material affordances of maker tools and integrates socioculturally responsive approaches for the inclusion of diverse learners in makerspaces (e.g., Richard & Kafai, 2015; Richard & Giri, 2019). Specific to this iterative, multi-stage, design-based research project is its purposeful integration of different contemporary digital and physical content creation tools (i.e., multiple interfaces), which each invite unique socially-mediated proclivities and uses and are scaffolded through the curriculum to invoke collaboration. In this way, we integrate work on bidirectionally responsive design (BRD), which proposes purposefully integrating diverse, contemporary maker tools in ways that encourage the design of simultaneously physically and digitally interactive projects (Richard & Kafai, 2015). BRD models authentic design practices found in computing professions, and involves purposefully utilizing simplified digital (eg. Scratch) and physical (eg. the Lilypad Arduino, the Makey Makey) programming, design and fabrication toolkits to create cohesive, integrated systems with simultaneous digital and physical feedback. In BRD, the focus is not specifically on how to use the tools, but is instead on the assemblage of complex and seemingly disparate systems in collaborative ways. As a result, learners engage in complex systems thinking, across a variety of computational systems, and social systems, as they work together to create a shared artifact. Our past work also finds that both the purposeful integration of maker tools that invoke different skill sets (e.g., the Lilypad Arduino, which utilizes sewing to create wearable circuits) and the promotion of an inclusive learning environment positively shapes counter-stereotypical collaboration practices and roles across gender and cultural backgrounds.

Specifically, this work extends upon frameworks related to understanding learning with complex systems (Richard & Giri, 2019). For example, multimodal learning theories propose that learners engage more deeply with instructional materials when they are provided different auditory, visual and textual representations (e.g., Meyer, 2003). However, until recently, most of this work did not consider tangible and integrative dimensions, such as those that could be fostered through BRD. Likewise, by participating in authentic interdisciplinary design practices (i.e., engineering design, coding, project management, etc.), learners are engaging in meaningful complex systems design practices (e.g., Lu et al, 2007). We further propose that the use of language itself provokes and invites another level of complex systems engagement – that of linguistics. The study was guided by sociolinguistic approaches to code switching (e.g., Lin, 2008). Lin (2008) identified three main categories of code shifting: (1) ideational (providing contextual understanding of content through lived experiences, including language); (2) textual (signaling topic shifts); and (3) interpersonal (appealing to shared cultural values).

In other words, in this paper, we focus on the ways that socioculturally inclusive learning can be fostered through "embodied, enactive, extended, and embedded learning," in line with this year's theme. We examine how first-time makers, who are both linguistically and culturally diverse, attempt to create both collaborative and individual multimodal projects, facilitated through multi-interface design**,** as part of the fifth iteration of this multi-year design-based research project, by exploring two teams of students. In our preliminary interaction analysis, we focus on detailed narrative summaries of interactions, guided by our central research question: How do racially, ethnically and linguistically diverse learners engage in collaborative meaning making through BRD?

Methods

Participants and setting

Participants were six (N=6) high school students, ranging from 14-18 years old, who were participating in a six-week TRiO summer program, which serves low-income youth from rural, high-poverty areas, in a rural part of the Northeastern United States. (All participant names have been changed to protect confidentiality.) Over 100 youth were enrolled and could register for classes of interest within the STEM and ELA curriculum. The setting

of this study was a STEM course entitled "Computer Coding," which focused exclusively on Scratch in prior years and added the maker activities this year. All but one student spoke fluent Spanish and all indicated they were first time "makers." Four students identified as Hispanic/Latinx, one as Black/African American, and one as both. Two primary instructors, both Black women, led class activities: one, a graduate student (author Whittington), taught the first three weeks of the course, which focused on Scratch coding, and the other, a professor (author Richard), taught the integrated making, coding and design course (the BRD curriculum) during the last three weeks. Three male graduate students, two White American and one Nepalese (including authors Giri and Ashley), provided hands-on instructional assistance along with the professor.

Course design (summary)

The BRD curriculum, iteratively designed by Richard, focuses on student-centered, constructionist, project-based learning (see Richard & Giri, 2019). This particular workshop lasted three weeks, four times a week at 2 hours a session. During the first few sessions, students learn concepts around circuitry, electronics and fabrication through short, expository videos and lectures with rich visual and textual representations, which is followed closely by hands-on activities to explore the concepts learned. Throughout the workshop, students learn how to use all of the digital and physical tools to code, design, fabricate and sew. During the last four sessions, learners first engaged in design thinking activities, negotiated final project designs with 1-2 others, and collaboratively created their integrated, multi-interface project, taking on different roles.

Data sources and analysis

We recorded audio/video observations using two wide-angle and two close-up cameras. Instructors engaged the students throughout the course in think aloud prompts in order to monitor their progress and engage the students' metacognitive strategies. We focus on a subset of data, which was transcribed, translated and analyzed, utilizing microanalytic techniques (Derry, et al., 2010). The microanalysis allowed us to review the video data through multiple lenses, including micro, meso and macro interactions. We provide first-stage findings using analytic induction (Derry, et al., 2010) on a subset of salient vignettes identified by the four authors.

Findings

We focus on two detailed narrative summaries as vignettes. The first centers on learning interactions amongst three bilingual, native Spanish speaking students in the class, as they navigate through learning how to create a bidirectionally responsive project. The second centers on the one native English speaker, an African American female student, and her partner, a young woman who identifies as both Latinx and African American, as they design their final multi-interface design project together.

Figure 1. (a) Ricki asks a question about project 3; (b) Lisa and Juan playfully cut thread together.

Vignette 1: Language use as learning with complex systems

Lisa (16), Juan (15) and Ricki (17) (All participant names have been changed to protect confidentiality.) are either finalizing or beginning their 3rd projects, individually, which combine all of the systems together (e-textiles, the MakeyMakey and Scratch) to create bidirectionally responsive designs. Juan, Lisa, and Ricki are sitting next to each other, working on their own projects. They are having a conversation in Spanish for two minutes about an unknown person while they work. Soon after, Ricki, looking confused, asks Lisa a question softly, in Spanish, which cannot be discerned (fig 1a). Lisa looks at his project and replies in English: "Oh that's for your thumb. You're supposed to do that." Ricki's facial expression is visibly shocked, "Really?"

> Lisa [*in English*]: "…keep reading the thing" [*She motions to the instructional pamphlet (figure 3a), which Ricki has not taken out of his Ziploc bag from the prior class. Ricki pulls it out and begins to look over it quickly, and says something inaudible to Lisa.*]
>
> Lisa: [*in English*]: "Yes it does just keep reading it". [*Lisa points to a particular part of the handout*.]
>
> Lisa: "Mira, ahí. ¿Tú me estabas diciendo mentira?" ("*Look, there. Are you lying to me?*") [*Ricki continues softly in Spanish, seemingly confused.*]

Lisa [*in English*]: "You never know." [*Ricki goes back to reading the instructions.*]

The three continue to work on their projects. Ricki is quietly reading through the pamphlet when Juan turns to Lisa who has a pair of scissors (fig 1b):

Juan: "Dame la tijera pa [sic] atrás." ("Give me back the scissors.") [*Lisa holds the scissors up. Instead of taking them, Juan holds up a piece of non-conductive thread.*]

Juan: "Dale" ("There") [*Lisa proceeds to cut the thread right in the middle*.]

Juan: "No era ahí." ("It wasn't there.") [*Juan playfully shakes his head to indicate Lisa has cut the wrong spot. Lisa laughs*.]

Lisa [*in English*]: "You said there, and then I did that." [*She points with the scissors in the center of the thread.*] "…and you didn't say no." [*Juan laughs and says he was playing. Ricki looks to see what Juan and Lisa are doing then looks back at the handout. He turns to Lisa and asks an inaudible question*.]

Lisa: "¿Que te pasa?" ("What's wrong?") [*Ricki whispers something Spanish, seeming exasperated.*]

Lisa [*in English*]: "I don't know." (*with surprise*) [*Ricki gets up with an expression of disappointment.*]

Lisa: "Es que tú le preguntabas" ("You asked them.") [*Ricki goes to one of the instructors for help*.]

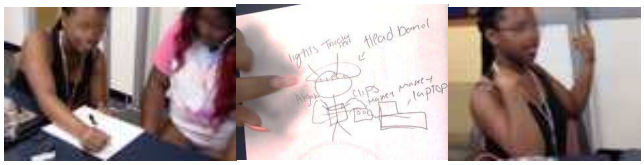

Figure 2. (a) Drawing preliminary interactions; (b) Ebony points to the diagram; (c) Priscilla demonstrating.

Vignette 2: Engaging in complex systems design through collaboration

The second vignette focuses on Priscilla (14) and Ebony (16), who are working on their collaboratively designed final project. The vignette begins during the final week, when the two are beginning to plan out their bidirectionally responsive final project. They start drawing out the interactions (fig 2a, b), and the professor comes over to ask them specifically about the Scratch interaction, having overheard some of the confusion, "So think about the Scratch interaction. What's going to happen in Scratch? Priscilla, what are you thinking of?"

Priscilla replies: "Um, we touch-" [*pointing to her shoulders where the left and right physical buttons would be attached (fig 2c)*] "-It's going to move left to right. And then the lights are going to blink."

Professor: "And Scratch?"

Ebony: "In Scratch the game will go left to right because we are doing a catch game so our basket will be left to right-" [*touching her shoulders*] "-and touch…what's it-?"

Priscilla: "…conductive tape."

Figure 3. (a) Priscilla and Ebony showing how they added the Velcro; (b) Ebony demonstrating the headband; (c) the final detailed diagram of the headband e-textile circuit.

The instructors leave Ebony and Priscilla to continue working on their storyboarding and project fabrication. The next part of the vignette begins during the next class session, when they have already hot glued three rectangular pieces of felt and have attached Velcro to make it adjustable. Ebony shows the project to one of the instructional assistants, explaining the adjustable design of the headband, depending on head size (see fig 3a, b). Priscilla also explains that you could wear it around your waist. Ebony adds that they are "going to sew the LEDs but we are going to finish programming first." She shows that the LEDs are going to be placed in the front. Ebony asks Priscilla where the ground should be. Priscilla suggests that it could on one end of the headband.

Ebony shows that they are going to have alligator clips on the side where the ground is and then clip the alligator clip to the conductive tape (ground). The instructional assistant reminds them to finish drawing out their designs.

About 20 minutes later, Ebony has finished drawing the diagram, and proudly explains their design to one of the instructional assistants (figure 3c): "Okay so, we have sort of an idea like how to do it… We're gonna put our, our LED's on the front and our Lilypad in the back with the piece felt covering it. So, when you put it on your head-" [*makes a gesture of wearing the headband*] "-you feel it, but you don't really feel it. You can feel the felt… So, we're gonna cover it with felt, we're gonna sew it on, and then we're gonna sew all our LED's from the back [of the headband]. And we'll go for each LED, we will go down and over, down and over, so our lines don't cross like this-" [*showing lines crossing her fingers on her diagram (figure 3c)*] "-Down and over. Down and over -" [*showing the dotted lines going down from the LEDs and running parallel on the diagram*] "-And then we'll have conductive tape right here [*points to the conductive tape on the far left of figure 3c*] "-that will go from our alligator clips to our Makey Makey." They both continue working on the project, and before the class session is over, Ebony is sewing the Lilypad to the back of the headband. The course assistant asks about their experience working in groups. Priscilla replies, "I like working with her," and Ebony adds "It's fun." He then asks how they have split up the work. Ebony replies, "[Priscilla] does the coding." To which Priscilla responds, "[Ebony] does the sewing," and Ebony further clarifies that they are "going to work on the Makey Makey together."

Discussion and conclusion

We purposefully selected vignettes that cover overarching areas of significance for understanding how learners engage in collaborative meaning making with and through complex systems. The second vignette is a more traditional example of how diverse learners engage in collaboration and complex systems understanding through BRD. Specifically, Ebony, who missed several prior classes, and Priscilla, who demonstrated an aptitude for coding, were able to complement each other's strengths in service of their final design. By working iteratively, they were able to bring their shared understanding of the physical (e-textile) and digital (Scratch) systems together. We argue that the complexity of interactions and engagement add another important layer to understanding inclusive collaboration. The first vignette evidences prevalent categories of code switching. For example, the learners employ Lin's ideational category, when Lisa provides targeted support for Ricki, who has only recently learned English. She would provide certain scaffolding in Spanish, but also encourage him to seek out resources independent of her, where he would have to apply English. An added category we identified is the use of action with code switching. For instance, both Ricki and Juan actively handed-off materials or projects to Lisa; in Juan's case, it is in service of Lin's textual category (i.e., off-topic camaraderie), and in Ricki's case, it is primarily to aid his understanding. We argue that learners are utilizing complex linguistic and gestural systems to better engage with intricate material, which extends prior work on BRD for fostering complex systems engagement (Richard & Giri, 2019). In sum, we find support that, at baseline, it is important to provide more inclusive learning opportunities, such as those that account for multilingual entry points; however, such learning opportunities would also benefit from designing for purposeful collaborative engagement. The overall implications of this preliminary analysis suggest that providing meaningful, yet student-centered activities allow learners to actively help each other through complex learning tasks, often in ways that they may be uniquely able to scaffold.

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Acknowledgements

This study was partially supported by a Penn State College of Education Technology Grant and NSF # DGE1255832. Opinions expressed are those of the author(s) and not necessarily of the institutions or funders.