Examining Two Learner Approaches in a Making Activity with University Students

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***Abstract*—As the maker movement has introduced children and adults to learning by making, researchers have begun to explore different approaches to learning by making and ways that participants take up new fabrication techniques. This work examines instruction in a making activity as a way to scaffold learning in a making activity. University students are introduced to a new-to-them fabrication technique using two learning approaches, learning via step-by-step instructions and open ended exploration. This study examines how students privileged the disciplinary ideas and practices of their major, mechanical engineering.**

I. Introduduction

As the maker movement has introduced children and adults to learning by making [1], [2], researchers have begun to explore different approaches to learning by making and ways that participants take up new fabrication techniques. In one study, grade school children were presented with two learning-by-making scenarios involving building an electronics project: one group constructed circuits via step-by-step instructions and the other group explored using open-ended play [3]. In this work-in-progress paper, we build upon this prior work by investigating university engineering students' perceptions of a making activity by presenting them with two similar making scenarios via step-by-step instructions and open-ended exploration.

Initial findings suggest that when the engineering students analyzed the learning by making activities, their analyses privileged the disciplinary ideas and practices of their major, mechanical engineering. In our analyses of the students in the two learning conditions, and we found that students analyzing the open exploration condition found more evidence of these disciplinary ideas and practices than those in the step-by-step condition. We discuss the implications of what the student observers perceived as important and of what they noticed about their own approaches to learning by making.

II. Literature review

The term framing has been used to refer to individuals' underlying expectations for what they are experiencing [4], [5]. Research on framing in educational settings investigates how learners – drawing on their myriad previous experiences – interpret what kind of activity they're engaged in [6], [7], [8]. The construct of epistemological framing deals with how learners understand their activity with respect to knowledge, reasoning, and learning [9]. We are interested in instruction-based and open-ended modes of learning in a making activity because they represent two common modes of learning in makerspaces [10]. Often, novice makers become involved in a makerspace by taking a workshop, where they are often presented with step-by-step instructions to complete a project. More advanced users often learn through long-term projects via open-ended exploration. Universities are beginning to build makerspaces as a development for engineering education to bring more design experiences to students in their middle years [11], [12]. We are interested in these modes of learning so we can develop scaffolding for a novice user in a makerspace, especially in the university setting.

To expand the knowledge base about the dynamics of university engineering students' participation in making activities, we established two research questions for our study:

- What resources do university engineering students activate or construct within an unfamiliar (for them) making activity posed in the context of a formal course?
- How do university engineering students frame their participation in a making activity posed within a formal course?

III. Data Collection and Analysis

The context for this work is an innovative elective course entitled *Applications of Theory and Research in Engineering Education.* The course is an upper-level elective introducing students to engineering education from the learning science lens. Senior and graduate-level engineering students act as learning scientists to explore learner responses to various engineering instructional approaches [13]. As part of the course, students apply analytical approaches from the learning sciences to observe and reflect on class sessions in engineering fields that are unfamiliar to them. They also engage in unfamiliar kinds of learning experiences within the class and analyze their own participation in those. In this study, students were tasked with learning an e-textiles fabrication technique that was unfamiliar to them. They were given the choice of two learning approaches: construction via step-by-step instruction or open-ended exploration of the fabrication materials.

The class is comprised of mostly senior-level engineering students. Of 14 enrolled, 11 students self-selected to participate in the study. Five of the students were presented with a hands-on making activity in e-textiles while their partners observed them through the activity. The observers played an active role in the activity and provided their partners insights and commentary during the activity. This activity was a new fabrication technique for the students.

The students subdivided into pairs, where one student performed the activity according to his or her chosen learning approach while the other made observations of the learner's interactions with the e-textiles fabrication tools, the instructional materials (in the step-by-step approach), and other learners. We took field notes as participant observers during the in-class activity and reflection conversation, and we collected students' written observations and reflection papers. Using these data sources, we investigated what students brought from previous experiences to learn the new fabrication technology and how they perceived their own and others' learning strategies.

Following a participant observer qualitative research approach [14], we drew from methods of grounded theory [15] and open and axial coding [16] to identify themes related to student resources and framing in the study's data set. We conducted three rounds of analysis. In the open coding round, both authors read all field notes, student written observations of their peers, and student reflection papers, and made note of the knowledge, practices, and affective dimensions that students noted about their own or their peers' experiences during the e-textiles session. We then discussed our notes and combined our initial codes into a list of possible categories related to student resources and student framing. In our second round of analysis, the first author used the constant comparative method to combine categories that referred to the same kinds of resources and framings. For the third round of analysis, the first author used these categories to analyze the full set of observations and reflections again. Categories were used to code the data at the grain size of sentence or long phrase (if the participant did not make notes in complete sentences). The second author reviewed all coded sentences/phrases and approved the applied codes. Finally, we grouped together all observation and reflection statements coded within a single category to create a flight of data [17]. We reviewed and discussed the flights in order to elaborate on the definition of the category. These categories and their definitions are the initial findings we present below.

IV. Initial Findings

We coded with respect to research question 1 (RQ1): *What resources do the participants bring to the activity?* We focus on what the student observers noticed their partners doing. The final coding scheme for RQ 1 on participant resources is shown in Table I.

With respect to RQ1, the bulk of the resources that the students brought were previous experiences with circuits. Circuit knowledge includes knowledge about series and parallel circuits, LED polarity, and material properties. Those with this experience chose the open-ended exploration. Note that the circuit in the e-textiles activity was fairly simple and did not require university-level circuits understanding. It is possible that having this knowledge base in circuits allowed the students to feel comfortable exploring with sewing, which most students did not have experience with. Sewing knowledge includes experience manipulating a needle and thread, tying knots, and beginning and finishing a project. Some students had experience fixing and testing and this was seen in their repeated testing and trial and error. All students were able to observe the status of their project and fix the circuit so that their project worked. Lastly, the student observers acted as learning partners for the participants and helped clarify steps and materials for their partners.

We coded with respect to research question 2 (RQ2): *How did the students frame the task?* The final coding scheme for RQ2 is shown in Table II. Most students framed the activity as testing, play, and exploration and saw this as a creative exercise rather than a stressful performance. Again, the previous knowledge of circuits may have allowed the students to feel free with their exploration of sewing technique. Students I and G were very social during this activity and discussed their projects with one another. Both had a similar approach for their constructions, focusing on design before circuit functionality. Student E came up with a goal design of a sun, cut and laid out the pieces, then planned out the circuit with 3 LEDs. Student S planned a star with 5 LEDs, but ran out of time before completion. Student K followed the step-by-step instructions. Observers noticed their partners' affect during the activity and took notes mostly about the sewing steps involved.

We tabulated codes as applied to participants and constructed a matrix (Table III). For each participant we evaluated if a condition was true (T) or false (F). Empty entries denote that we saw no indication of the condition. Most students found that the circuits were easy due to their previous experience. Conversely, most did not find the sewing easy due to lack of experience. Despite this lack of knowledge, students were able to find successful sewing techniques through trial and error. Some students expressed that the activity was frustrating due to faulty tools. Despite this frustration, most students described the activity as not stressful. One observer saw that his partner found the sewing to be rhythmic and "calming" and started his own project. The observer later abandoned the project because he found that doing the project was more work than he initially anticipated.

Most students completed the project and their projects worked in the end. Despite being comfortable with both the circuit and sewing aspects of the activity, student S did not complete the activity because his project was too broad in scope. All other students completed their projects. It is important to note that while S did not complete his project, he still felt successful. He could visualize himself completing his project with some more time. Having completed the project wasn't necessarily an indication that the student felt personally successful. We will later explore a case study of K who did

Code	Definition	Example
Circuit knowledge	Functional knowledge about circuits (i.e. shorting), series and parallel circuits, LED polarity, electrical properties of conductive thread	S: "Is this conductive thread? I thought it was regular thread." S: "test using needle as contact with battery pack" I: "positive LED corresponds to long side"
Formal instruction in circuits	University class/recent experience	E: "Took [Introduction to Electrical Systems]." I: "Done circuits since 2nd grade."
Sewing knowledge	Threading a needle, tying knots, beginning and ending	E: "Not having sewing experience makes the connections/tie offs tricky" I: "has difficulty threading"
Fixing/testing experience	Repeated testing/trial and error	S's repeated testing (8 times) "E uses trial and error to figure out which ends of the light/thread will make the light go on."
Partner's knowledge	When the partner provided insight to participant	"K asked, 'what does the thread do?' I explained it was like wire."

TABLE I
PARTICIPANT RESOURCES

Code	Definition	Example
Frame as play/test/creative exploration	Participant views activity as one where learning process is more important than the product. The participant associates this activity as fun and not stressful.	S: "I mess around. I usually can figure things out." E: "Open-ended. Learn more w/o [instructions] and more fun." G: "Don't want creativity to be limited." I: "Open because enjoys struggling."
Frame as judgment/performance	Participant views the activity as one where the product of their work judged and compared to other participants.	K: "She thinks others are doing it better than she is." K: "Confused, overwhelmed that others know more."

TABLE II
PARTICIPANT FRAMING

Participant	Circuits easy	Sewing easy	Activity frustrating	Activity not stressful	Project worked	Activity frame	Frustration frame
S	T	T	F	T	F	Play/test	P
K	F	F	T	F	T	Performance	P/N
G	T	F	T	T	T	Creative	P/N
I	T	F		T	T	Exploration	
E	F			T	T	Creative	N

TABLE III
CODING WITH RESPECT TO PARTICIPANTS

complete the project but felt frustrated and overwhelmed by the activity. Table III shows that for RQ1, previous knowledge does not relate to activity completion. It also appears to show that the level of stress students felt during the activity was associated with the way they framed the task.

Students' feelings of success may be influenced by the way they framed the activity – that is, their sense of the expectations and goals for the activity, or the kind of "game" they were being asked to play. Because student S framed the activity as an opportunity to play/test, the outcome of the activity may not have been very important to him. Most students framed the activity as play, testing, or creative exploration. The following week, all the participants and observers were asked to reflect upon frustration and the ways it can have a positive (P) or negative (N) effect in learning. Most students acknowledged that frustration can have a balance of a positive and negative effects – that it can inspire someone to try harder, but also cause a person to give up.

This e-textiles activity was intended to be representative of a one-time workshop activity as in a makerspace, where the goal is often for participants to leave with working projects. Workshops often present novice users the opportunity to learn something new and leave with a working project [10], in contrast to engaging in a long term project which may not have a clear end goal. One marked contrast between makerspace users and the class participants is that the students in the class did not seek to learn e-textiles. The activity was presented in class as an opportunity for students to examine themselves and their peers as learners.

V. CASE STUDY

We summarize a case study of student K, who was the only student to choose the step-by-step instructions. K is a senior in an engineering department that did not require a circuits class. In class, she typically participated actively and confidently in course discussions. During the activity, she appeared very overwhelmed and frustrated, but persisted in making a functional project. We noticed K explicitly comparing her knowledge and her work to that of her classmates, and we explored how this particular group making setting may have influenced her framing of the activity and the affective dimensions of her learning. From the beginning, student K framed the activity as one of performance and judgment. She had no university level circuit experience and felt uncomfortable with her lack of circuit knowledge. She felt that "she had seen something like this before but couldn't remember." She compared herself with others and thought that "others are doing it better" and that "others know more". Student K overheard another partner pair thinking out loud and demonstrating previous knowledge, and her partner commented that this caused her to feel less capable than she wanted to feel. She struggled through the activity and relied on the instructions heavily. Partway through, the circuit did not work, but K knew to flip the LED and got the circuit to work. In the end, she persisted and felt proud that her project worked. In her reflection the following week, she confirmed her framing that the activity was one of performance and that the activity was isolating despite having her partner available as a co-learner.

VI. Future Work

In future studies building on these initial findings, subjects will be divided by research condition rather than having both conditions occurring in the same room. In addition to participant observation by researchers, future experiments will be video recorded with pre- and post-questionnaires gauging the circuit and sewing knowledge of the participants. In our study, we saw students with previous circuit knowledge feel comfortable in the open-ended exploration. For a more complete data set, we would like to have subjects both with and without previous sewing knowledge complete both the instructions-based and open-ended activities. This kind of activity has the potential to bring engineering skills to those with sewing experience who do not see themselves as capable of engineering activities. One of the challenges of teaching an e-textiles activity is that two unrelated skills are learned simultaneously instead of one.

Our initial findings suggest that while students privileged the disciplinary ideas and practices of their major, framing played a strong role in the affective dimensions of their approach to the making activity. Participants who framed an e-textiles making activity as testing and exploration had an easier time taking up a new fabrication technique. Framing also played a role in the affective dimensions of participants? learning; the student who framed the making activity as an opportunity for performance felt more frustrated and stressed. Future comparisons of step-by-step instructions and open-ended making will inform modes of learning in informal learning environments such as makerspaces.

References

[1] E. R. Halverson and K. Sheridan, "The Maker Movement in Education," *Harvard Educational Review*, vol. 84, no. 4, pp. 495–504, 2014. [Online]. Available: http://dx.doi.org/10.17763/haer.84.4.34j1g68140382063

[2] S. L. Martinez and G. Stager, *Invent to learn: Making, tinkering, and engineering in the classroom*, 2013.

[3] A. Konopasky and K. Sheridan, "An Experimental Study Comparing Two Educational Approaches to Making With Simple Circuits." 2015.

[4] E. Goffman, *Frame analysis: An essay on the organization of experience.* Harvard University Press, 1974.

[5] D. Tannen, "What's in a frame? surface evidence for underlying expectations," *Framing in discourse*, vol. 14, p. 56, 1993.

[6] L. K. Berland and D. Hammer, "Framing for scientific argumentation," *Journal of Research in Science Teaching*, vol. 49, no. 1, pp. 68–94, 2012.

[7] D. Hammer, A. Elby, R. E. Scherr, and E. F. Redish, "Resources, framing, and transfer," *Transfer of learning from a modern multidisciplinary perspective*, pp. 89–120, 2005.

[8] P. Hutchison and D. Hammer, "Attending to student epistemological framing in a science classroom," *Science Education*, vol. 94, no. 3, pp. 506–524, 2010.

[9] R. E. Scherr and D. Hammer, "Student behavior and epistemological framing: Examples from collaborative active-learning activities in physics," *Cognition and Instruction*, vol. 27, no. 2, pp. 147–174, 2009.

[10] K. Sheridan, E. R. Halverson, B. Litts, L. Brahms, L. Jacobs-Priebe, and T. Owens, "Learning in the making: A comparative case study of three makerspaces," *Harvard Educational Review*, vol. 84, no. 4, pp. 505–531, 2014.

[11] V. Wilczynski, "Academic maker spaces and engineering design," *American Society for Engineering Education*, vol. 26, p. 1, 2015.

[12] C. R. Forest, R. A. Moore, A. S. Jariwala, B. B. Fasse, J. Linsey, W. Newstetter, P. Ngo, and C. Quintero, "The invention studio: A university maker space and culture," *Advances in Engineering Education*, vol. 4, no. 2, 2014.

[13] A. Johri and B. M. Olds, "Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences," *Journal of Engineering Education*, vol. 100, no. 1, pp. 151–185, 2011. [Online]. Available: http://dx.doi.org/10.1002/j.2168-9830.2011.tb00007.x

[14] S. B. Merriam, *Qualitative Research and Case Study Applications in Education. Revised and Expanded from.* ERIC, 1998.

[15] B. G. Glaser, A. L. Strauss, and E. Strutzel, "The Discovery of Grounded Theory; Strategies for Qualitative Research." *Nursing Research*, vol. 17, no. 4, p. 364, 1968.

[16] A. Strauss, J. Corbin, and others, *Basics of qualitative research.* Newbury Park, CA: Sage, 1990, vol. 15.

[17] J. Corbin and A. Strauss, "Basics of qualitative research 3e," 2008.