

Sheltered-in-Place Considerations for Science Teacher Educators Interested in Educative Making

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Abstract: This descriptive brief paper is an abbreviated report about a larger autoethnographic study written by the first author as a post-doctoral research associate working in educative making as part of an NSF grant for which the goal is to attract a diverse population to the career path of mechatronics. Teleworking from home under shelter-in-place orders, she employed the methodology of reflexive embodied autoethnography with applied sensibilities to investigate the cultural experience of her two semesters as a participant observer who built a new university Makerspace in the USA and supported its use by undergraduate science education preservice teachers. Sans the underlying personal experience narrative of the larger study, this account encapsulates its findings with regards to conceptual, physical, and cultural characteristics of the Makerspace and the teaching and learning therein. This report concludes with considerations for the design, utility, and culture of fabrication laboratories which support deep engagement. This account may inform the work of informal and formal science education and educative making learning communities which strive for transformative learning. (Funding - NSF Grant 1842342.)

Keywords: autoethnography, COVID-19, educative making, makerspace, pandemic, preservice teachers, reflexive embodied autoethnography with applied sensibilities, science education

Educative Making

Educative making is a discipline specific or interdisciplinary pedagogical approach grounded in constructionism (Papert, 1991) and centered around design-build activities which may be further categorized as assembly, creative construction, and tinkering (Bevan, 2017). Making in educational settings mostly focuses on STEM curricula and learning outcomes include increased competence in content knowledge and skill; increased self-efficacy which leads to pleasure and further interest; increased engagement and positivity; collaboration which inspires and supports learning; and increased learning gains when self-discovery is part of the process (Papavlasopoulou et al., 2017). Educative making also addresses the habits of mind considered high school benchmarks for scientific literacy in the USA: values and attitudes; computation and estimation; manipulation and observation; communication skills; and critical-response skills (American Association for the Advancement of Science, 2009).

Guided educative making is both hands-on and minds-on learning (National Research Council, 2005) and the complexity of its implementation warrants the need for preservice and in-service teacher training. The rationale for its place in science education is that the “best way to learn science...is to do science and to experience its relevance and value in the world beyond the classroom” (Bevan, 2017, p. 83). Educative making may engage students otherwise uninterested in STEM-C fields and prepare them for this career pathway through the introduction of and experimentation with design principles and computational thinking. Specifically, hands-on engineering educative making experiences in formal makerspaces may be a reason the field of mechatronics has grown exponentially over the last decade (Kececi, 2019).

The Larger Study

Context

This descriptive paper is an abbreviated report of a larger study about a newly created Makerspace at the University of Northern Colorado, a mid-sized university in the Rocky Mountain West, USA. The Makerspace was built in the College of Natural and Health Sciences as part of a current National Science Foundation grant funded mixed methods STEM-C research project [NSF Grant 1842342]. This project involves a multi-site collaboration of constituents in higher education and high schools and its goal is to attract and prepare a diverse population for the career path of mechatronics, a field in manufacturing which incorporates mechanical engineering, electrical engineering, and computer science (Bradley, 2010) and in which diversity is underrepresented (National Science Foundation, 2019).

One of the first author's roles as the post-doctoral researcher in the CO partner site is to pilot the grant's educative making curriculum and later support the local partners in its beta testing implementation. To fulfill this role, she built a Makerspace in a small abandoned classroom, complete with the necessary tools and machinery (including 3D printers, a laser cutter, and digital desktop cutters), and learned how to use them. Since having a skill set and supporting others as they learn are not one in the same, she needed to gauge her teaching capacity and the utility of the Makerspace while supporting others during educative making. In order to do so, the post-doc partnered with the second author, a co-PI for the grant and a faculty science teacher educator who incorporates maker experiences in her STEM courses for preservice teachers.

Together, with the support of two undergraduate student workers, they guided 57 undergraduate preservice teachers (primarily females) in a two-part experience to scaffold learning through design challenges. This work happened over a full fall semester and partial spring semester (118 hours collectively) before the Makerspace was shuttered by shelter/safer at home orders placed due to the COVID-19 pandemic. As the principal investigators regrouped and strategized ways to continue the work of the grant, the post-doc suddenly had the luxury of time while teleworking to reflect on her Makerspace experiences.

Methodology

Literature reviews about the maker movement and making indicate qualitative methodology is most prevalent in the scholarship (Bevan, 2017; Schad, 2019). Browder et al. (2019) suggest "ethnographic fieldwork...constitutes the most effective data collection strategy" (p. 473) for research about makerspaces. The primary account for this brief paper is the post-doc's autoethnographic narrative (Ellis et al., 2011), written using the methodological orientation advanced by Field-Springer (2020) as reflexive embodied ethnography with applied sensibilities. The narrative describes the researcher's involvement and observations as a participant observer building the Makerspace and supporting its use by undergraduate science education preservice teachers. Central to the purposefully broad and reflective exploration were why the physical space and the learning therein had come to hold meaning, and what could be learned about the culture of the fabrication lab. Autoethnography was optimal for addressing these questions because the post-doc sought "to describe and systematically analyze personal experience in order to understand cultural experience" (Ellis et al., 2011, p. 271). Specifically, reflexive embodied ethnography was appropriate because it "recognizes that each field experience potentially changes how we come to perceive, understand, and act in the world" (Field-Springer, 2020, p. 197) and applied sensibilities include "reconstructing our social world through storied reflections grounded in our bodies" (p. 198). Anecdotal records, member checking with grant partners, and peer review by expert colleagues were used in the document's creation.

Findings

Reflection upon the creation and use of the Makerspace resulted in findings in the categories of a) conceptualizing and building the fab lab, b) cultural components observed during its use, and c) whether student experiences were characterized by deep engagement which may have resulted in transformative learning applied during the challenges of a pandemic. In order to make meaningful connections between theory and practice, and inform future work in the Makerspace, the post-doc associated findings with scholarship as follows.

Conceptualizing and building.

Makerspace framework. A conceptual framework of our fabrication laboratory was formalized and a pictorial representation was created based on a literature which situated our makerspace's purpose, people, and activities (Hira & Hynes, 2018) in the maker mindset (Martin, 2015), and the maker movement (Browder et al., 2019).

Designing for student preferences. In retrospect, the pleasurable and frustrating process of designing, organizing, and utilizing the makerspace was a process of discovering the attributes of complexity, coherence, mystery, and legibility, all environmental preferences of users of fabrication labs (Hynes & Hynes, 2017; Kaplan, 1987).

Cultural components.

Acquisition of skills and growth mindsets. Displaying an absence of a growth mindset (Ng, 2018; Pettersen et al., 2019), female students apologized incessantly even while learning the tools and machinery without obvious difficulty. Concerns about gender related stereotypes around apology were partially laid to rest by scholarship which explores the trust building aspect of superfluous apology (Brooks et al., 2014) and that indicates "no gender difference in the proportion of offenses that prompt[ed] apologies" may exist (Schumann & Ross, 2010, p. 1649).

Cultivation of relationships which build community. The preservice teacher science education students contributed to the positive atmosphere of the room by being optimistic, sharing knowledge in helpful ways, and offering emotional support in frustrating moments. They appeared to be intelligent, caring, creative problem solvers, which bodes well for their future teaching careers and the children in their charge. These descriptors align with the cultural descriptions of maker communities by Dougherty, the movement's founder, as happy, optimistic, and "nurturing the diversity of ideas" (2012, p. 14).

Altered experiences of time. Students lost track of time as they acquired skills and focused on their creative work. This may be attributed to the fact that novelty stretches the perception of time (Eagleman, 2008), as does the flow experience (Harmat et al., 2016), both observed in the makerspace.

Parsimony. Like all humans, undergraduates complicate all manner of things while learning. A typical scenario in the fab lab involved a student group problem solving by plowing through a tangle of options until someone offered a simple solution, which in hindsight they agreed laughingly should have been obvious all along. Investigation of elegant design, or the lack thereof, in educative making learning processes may be informed by views of parsimony in social science (Gunitsky, 2019).

Deep engagement.

Strategies which foster transformative experiences in science education. As the post-doc and student workers launched the makerspace, their basic decent instincts and educational histories served as guides. Unknowingly, they later discovered they were employing the design principles and teaching strategies of the *Teaching for Transformative Experiences in Science* research-based instruction model (Pugh et al., 2017). Future formal and purposeful application of this model in the fab lab may support transformative learning in educative making.

Traits and abilities of scientific literate adults. The preservice teachers who used the makerspace exhibited specific traits and abilities which may be characteristic of the habits of mind of science-literate adults. Among them were a "curiosity, honesty, [and] openness" which afforded the capacity to "make calculations for solving real world problems," "follow instructions in manuals or seek help from an experienced user," "troubleshoot...malfunction" of tools and devices; and "participate in group discussions on scientific topics" (American Association for the Advancement of Science, 2009).

Implications

Valuable considerations for the design, utility, and culture of makerspaces which support transformative science education surfaced during the larger study. The implications of the findings are offered as recommended

questions for consideration by educators who may be dreaming about or building a fabrication laboratory, managing an existing facility, or incorporating educative making into coursework.

- a) What is the Makerspace's conceptual framework?
- b) Are student preferences incorporated into the design and utility of the Makerspace?
- c) What cultural components are being cultivated in the Makerspace?
- d) Are the design principles and strategies which foster transformative experiences in science education present in the Makerspace?
- e) Do Makerspace constituents exhibit the traits and abilities of scientific literate adults?
- f) Given the pandemic and necessary pedagogical and delivery adaptations for courses and their activities, how can all the above be created, implemented, sustained, and assessed with integrity in both face-to-face and virtual settings?

Final Thoughts and Future Research

Given that educative making is becoming increasingly common in formal and informal educational settings across disciplines around the globe, it is important leaders of such learning communities link scholarship to practice so they build and maintain makerspaces with the physical and cultural characteristics which support potential transformative learning experiences. Reflexive planning has become a critical skill for educators as they invent and implement alternative pedagogical approaches, curricula, and delivery methods to meet the safety and educational challenges of the COVID-19 pandemic. With creative effort and investment of logistical planning and time, some educators are offering virtual learning educative making opportunities which may prove to be as rich as face-to-face learning (Corder, 2020, September 9). Timely further study includes how to maintain the integrity of curricula usually taught in person in the transition to virtual environments (Ferdig et al., 2020); outdoor makerspaces (Marsh et al., 2019) which may afford working in proximity safely; as well as efforts to place “culture, power, and equity at the center of the design and research of making” (Vossoughi et al., p. 227) to ensure all who want to participate in making communities are supported in meaningful endeavor.

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