Preservice Elementary Teachers' Educative Making Experiences Redux

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Abstract: In this descriptive brief paper three science education university faculty and a post-doctoral researcher share the difference between the delivery, execution, and assessment of the same educative making learning opportunities assigned to science education preservice teachers-first in face-to-face undergraduate courses taught before the COVID-19 pandemic, and then in an online version of the same courses. This presentation may inform the work of constituents of science and teacher education and maker learning communities who want to employ best practices as they modify curriculum for virtual delivery. (Funding-NSF Grant 1842342.)

Keywords: COVID-19, educative making, makerspace, pandemic, preservice teacher education, science education

Educative Making in Preservice Teacher Preparation

Integrating educational technologies in elementary classrooms to improve science, technology, engineering, and mathematics (STEM) instruction and 21st-century skills is a major goal of science education reform (NETS, 2000; NGSS Lead States, 2013). There is a growing body of evidence that preservice teachers' experiences in preparation courses influence whether and to what extent they will integrate technology in their future classrooms (Admiraal et al., 2017). Therefore, it is vital preservice teachers gain experience using educative technology during their teacher preparation courses to effectively teach STEM and 21st-century skills.

One avenue for including technology in elementary classrooms is the incorporation of educative making using digital fabrication tools, such as 3D printers and laser cutters. These technologies are becoming more common in K-12 settings, making them a focal point of research in STEM teaching and learning (Chen et al., 2020). Using such tools has the potential to transform STEM teaching and learning by fostering a mindset of curiosity and creativity as well as a sense of community (Peppler & Bender, 2013). Indeed, providing opportunities for preservice teachers to gain competency using digital fabrication tools has been shown to increase self-efficacy and decrease anxiety for teaching science (Novak & Wisdon, 2018) and promote a growth mindset (Ng, 2018; Parrish & Mulvey, 2020). Despite this growing body of evidence which supports the benefit of providing preservice teachers with educative making opportunities, a recent survey of over 100 teacher preparation programs revealed less than half of institutions provided opportunities for educative making (Cohen, 2017).

Research Aims

This in progress work is exploratory in nature and aims to a) further explore the benefits of including educative making activities in our elementary preservice teacher education program, and b) identify key features of educative making in preservice teacher preparation in order to design and deliver the same learning experiences in both face-to-face and virtual environments. Central to this effort is how this type of adaptation may remain true to the development of scientific habits of mind, particularly the adoption of a growth mindset and self-efficacy for STEM instruction. This brief paper reports what we have learned to date.

Theoretical Frameworks

The following theoretical frameworks are evidenced in the characteristics of the Makerspace's physical space and culture and the nature and outcomes of the work and play therein. The design-build activities of educative making (Bevan, 2017) have pedagogical roots in constructionism (Papert, 1991) and in most educational settings, including this fabrication laboratory, the activities focus on STEM instruction (Papavlasopoulou et al., 2017). The Makerspace's conceptual framework regarding its purpose, people, and activities, and how its work is grounded in the maker mindset and movement, is based on the ideas of Browder, et al. (2019), Martin (2015), and Hira and Hynes (2018). When teaching STEM and computer science concepts, it is important to consider shared values and attitudes held by students, as well as the critical thinking skills associated learning (e.g., logic). These attitudes, beliefs and skills are referred to as habits of mind (American Association for the Advancement of Science, 2009) and cultivated by Makerspace staff and faculty in the fabrication laboratory. Serendipitously, the staff employed the design principles and teaching strategies of the research-based instruction model called *Teaching for Transformative Experiences in Science* (TTES) (Pugh et al., 2017) during the construction and its first semesters of use, and the plan is to purposefully implement its practices in the future.

Setting and Participants

The Makerspace at our mid-sized university in the Rocky Mountain West was built as part of a current NSF STEM-C multi-partner research grant. Constructed in a long and narrow 180 square foot abandoned classroom, the room now serves as an office and meeting space as well as a fabrication laboratory. It is equipped with three Afinia H400+ 3D printers, an Emblaser 2 laser cutter, two Silhouette desktop digital die cutters, and an abundance of computers, microcontrollers, hand tools, and supplies which support educative making.

As part of a related study (not grant funded), undergraduate preservice teachers (mostly females) used the fabrication laboratory to complete a two-part design-challenge experience as part of a 6-week unit in a science and engineering course for elementary preservice teachers. The learning activities required using CAD software and a 3D printer. These activities (see Table 1) were completed during the fall and spring semester face-to-face delivery of the courses. Fifty-seven (57) juniors and seniors spent 118 hours collectively working on their challenges during the fall 2019 and spring 2020 semesters. None of the participants had experience using 3D printers or CAD software prior to the course. Upon completion of the design and production processes, preservice teachers reflected on and wrote about their experiences in terms of challenges, solutions, habits of mind, and whatever else they found important about their experiences. Later they presented their reflections, drawings, and physical artifacts to their classmates.

Table 1

Digital Fabrication Design Challenges

Demonstrate Proficiency Using Digital Fabrication	Application of Digital Fabrication to Solve a Problem
Individual Ring Challenge Using Tinkercad, design a ring to fit one of your fingers and print it in our makerspace. Participate in a "Parade of Rings" showcase for the class to view successes, failures, and habits of mind experienced during the process	Team Design Challenge You have been tasked with developing a device to be able to observe the result of dropping a golf ball and ping pong ball when they are stacked together and dropped simultaneously. You tried to demonstrate this to a friend without a device, but the two balls would not stay together when dropped and when they rebounded off the floor they went flying in different directions, making it nearly impossible to collect any meaningful data to make observations of a vertical drop and rebound and demonstrate a consistent outcome. Using digital fabrication, create a device and prepare a demonstration to show how the device works.

Note. The Ring Challenge was completed by each student. Students were required to demonstrate mastery using Tinkercad and 3D printing prior to working on the Team Design Challenge.

Findings

Overall, preservice teachers reported experiencing meaningful engagement upon completion of the face-to-face learning experiences and valued the experience because integrating educational technology and engineering in science teaching will be an expectation them when they have their own classroom. Prior to completing the activities, students reported feeling anxious about using a technology they were unfamiliar with. For example, when asked how they felt when given the design challenge, one participant stated: "I was very nervous. I have never done anything like this and was scared that I would not understand it." During both the Ring Challenge and Team Design Challenge activities, they reported struggling while using Tinkercad, specifically navigating the platform and accurately scaling their designs. For example, the participants' reflections about challenges they experienced when completing the Ring Challenge included this statement: "I am getting more and more frustrated and angry about what is required and if this idea is the best."

After completing the design challenge experiences, the majority of preservice teachers reported overcoming challenges and feeling confident they could include making in their elementary classroom to support STEM teaching and learning. In general, the students' written reflections indicated the making activities improved the preservice teachers' self-efficacy and supported the development of habits of mind and growth mindsets. For example, one participant stated it was necessary for their group to develop persistence, creativity, think interdependently, manage impulsivity, and think flexibly to complete the activities. Another student reported, "I'm proud of my ring, even if it isn't perfect. I learned I can successfully create something and be proud of my work." Yet another student said, "Although I did not get the optimal outcome, I still learned many new things and gained my first experience 3D printing, so I am very happy." This motivated faculty to continue to offer making experiences in the elementary teacher preparation program courses.

Two unexpected themes emerged from the data sources: how the characteristics of our Makerspace impacted preservice teachers' overall making experience, and the role collaborative relationships with peers and instructors played in developing habits of mind and a growth mindset (see Table 2).

Table 2

Findings: Themes and Examples from Educative Making

Themes from Educative Making		Examples of the Themes
Characteristics of the MakerSpace		
Components addressed by predictors of environmental preference (Kaplan, 1987)	Aesthetics	"I just LOVE coming in here!" (Student)
	Affect	"I always feel better after I've been here." (Faculty)
	Cognition	"Oh no! I didn't know what time it was! I'm late!" (Deeply engaged students)
Attributes which predict student preferences (Hynes & Hynes, 2017, pp. 872, 877-878)	Complexity- the richness of the space defined by the number of things going on and a conveyed sense of purpose	The Makerspace is used for constituent meetings, office space, and design and fabrication, sometimes simultaneously. Spaces for each activity are immediately recognizable upon entry.
	Coherence- the scene makes sense and its purpose is clear	Each area of the fabrication lab has a specific purpose. Machines, tools and materials used for that purpose are nearby or in labeled storage. There is a place for everything, and when not in use, everything is in its place.
Attributes which predict student preferences (Hynes & Hynes, 2017, pp. 872, 877-878)	Mystery- the space inspires intrigue leaving one wanting to see or learn more	Artifacts and current work are displayed on tables and shelves. The chalkboard is covered with drawings and written plans of students and staff. Inspirational quotes, stories, and photographs from the arts and sciences adorn the walls. Classical music plays softly in the background and a streaming nature cam or NASA feed plays on the Smartboard.
Attributes which predict student preferences (Hynes & Hynes, 2017, pp. 872, 877-878)	Legibility- the space is easy to figure out how to navigate and use regarding materials and processes	The center of the long narrow room is open and the seating arrangements for individual workers and groups around the walls are obvious. Workstations include 3D printers, digital desktop cutters, a laser cutter, and accompanying computers. Manuals and notebooks to record user experiences are near each machine and laboratory protocols are posted. Staff are present for support.

Themes from Educative Making		Examples of the Themes
Relationship Building		
Communities of practice: Situated learning (Lave & Wenger, 1991)	Learning is a social process	"I'm not the only one who is confused and struggling"
Importance of relationships in the context of teaching and learning (Mansfield et al., 2016)	Positive preservice teacher-mentor relationship	"You [the instructor] never said 'no' or our ideas were incorrect and you shared you have struggled. This encouraged us."
	Productive collaboration	"Together we all worked as a group to come up with our design ideas and would discuss the pros/cons of each idea before going ahead and purchasing the materials we needed. Everyone worked together and considered each and every plan that was brought to the table"

Educative Making in a Virtual Space

The Makerspace is now closed, and the delivery of these courses is currently online. The COVID-19 pandemic and its restrictions are driving faculty to transition to and from face-to-face to virtual environments and change their pedagogical approaches repeatedly. Such changes need not force the loss of inquiry-based, hands-on and minds-on, STEM learning experiences. Students' reports evidenced the benefits of educative making to the development of preservice teachers' self-efficacy for STEM teaching and habits of mind. The challenge before educators is how to maintain the integrity of such activities when shifting instruction to a virtual learning environment. The themes which emerged in the face-to-face making activities may serve as foundational considerations for an adaptation model for redesigning making activities for virtual learning spaces.

Instructional Adaptations

Delivery adaptation of the physical construction component of educative making is possible with an investment of time and attention to logistics as exemplified by Finan's work at the university level (Corder, 2020, September 9). Making materials or kits can be assembled by the course instructor and delivered to students to use at home. Moving educative making using digital fabrication tools into a virtual space presents a few more logistical challenges. The 3D printers were moved to the home offices of two faculty who would teach the courses synchronously online during the fall of 2020. The core features of the design challenges would still be included in the making activities: preservice teachers would use Tinkercad to create their artifacts, save their files in a class folder (e.g., Google Drive), then set up a time to meet with the instructor to virtually print the file. Virtual printing would be completed during a Zoom session, with students controlling the screen and following the basic guide to using the 3D printer typically available in the Makerspace. For the Ring Challenge, each student would participate in the parade of rings Showcase by creating a Flipgrid video that includes the challenges the student faced, solutions that were tried, and other information about their experience using Tinkercad and the 3D printer. Peers would respond verbally through Flipgrid to provide comments and suggestions. For the Team Design Challenge presentation, each team would present the product of the design challenge in a synchronous Zoom session. Adaptation considerations involved recreating the supportive characteristics of the physical Makerspace in a virtual space (see Table 3).

Table 3

Course Adaptation Ideas

Adaptation Considerations		Pedagogical Strategies	
		Face-to-Face	Virtual
Makerspace Characteristics	Affect	Display welcoming signs and messages throughout the makerspace; play calming music	Embed growth mindset posters and messages in instructional guide and videos of making artifacts; play calming music
	Aesthetics	Present materials with consideration of utility, organization, and beauty	Present delivered material kits with consideration of utility,

			organization, and beauty

Adaptation Considerations		Pedagogical Strategies	
		Face-to-Face	Virtual
Makerspace Characteristics	Mystery	Display exemplar and epic failure digital fabrication artifacts	Create Flipgrid instructor led video showcasing past digital fabrication artifacts, both successes and failures
	Legibility	Offer staff led makerspace tour which includes room norms, procedures, and equipment instruction; staff are physically present to meet students' needs	Record a staff-led video tour of the physical makerspace which includes room norms, procedures, and equipment instruction; instructors are virtually present to meet students' needs; students control the instructor's screen remotely
Relationship Building	Instructor/student and peer relationships	Dedicate class time to get to know one another; introduce support staff who share personal experiences in educative making	Icebreakers and team-building activities at the start of each synchronous class; via Zoom or Flipgrid, introduce support staff who share personal experiences in educative making
	Productive collaboration	Create semester-long teams with meaningful names and schedule group work meetings outside of class time	Via Zoom, create semester-long teams with meaningful names and schedule group work meetings outside of class time, and use Sign up Genius to schedule group work meetings outside of class time
	Learning is a social process	Exit ticket "grows and glows" gallery walk; class presentations about coursework	Google Doc exit ticket responses and discussion; Flipgrid video reports about assignments

Discussion

The pedagogical approaches proposed to adapt inquiry-based, making experiences from a face-to-face setting to a virtual space are not novel. For example, developing positive peer relationships in online learning using icebreakers or personal introduction assignments are standard practices for developing collaborative classroom culture (Sawyer, et al., 2009). Giving students autonomy to choose the members of their team and form a team identify also promotes productive teamwork (Staggers, et al., 2008). Creating a welcoming classroom space which evokes feelings of safety and a therefore supports a low risk learning environment is also a best practice for effective teaching. The aim of this ongoing investigation is to reflect on pedagogical considerations specific to educative making in preservice teacher education in a virtual setting. Of particular interest are which adaptations maintain the integrity of face-to-face making activities and mirror the desired outcomes of self-efficacy, habits of mind, and growth mindsets exemplified in successful in-person preservice teacher education. Also to be considered are whether adaptations are feasible with regards to budget and logistical constraints, as well the technological pedagogical and content knowledge (TPACK) instructors need to integrate adaptations into their classroom practices (Mishra & Koehler, 2006).

Next Steps and Limitations

The adaptations to the making activities described here have not been implemented to date. They will be included in one of the courses during the end of the fall 2020 semester and again during the spring of 2020. In addition to written reflections, preservice teachers' self-efficacy and growth mindsets will be examined more in-depth using the STEBI-B (Enochs & Riggs, 1990), a modified version of the growth mindset survey (Willingham et al., 2020 in press), and an intrinsic motivation survey (Deci et al., 1994). The obvious limitations of this in progress exploration and preliminary report are that the investigation is in its early stages and additional data collection and analysis are warranted.

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