"VIRTUALLY" A MAKER: MAKING IN AN ONLINE GRADUATE COURSE

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Makerspaces have become established as communal and collaborative environments for making meaning, solving problems, and developing essential global skills and competencies. However, these spaces are commonly utilized by makers who are geographically co-located. In this qualitative study, we explored the intersection of a maker approach to learning and the affordances of online education—specifically, learning in one's own community by accessing the online course remotely as opposed to traveling to a physical classroom, and connecting the learning/making activities directly to one's home context—in a graduate-level course focused on critical making. We also discuss the theory and methods that informed the development and implementation of this course, given a recent shift from the use of traditional teacher-centered pedagogies in online learning. Our results suggest that the online course acted as a supportive community of inquiry that both scaffolded students' independent exploration of making in their local communities and facilitated continuous, collaborative learning through an effective blend of synchronous and asynchronous technologies. The need for a platform that enabled ongoing, organic sharing and connection between students was also highlighted.

KEY WORDS: online education, post-secondary education, maker education, makerspaces, digitally mediated learning, student perspectives, qualitative research

1. INTRODUCTION

Makerspaces began as informal, community-based spaces with people learning and making together to create digital and tangible artefacts in response to real-world problems. They are now also found in formal Science, Technology, Engineering, the Arts, and Mathematics (STEAM)-based education settings (Freeman et al., 2017). Maker pedagogies, which include agentive, inquiry-based learning grounded in constructionism

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(Papert & Harel, 1991), offer an alternative to traditional learning since they focus on collaboration and rely on the distributed knowledge of the group and connecting theory to practice. Although online learning in its original format mimicked traditional teaching methods (Clark & Mayer, 2011), more recent online learning courses leverage collaborative learning and distributed knowledge, as well. Often, this is facilitated through learning management systems that resemble social networking sites with embedded interactive and performative features (i.e., profile pages, sharing capabilities, and forums). These collaborative affordances enable geographically separated students to collectively orient themselves around learning tasks (Zhu, 2012); to socialize, promoting group cohesion (He & Gunter, 2015); and to provide a bridge between personal creative practices and public maker communities (Orton-Johnson, 2014). Providing opportunities for sharing and socialization is essential in online learning spaces since group cohesion is a significant factor in the process of student knowledge building and understanding (He & Gunter, 2015; Jeong & Hmelo-Silver, 2016; Yilmaz, 2016); in particular, among learners from heterogeneous backgrounds (Lin et al., 2008).

Lock et al. (2020) explained that “virtual making is the process of synchronous and/or asynchronous making in an online environment” (no page). Of makerspaces, they share that “the makerspace trend normally involves a physical space for makers to come together to create and innovate … [however] there is an emergence for the promotion of virtual makerspaces” (no page). In part, this is due to the fact that virtual makerspaces have the potential to alleviate issues of equity and access (Oliver et al., 2017). The global COVID-19 pandemic has also forced this kind of innovation as makers shift their practices to online platforms and communities. Loertscher (2015) defined a virtual makerspace as a “virtual environment where students and adults can create, build, and invent and where all the other creative, informal, educational self-directed learning passions can develop” (no page). This creation is facilitated through a variety of online platforms, such as Google Sites, Drive, and Documents; and virtual tools, such as Symbaloo, a web curation tool. To reflect the sharing and interpersonal engagement that take place in traditional makerspaces, online maker communities must utilize these collaborative features to their full effect (Litts et al., 2016; Oliver et al., 2017). Synchronous (e.g., live text chat and video calls) and asynchronous (e.g., discussion forms and Twitter threads) forms of communication enable makers to discuss ideas, request feedback, and share completed artefacts (Oliver et al., 2017). Similarly, personal profile pages can act as a space for makers to display their projects and share knowledge and resources (Orton-Johnson, 2014). Through these affordances, physical making becomes digitally mediated, supported by meaningful participation in a community of geographically disconnected makers and learners (Orton-Johnson, 2014).

In response to this shift in online teaching and learning methods, we sought to explore the intersection of a maker approach to learning and the affordances of online education in an online graduate course focused on critical making. Specifically, we asked: What are the affordances and limitations of learning about maker pedagogies and tools in an online Master of Education course?

2. LITERATURE REVIEW

2.1 Online Maker Professional Learning

Online maker professional learning brings together the theory and practices related to online learning, such as Community of Inquiry (CoI) (Garrison et al., 1999); maker pedagogies, such as constructionism and collaborative learning (Hughes, 2017); and professional learning, such as reflective, context-based, and ongoing (rather than one-off) sessions (Stoll et al., 2006). The literature on online maker professional learning focuses on the conditions that encourage student engagement with maker theory and activities and on the importance of community building, collaborative learning, and sharing.

Previous research has focused on connecting makerspaces in the online environment. The study from Oliver et al. (2017) focused on the creation of a virtual makerspace for an online graduate course. The authors found that organizing maker kits and activities for their students in advance meant that materials costs were kept reasonable (on par with normal textbook-related costs) and the predetermined activities meant that certain skills and competencies such as troubleshooting and problem solving could be targeted for development. However, the activities were also general enough such that they could be personalized by the students (for example, creating a circuit-embedded greeting card, where the art, circuit design, and messages were also individualized). The projects in this course included a focus on circuitry, robotics, and physical computing and fabrication.

Similarly, studies from Hughes et al. (2016) and Hughes and Morrison (2018) focused on the experiences of graduate students in an online critical making course. The course included online maker modules that focused on electronics, wearables, three-dimensional (3D) printing, and coding. While the Oliver et al. (2017) study included predetermined activities, the studies from Hughes et al. (2016) and Hughes and Morrison (2018) had the participants learn about the topics through curated scholarly research and media (i.e., linked tutorials, Ted Talks, etc.), in which the students selected from a variety of activity options that included lesson plan creation, reflection on a critical question related to each topic, and/or a practical activity. Students also always had the option to "hack" one of the activities or to suggest something new. While the Oliver et al. (2017) study focused more on the practice of making and the skills and competencies that can arise from these practices, the studies from Hughes et al. (2016) and Hughes and Morrison (2018) focused

more on the critical elements connected to the practice of making; in particular, as it related to education. In all three studies (Hughes et al., 2016; Hughes & Morrison, 2018; Oliver et al., 2017), students were encouraged to involve one another in their making processes via online discussion. In the Oliver et al. (2017) study, VoiceThread (https://voicethread.com) was used to capture the students' learning processes and finished work, and then peers were able to provide/embed feedback to one another within the program. This encouraged dialogue among students since the feedback was intended to advance thinking and build on one another's work. In both the Hughes et al. (2016) and Hughes and Morrison (2018) studies, peer feedback was encouraged on the class social networking site. Students were asked to share their work on the site (i.e., reflections on readings and maker projects) and to provide feedback to one another in order to create a community of practice. Hughes et al. (2016) reported that “By the end of the course, it was clear to see that the maker modules had a tremendous impact on professional development—understanding of where and how to meaningfully integrate the tools and maker pedagogy” (p. 17). This was particularly true for those students located in remote regions of Canada, such as Nunavut, where making experiences were otherwise limited. One student engaged in fully online making using tools such as Tinkercad, a free online 3D modeling software program (https://www.tinkercad.com/) and the online circuit-building tool, virtual Arduino (which is now hosted on Tinkercad's website). The online course meant this student could still be actively involved in a maker community of practice.

These three studies on online making in graduate-level courses highlight the engagement, learning, and community building that can happen even when students are geographically separated.

2.2 Importance of Practice-Based Learning Tasks in Maker Professional Learning

The literature on making (see Hughes, 2017; Hughes & Morrison, 2020; Halverson & Sheridan, 2014; Hlubinka et al., 2013; Lock et al., 2020; Peterson & Scharber, 2018) suggests that making does not need to be confined to a designated makerspace or the use of particular tools, but rather that it can happen anywhere. In their seminal work, Halverson and Sheridan (2014) explained that “Making can happen in a variety of places that may be labeled ‘makerspaces’ as well as in classrooms, museums, libraries, studios, homes, or garages” (p. 501). Simply put, the essence of making as a learning approach comes down to the fact that “makers are constructing knowledge as they build physical artifacts that have real-world value” (Martinez, 2019, no page). Jin (2019) explained that cultivating a maker mindset (which includes the use of the design thinking process) in professional learning is particularly important in helping develop teachers' understanding and application of maker pedagogies: when pre-service teachers cultivate a maker

mindset "they will strive to learn the content and be engaged in the learning process" (p. 1566). Bower et al. (2018) similarly found the authentic learning approach to professional learning can facilitate teachers' uptake of pedagogies that are "more open, communal, collaborative, purposeful, contingent and dynamic" (p. 104). This echoes the Paganelli et al. (2017) work, in which it was asserted that "if we want teachers to implement the type of best practices highlighted as effective in research, it is imperative that teachers are having the same type of experiences when participating in professional development" (p. 234). In the recent study on professional learning and virtual makerspaces by Lock et al. (2020), the authors articulate the importance of teachers going through the same virtual making experiences as their students. They explained:

> What was evident from the study was how virtual making is different from face-to-face making. The lived experience of the participants provided them an opportunity to reflect on how to design such learning with the synchronous communication technology but also how to facilitate the learning experience at a distance. Adding to the complexity is the facilitating the learning at a distance where the educator does not have the ability to stand beside the learner or to do a quick demo. Rather, it requires developing confidence and competence in using the technology in purposeful and meaningful ways to support robust learning. This case study provides a practical example of how virtual learning through making can be done, and how to give educators the lived experience so as to inform their practice as they work with their students. (no page)

Furthermore, collaborative learning and lesson planning is important in professional learning since teachers often do better in these scenarios (see Voogt et al., 2011). Properly scaffolded questioning prompts are important in helping teachers develop the thinking skills associated with problem-based learning experiences (i.e., analyzing and self-reflection) (Chua et al., 2015) that are associated with making and the design process.

3. THEORETICAL FRAMEWORK

3.1 Constructionism

The current maker movement in education is commonly attributed to the Papert (1980) theory of constructionism and its emphasis on the roles of problem solving and fabrication in learning (Halverson & Sheridan, 2014). Constructionism suggests that designing, creating, and sharing artifacts are essential learning processes, facilitating the development and reinforcement of conceptual understandings (Papert & Harel, 1991). As students engage with learning objectives through the construction of a physical or digital product, they make authentic, personal connections to the material, demonstrated through

what becomes a tangible representation of their knowledge (Noss & Clayson, 2015; Ratto, 2011).

Constructionist learning environments utilize “a range of activities that blend design and technology, including textile crafts, robotics, electronics, digital fabrication, mechanical repair or creation, tinkering with everyday appliances, digital storytelling, arts and crafts—in short, fabricating with new technologies to create almost anything” (Wohlwend et al., 2017, p. 445). To promote inclusive access, Papert (1980) recommended that maker contexts and technologies be designed with “low floors and high ceilings,” in which participation is feasible with minimal prior knowledge (i.e., low floors), but the tools and environment possess the flexibility to support sophisticated projects that support student progress (i.e., high ceilings). Other considerations include the addition of “wide walls” that enable various forms of self-expression (Resnick & Silverman, 2005), as well as “ramps,” “ladders,” and “reinforced corners” in the form of intentional scaffolding to broaden access for students with exceptionalities (Alper, 2013). Student-centered, inquiry-driven learning is the focus in constructionist contexts, promoting critical thinking (Ratto, 2011), perseverance (Hughes, 2017), the development of scientific knowledge and procedural skills (Bunterm et al., 2014), and technological fluency (Kafai, 2006).

3.2 Passion-Based Learning

Given the emphasis on inquiry and student-centered learning in making, the makerspace (be it physical or virtual) is a natural environment for education to be driven by students' personal interests (Marsh et al., 2019). Not only do students value opportunities to exercise agency over their learning (Gallup, 2019), integrating topics of personal interest can facilitate increased engagement (Hansen et al., 2017; Robertson, 2013), the development of global competencies (Hughes, 2017), and deeper conceptual understanding (Mas'ud et al., 2019; Ratto, 2011). Interest-driven learning is passion-based learning. Passion-based learning promotes student empowerment, particularly among marginalized students, by “allow[ing] them to find their voices, understand their own learning processes and challenges, develop greater autonomy in their learning, and begin to recognize their own strengths and talents” (Robertson, 2013, p. 211).

Nurturing creativity through interest-driven inquiry and thoughtful integration of maker technologies adds a dimension of personalization to students' learning, creating a sense of ownership and enabling students to situate their learning in the world beyond education (Gallup, 2019). Punctuating the role of passion-based learning in modern education, Brown and Adler (2008) argued that finding something

> that ignites a student's passion can set the stage for the student to acquire both deep knowledge about a subject (‘learning about’) and the ability to participate in the

> practice of a field through productive inquiry and peer-based learning ('learning to be'). (p. 28)

3.3 Community of Inquiry

The CoI framework was originally developed by Garrison et al. (1999). Although its original purpose was to analyze online learning via asynchronous discussion, it is now commonly used as a framework to guide the development and assessment of online learning. The framework includes three presences that, together, support learning in an online environment. These presences include cognitive presence, social presence, and teaching presence. Cognitive presence includes the critical thinking-connected activities students engage in during their online learning experiences. It is also categorized by "…the extent to which the participants … are able to construct meaning through sustained communication" (Garrison et al., 1999, p. 89) with others in the online learning environment. Social presence is "the ability of participants in the Community of Inquiry to project their personal characteristics into the community, thereby presenting themselves to the other participants as 'real people'" (p. 89). Finally, teaching presence is "the design of the educational experience" (p. 90). It also includes facilitation that "…may be shared among the teacher and some or all of the other participants or students" (p. 90). Each presence works together with the others to promote student learning and engagement: cognitive presence is supported and developed through social interaction and teaching presence; social presence and teaching presence overlap to set the learning climate; social presence and cognitive presence overlap and support critical discourse; and cognitive presence and teaching presence overlap to regulate learning.

3.4 A Combined Framework: Making and CoI

In the CoI framework (Garrison et al., 1999), a combination of cognitive, social, and teaching presences is needed to effectively promote student learning and engagement in online environments. These qualities are also encouraged in makerspaces, where student-driven learning, peer support and collaboration, and teacher facilitation guide the inquiry learning process. Furthermore, the CoI framework outlines how community can be developed in an online environment, which is essential for a virtual makerspace. This overlap between maker pedagogies and strategies for effective online learning (e.g., collaborative, context-based learning) acted as a supportive framework upon which to develop the graduate course. Currently, there has been little research published related to the affordances and limitations of learning about maker pedagogies and tools in an online setting, hence the focus of our study.

4. METHODOLOGY

This study followed a qualitative design and made use of a case study methodology (Merriam, 1998). A case study approach was appropriate for this research since the research focused on two participant cases within the bounded system of a Master of Education course at one Faculty of Education in Ontario. We adhered to the Merriam (1998) description of case study, which supports the social constructivist epistemological perspective that "reality is constructed by individuals interacting with their social worlds" (Merriam, 1998, p. 6). Merriam (1998) advocated for the use of rigorous research processes to ensure credibility and dependability of the case study research, such as rich descriptions and the triangulation of multiple sources of data. Merriam (1998) explained that, unlike a quantitative study, "the qualitative study provides the reader with a depiction in enough detail to show that the author's conclusion 'makes sense'" (p. 199) and that "reality is holistic, multidimensional, and ever-changing; it is not a single, fixed, objective phenomenon waiting to be discovered, observed, and measured as in quantitative research" (p. 202). Bearing in mind that Merriam (1998) called for rigor, rich description, and co-constructed interpretation, in the following sections we outline, in detail, the design of the online maker course, and in the findings we present the voices of our two case study participants. We then provide our discussion on the findings and a summary of the research.

4.1 Design of the Online Maker Course

The online maker course had three primary goals: (a) to critically explore the social issues inherent in critical making and constructionist pedagogies; (b) to acquaint students with some of the affordances and constraints of new physical and ubiquitous digital technologies; and (c) to help students develop basic skills in designing, making, and/or evaluating educational uses of these new pedagogies and technologies. As a result, the course was broken down into six modules that extend over a 12-week period. Each week included a 3-hour, synchronous, online session coupled with asynchronous maker activities, readings, and reflections to extend what was covered during class time. The 2-week-long modules were broken down thematically into the theory-based topics, which were coupled with hands-on making activities. The activities and associated tools were introduced during the online, synchronous sessions—initially, by the instructor; later, this responsibility was shifted to the students. Further making/exploring was continued into the subsequent week in the students' own context (home, community, work, and/or school context). The theory-based topics and hands-on making activities included in the modules were the following:

- **Module 1:**
  - Theory: Introduction to maker pedagogies and the design process
  - Activity/Tool: Circuit cutting machine
- **Module 2:**
  - Theory: Anti-consumerism and sustainability
  - Activity/Tool: Circuits
- **Module 3:**
  - Theory: Equity, diversity, and inclusion
  - Activity/Tool: E-textiles
- **Module 4:**
  - Theory: Indigenous ways of making
  - Activity/Tool: 3D printing and computer numerical control routing
- **Module 5:**
  - Theory: Artificial intelligence and the Internet of Things
  - Activity/Tool: Game-based learning and mixed reality
- **Module 6:**
  - Theory: Assessment and support in the makerspace
  - Activity/Tool: Coding and programmable robots

The students were assessed based on their making and reflections portfolio (50%) and their passion project (50%). The portfolio was a digital collection of their ongoing making during the course, along with reflections related to their unique making process (challenges, successes, and "aha" moments), the readings, and class discussions. The passion project was an inquiry-based assignment, where the topic was selected by the students and related to their personal work/education context. The course was unique in that the students were all accessing it from different locations (i.e., Mexico and various cities/towns in Ontario) and they were also learning and making in response to their individual needs. In this way, the learning was localized and situated within the context of their own circumstances, settings, and goals (Kennedy, 2014). The online platform (Adobe Connect; https://www.adobe.com/products/adobeconnect.html) used during the weekly

synchronous sessions was the common denominator, bringing together learners from disparate locations. The students also collaborated on an education-based social media platform (NING; https://www.ning.com) during the week. Here, they stayed connected to one another asynchronously by posting photographs of their making and commenting on one another's work. In these ways (through Adobe Connect and NING), the students explored topics related to critical making in a community, but their maker activities and projects were situated.

4.2 Participants

The course had 17 students in total: 13 women and four men. Ethics was obtained in order to research the students' experiences in the course. For the scope of this paper, we focus on a subset of the data from two participants, Sharon (a school administrator) and Carl (a teacher/librarian), who were selected using purposive sampling due to their high engagement in the course and the high quality of work they produced during their time in the course. Prior to the student interviews and any analysis, informed consent was obtained from the participants.

4.3 Data Collection and Analysis

The researchers collected multiple sources of data, including pre-project surveys, student work, researcher field notes, and post-project interviews. Student work included the formal and informal work posted on the course's social media site, NING (maker projects, comments to peers, descriptions/reflections on their making, and academic article reading reflections), and the major activities and assignments the students produced (including synchronous student-led making sessions, the Maker Activities digital portfolio, and the Passion Project).

Merriam (1998) explained that data analysis is “the process of making sense out of the data. And making sense out of data involves consolidating, reducing, and interpreting what people have said and what the researcher has seen and read—it is the process of making meaning” (p. 178). We analyzed the data using thematic content analysis and we adhered to the Creswell (2007) description of the cyclical qualitative coding process, which requires “moving in analytic circles…” and exiting “with an account or narrative” (p. 150). As a result, our data analysis began with a number of preliminary in vivo codes “that seem[ed] to best describe the information” (Creswell, 2007, p. 153). These codes were then expanded, revised, combined, and reduced to two overarching themes. These were used to write our account of the findings through the interpretive lens of our theoretical framework: constructionism, passion-based learning, and CoI.

5. DISCUSSION OF FINDINGS

5.1 Affordance No. 1: A Balance of Focused/Supported and Context-Based Learning

Having a making course that included online synchronous making and independent asynchronous making meant that making could be a commonly shared learning experience (Jeong & Hmelo-Silver, 2016; Orton-Johnson, 2014). For example, making could first be done together during the online synchronous sessions and then the learning from these sessions could be applied in each educator's unique context for further learning, development, and/or application (during asynchronous time). For both Sharon and Carl, coming together once a week to learn about a new aspect of the maker pedagogies and tools from their respective locations (Carl in Mexico and Sharon in northern Ontario) allowed both participants to first learn the new content (e.g., making simple circuits or drafting 3D designs) in a supported community of inquiry with a shared focus (Garrison et al., 1999; He & Gunter, 2015). They were then able to take that focus back to their unique settings to continue to make and learn with the express purpose of applying their making to their own personal and/or work contexts. In a post-project follow up, Carl explained:

> I found it helpful to have both. My learning process allowed me to explore further the things I'd started in class. The synch time was helpful for instruction and for building in the time to start. For me, starting is the hardest so that was a nice feature.

This suggests that Carl was able to get the support and motivation he needed during the synchronous sessions to learn about the new maker pedagogies and tools, and he was then able to further his learning the rest of the week, applying what he had learned in class to his own work context (Oliver et al., 2017; Orton-Johnson, 2014; Yilmaz, 2016). One example of this was Carl's 3-day professional learning course he created for elementary teachers on inclusive STEAM learning. Of this balance between supported synchronous learning and independent asynchronous (context-based learning), Sharon explained "What I did appreciate significantly with this course was some of the assigned application activities that solidified my learning. For example, the maker sessions sometimes had 'independent' components that we would work on in asynchronous time." After engaging with instructors and peers during synchronous classes, opportunities for students to apply concepts asynchronously and at their own pace, with access to discussion forums and social networking sites as needed (Oliver et al., 2017), were essential for situating their understandings of making and maker pedagogies in their respective contexts. Similar to Carl, Sharon continued her making and learning in her work context. She described that she "…was energized by [her] own experiences, and [her] learning was transferred (in

some cases almost immediately) to teachers in our school." For example, after learning papertronics (the process of creating circuits on paper with copper tape, light-emitting diodes, and coin cell batteries), Sharon developed a professional learning session for the teachers at her school. Regarding this she shared, "it was a very valuable exercise and we debriefed about a few things at the end … [for example] We talked about the skills/competencies, etc., that can be developed through making."

5.2 Affordance No. 2: A Blended Approach to Support Continuous Learning and the CoI Framework

The course design (synchronous sessions and asynchronous work) facilitated on-going, continuous learning within the context of a CoI framework (Garrison et al., 1999). The tools used in the online course meant that the participants stayed connected throughout each week, communicating both synchronously and asynchronously to share resources, showcase their making products, and further their collective understanding of maker concepts (Jeong & Hmelo-Silver, 2016; Zhu, 2012). The Adobe Connect sessions allowed for real-time and immediate knowledge-building opportunities, where the teacher facilitated the learning process (teacher presence) and the students engaged in making, reflection, and discussion (social and cognitive presences) (Garrison et al., 1999). Sharon and Carl both reported that all three elements of the CoI framework were present in the synchronous and asynchronous learning opportunities. Of the synchronous sessions, Carl explained the social and cognitive presences were felt in the hands-on, small group learning: "I enjoyed breakout rooms to work at your level with others who were also at the same level of learning. This allowed me to push my practice forward." Learning with others in an online community is important, as Garrison et al. (2001) explain that "cognitive presence by itself is not sufficient to sustain a critical community of learners. Such an educational community is nurtured within the broader social-emotional environment of the communicative transaction" (p. 94). The heterogeneity of these groups may also have had an impact on students' learning; while Carl noted that the breakout rooms were structured according to "level of learning," the online context meant that students had diverse educational backgrounds and teaching roles from which they shared and collaboratively constructed knowledge (He & Gunter, 2015; Lin et al., 2008). Carl also articulated the teaching presence was felt in the scaffolded support and encouragement: "By empowering learners to lead sessions, each of us had the opportunity to grow." Teaching presence in an online community is equally as important since it has the power to facilitate student participation and interaction (Watson et al., 2016) and to connect the social and cognitive presences (Law et al., 2019). Of all three presences, Sharon explained that "There were many opportunities for learning through discourse in breakouts" and that her "biggest learning came through the [student led] maker sessions and the short presentations that

preceded the opportunities the individual groups gave for us to 'make.'" Sharon felt that this structure encouraged students to be "authentically engaged with each other in [the] maker sessions because [they] HAD to really do so in order to understand what [they] were going to be tasked to do [themselves during the asynchronous work]." In this way, social presence supported the development of cognitive presence through the "discourse in breakout groups" and teaching presence supported the development of the social and cognitive presences through the course design of peer presentations, learning groups, and the curation of course content (Garrison et al., 1999).

In addition to the synchronous sessions, the course's social networking site, NING, facilitated continuous learning within a CoI framework (Garrison et al., 1999) throughout each week. The NING allowed students to upload their making processes and reflections, to comment on one another's work, and to provide feedback to one another, extending students' physical making practices and contributing to a "digitally mediated maker identity" (Orton-Johnson, 2014, p. 145). With NING, the making that was happening offline during the week was still witnessed by the participants' online learning community (Litts et al., 2016; Orton-Johnson, 2014), and this—as well as the important discussions and knowledge building that occurred—facilitated social presence. These knowledge building interactions were also connected to the development of the participants' cognitive presence. Teacher presence was felt during the asynchronous components of the course through the design structure. For example, of teacher presence Sharon explained that the required research, research-based writing, and "the application opportunities and associated reflections (including asynchronous ones) solidified [her] learning." Having a mix of the synchronous and asynchronous components allowed for ongoing and continuous learning to occur (Jeong & Hmelo-Silver, 2016), and the three elements of the CoI framework were attended to: social presence, cognitive presence, and teacher presence (Garrison et al., 1999).

5.3 Areas for Improvement

While both participants articulated the benefit of the NING platform, Carl reported that he "found that NING was underutilized for this course" and that "it wasn't as powerful as it could have been." He felt the expectation for sharing could have been further encouraged by the instructors through more explicit course expectations. Online courses with both synchronous and asynchronous communication platforms create ample opportunities for collaborative knowledge building and social support; however, the flow of conversation is staggered, and unlike face-to-face contexts, students may not feel obligated to respond (Lin et al., 2008). This concern can be mitigated through the inclusion of guidelines for participation in the course syllabus. Another area for improvement might be an explicit focus on the best practices associated with making in a virtual environment in the course

syllabus. As education around the world has shifted to include hybrid and fully online learning models as a result of the COVID-19 pandemic, educators will need to be cognizant of these best practices. They will also need to possess the skills to apply these best practices in their future online teaching and learning practices. Since conducting this study, we have partnered with a digital credentialing company in the development of digital badges related to virtual making. Our future goals include awarding these badges to students who successfully complete the Critical Making course. These can serve as professional learning credentials.

6. CONCLUSIONS

By accessing the course remotely and through a maker pedagogies-based curriculum, the students were able to tailor their learning and maker projects to their unique education/work contexts, such that their learning was personally relevant and deeply meaningful. By leveraging the digital world through web-based tools (such as Tinkercad) and platforms (such as NING), the students were also able to learn and make in a supportive and collaborative community of practice. Fusing the affordances of online learning with maker pedagogies resulted in a rich course with deep learning for students.

REFERENCES

Alper, M. (2013). *Making space in the makerspace: Building a mixed-ability maker culture* [workshop presentation]. Twelfth International Conference on Interaction Design and Children, New York. https://teethingontech.files.wordpress.com/2013/03/idc13-workshop_meryl-alper.pdf

Bower, M., Stevenson, M., Falloon, G., Forbes, A., & Hatzigianni, M. (2018). High impact learning and teaching using 3D design and 3D printing in primary school makerspaces. In D. Bourne & L. Cameron (Eds.), *ImpaCT: Australian Council for Computers in Education 2018 Conference Proceedings* (pp. 93–106). ICT Educators NSW.

Brown, J. S., & Adler, R. P. (2008). Open education, the long tail, and learning 2.0. *Educause Review*, *43*(1), 17–32.

Bunterm, T., Lee, K., Kong, J. N. L., Srikoon, S., Vangpoomyai, P., Rattanavongsa, J., & Rachahoon, G. (2014). Do different levels of inquiry lead to different learning outcomes? A comparison between guided and structured inquiry. *International Journal of Science Education*, *36*(12), 1937–1959. https://doi.org/10.1080/09500693.2014.886347

Chua, B. L., Tan, O. S., & Liu, W. C. (2015). Using technology to scaffold problem-based learning in teacher education: Its tensions and implications for educational leaders. In C. Koh (Ed.), *Motivation, leadership and curriculum design* (pp. 119–135). Springer. https://doi.org/10.1007/978-981-287-230-2_10

Clark, R. C., & Mayer, R. E. (2011). *E-learning and the science of instructio*n. Pfeiffer.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Sage Publications, Inc.

Freeman, A., Adams Becker, S., Cummins, M., Davis, A., & Hall Giesinger, C. (2017). *NMC/CoSN Horizon Report: 2017 K-12 Edition*. The New Media Consortium.

Gallup. (2019). *Creativity in learning.* Gallup Inc. https://www.gallup.com/education/267449/creativity-learning-transformative-technology-gallup-report-2019.aspx

Garrison, D., Anderson, T., & Archer, W. (1999). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2–3), 87–105. https://doi.org/10.1016/S1096-7516(00)00016-6

Garrison, D., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education*, *15*(1), 7–23. https://doi.org/10.1080/08923640109527071

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84*(4), 495–504. https://doi.org/10.17763/haer.84.4.34j1g68140382063

Hansen, A. K., Hansen, E. R., Hall, T., Fixler, M., & Harlow, D. (2017). Fidgeting with fabrication: Students with ADHD making tools to focus. *Proceedings of the 7th Annual Conference on Creativity and Making in Education* (Article 13, pp. 1–4). Association for Computing Machinery. https://doi.org/10.1145/3141798.3141812

He, J., & Gunter, G. (2015). Examining factors that affect students' knowledge sharing within virtual teams. *Journal of Interactive Learning Research*, *26*(2), 169–187. https://www.learntechlib.org/p/111760/

Hlubinka, M., Dougherty, D., Thomas, P., Chang, S, Hoefer, S., Alexander, I., & McGuire, D. (2013). *Makerspace playbook*. Maker Media. https://makered.org/wp-content/uploads/2014/09/Makerspace-Playbook-Feb-2013.pdf

Hughes, J. (2017). Meaningful making: Establishing a makerspace in your school or classroom. In *What Works? Research into Practice.* Queen's Printer. http://www.edu.gov.on.ca/eng/literacynumeracy/inspire/research/meaningful_making_en.pdf

Hughes, J., & Morrison, L. (2018). Works of heart: Revisiting creativity and innovation through maker pedagogies. *UAL Spark Journal*, *3*(2), 150–160. https://sparkjournal.arts.ac.uk/index.php/spark/article/view/91

Hughes, J., Fridman, L., & Morrison, L. (2016). *Online "maker" modules to support production pedagogies in education* [presented paper]. Higher Education in Transformation Symposium, Oshawa, ON, Canada. https://arrow.tudublin.ie/heit162/8/

Hughes, J. M., & Morrison, L. J. (2020). Innovative learning spaces in the making. *Frontiers in Education*, *5*, Article 89. https://doi.org/10.3389/feduc.2020.00089

Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Educational Psychologist*, *51*(2), 247–265. https://doi.org/10.1080/00461520.2016.1158654

Jin, Y. (2019). Beyond content: What else did pre-service teachers learn in a making course in a teacher education program? In K. Graziano (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1563–1568), Las Vegas, NV. Association for the Advancement of Computing in Education. https://www.learntechlib.org/p/207853/

Kafai, Y. B. (2006). Playing and making games for learning: Instructionist and constructionist perspectives for game studies. *Games and Culture*, *1(1)*, 36–40. https://doi.org/10.1177/1555412005281767

Kennedy, A. (2014). Models of continuing professional development: A framework for analysis. *Professional Development in Education*, *40*(3), 336–351. https://doi.org/10.1080/19415257.2014.929293

Law, K. M. Y., Geng, S., & Li, T. (2019). Student enrollment, motivation and learning performance in a blended learning environment: The mediating effects of social, teaching, and cognitive presence. *Computers & Education*, *136*, 1–12. https://doi.org/10.1016/j.compedu.2019.02.021

Lin, F., Lin, S., & Huang, T. (2008). Knowledge sharing and creation in a teachers' professional virtual community. *Computers & Education*, *50*(3), 742–756. https://doi.org/10.1016/j.compedu.2006.07.009

Litts, B. K., Kafai, Y. B., Fields, D. A., Halverson, E. R., Peppler, K., Keune, A., Tissenbaum, M., Grimes, S. M., Chang, S., Regalla, L., Telhan, O., & Tan, M. (2016). Connected making: Designing for youth learning in online maker communities in and out of schools. In C.-K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *Transforming learning, empowering learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2* (pp. 1041–1047). International Society of the Learning Sciences. https://repository.isls.org/handle/1/371

Lock, J., Redmond, P., Orwin, L., Powell, A., Becker, S., Hollohan, P., & Johnson, C. (2020). Bridging distance: Practical and pedagogical implications of virtual Makerspaces. *Journal of Computer Assisted Learning*, *36*(6), 957–968. http://doi.org/10.1111/jcal.12452

Loertscher, D. V. (2015). The virtual makerspace: A new possibility? *Teacher Librarian*, *43* (1), 50–51.

Marsh, J., Wood, E., Chesworth, L., Nisha, B., Nutbrown, B., & Olnev, B. (2019). Makerspaces in early childhood education: Principles of pedagogy and practice. *Mind, Culture, and Activity*, *26*(23), 221–233. https://doi.org/10.1080/10749039.2019.1655651

Martinez, S. (2019, February 11). The maker movement: A learning revolution. *ISTE Blog*. https://www.iste.org/explore/In-the-classroom/The-maker-movement%3A-A-learning-revolution

Mas'ud, B., Fachruddin, A. T. C., & Syamsinar, S. (2019). Promoting passion-based learning as a solution of improving creativity in English classroom. *Inspiring: English Education Journal*, *2*(2), 165–179. http://doi.org/10.35905/inspiring.v2i2.1273

Merriam, S. B. (1998). *Qualitative research and case study applications in education* (2nd ed.). Jossey-Bass Publishers.

Noss, R., & Clayson, J. (2015). Reconstructing constructionism. *Constructivist Foundations*, *10*(3), 285–288. http://constructivist.info/10/3/285

Oliver, K. M., Moore, R. L., & Evans, M. A. (2017). Establishing a virtual makerspace for an online graduate course: A design case. *International Journal of Designs for Learning*, *8* (1), 112–123. https://doi.org/10.14434/ijdl.v8i1.22573

Orton-Johnson, K. (2014). DIY citizenship, critical making, and community. In M. Ratto & M. Boler (Eds.), *DIY citizenship: Critical making and social media* (pp. 141–155). MIT Press.

Paganelli, A., Cribbs, J. D., Huang, X., Pereira, N., Huss, J., Chandler, W., & Paganelli, A. (2017). The makerspace experience and teacher professional development. *Professional Development in Education*, *43*(2), 232–235. https://doi.org/10.1080/19415257.2016.1166448

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Papert, S., & Harel, I. (1991). Situating constructionism. In *Constructionism* (pp. 1–11). Ablex Publishing.

Peterson, L., & Scharber, C. (2018). Learning about makerspaces: Professional development with K-12 inservice educators. *Journal of Digital Learning in Teacher Education*, *34*(1), 43–52. https://doi.org/10.1080/21532974.2017.1387833

Ratto, M. (2011). Critical making: Conceptual and material studies in technology and social life. *The Information Society*, *27*(4), 252–260. https://doi.org/10.1080/01972243.2011.583819

Resnick, M., & Silverman, B. (2005). Some reflections on designing construction kits for kids. *Proceedings of the 2005 Conference on Interaction Design and Children* (pp. 117 –122). Association for Computing Machinery. https://doi.org/10.1145/1109540.1109556

Robertson, J. A. (2013). *Passion-based learning: The design and implementation of a new approach to project-based learning (PBL) for alternative education* (unpublished doctoral dissertation). Simon Fraser University, British Columbia.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*(4), 221–258. https://doi.org/10.1007/s10833-006-0001-8

Voogt, J., Westbroek, H., Handelzalts, A., Walraven, A., McKenney, S., Pieters, J., & De Vries, B. (2011). Teacher learning in collaborative curriculum design. *Teaching and Teacher Education*, *27*(8), 1235–1244. https://doi.org/10.1016/j.tate.2011.07.003

Watson, S. L., Watson, W. R., Richardson, J., & Loizzo, J. (2016). Instructor's use of social presence teaching presence, and attitudinal dissonance: A case study of an attitudinal change MOOC. *The International Review of Research in Open and Distributed Learning*, *17*(3). https://doi.org/10.19173/irrodl.v17i3.2379

Wohlwend, K. E., Peppler, K. A., Keune, A., & Thompson, N. (2017). Making sense and nonsense: Comparing mediated discourse and agential realist approaches to materiality in a preschool makerspace. *Journal of Early Childhood Literacy*, *17*(3), 444–462. https://doi.org/10.1177/1468798417712066

Yilmaz, R. (2016). Knowledge sharing behaviors in e-learning community: Exploring the role of academic self-efficacy and sense of community. *Computers in Human Behavior*, *63*, 373–382. https://doi.org/10.1016/j.chb.2016.05.055

Zhu, C. (2012). Student satisfaction, performance, and knowledge construction in online collaborative learning. *Journal of Educational Technology & Society*, *15*(1), 127–136. https://www.jstor.org/stable/jeductechsoci.15.1.127