Work in Progress: Exploration of Student Learning in Online Maker Communities

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Abstract

Over the past decade, practices related to online learning have become increasingly varied and legitimated. Whether it be formal e-learning in K-12 or at colleges and universities or casual perusing of the internet, many people have found communities online to support their own endeavors. Recently, due to the Covid-19 pandemic most colleges and universities have been forced to shift partly or entirely to remote learning due to campus closures. Further, even in cases in which a campus is open, many universities have limited access to their makerspace due to social distancing and capacity requirements. In response, this Work in Progress study investigates how online making communities and resources are supporting student learning through making. Through in-depth phenomenologically-based interviews conducted both before and during the pandemic, this study offers rich insights into how students are learning from and engaging in online maker communities/resources as a central part of their development as a maker. Through qualitative data analysis, we develop a model for how students are learning online. These findings show the role digital spaces play in developing competent, inspired makers.

1 Introduction

Increasing complexity continues to challenge engineers. Today, designers are required to expand the boundaries of design, often involving multi-disciplinary skills [1, 2]. To help cope with complexity, engineering designers must be adept at seeking and learning new information and relevant skills. Fortunately, in the digital age, we have instant access to endless knowledge and inspiration through the internet.

21st century students are integrating web-based technologies to augment their studies. Students are highly adept in using online platforms to find answers to many questions they may have and to solve academic problems [3, 4]. This informal, self-directed practice can facilitate students' active and experiential learning [5]. We have found that these self-directed online learning practices also have important implications for nascent makers.

Digital technology has revolutionized communication and transformed collaboration and networking. The rise of the maker movement, coupled with this digital transformation, has paralleled rapid growth of online making communities [6]. Online tools and communities advocate learning through making, building, tinkering, playing, and creating [7]. Members' activities in such communities generally seek to master one's own making abilities while contributing to shaping the practice for others [8]. While makers learn through these online platforms, this online learning is known to supplement in-person learning and experimentation [8].

Previous examinations of maker communities have focused on student learning within academic makerspaces. But in the digital age, student learning goes far beyond the walls of the makerspace. Online communities extend our local academic making communities connecting our students internationally to makers of all backgrounds and expertise. This paper aims to answer the question: *How are online communities and resources supporting student learning in makerspaces?*

2 Background

Makerspaces provide open-access for individuals to engage in tinkering, social learning, and group collaboration on creative and technical projects [9]. The hands on, learning by doing nature of the makerspace experience requires a design approach to problem solving [10].

Design is often recognized and taught as a team process. The ABET general engineering criteria address the social aspects of engineering education, such as the need to function on multidisciplinary teams [2]. Makerspaces provide communities of knowledge sharing and peer-to-peer learning, combined with close instruction and supervision from more advanced peers [11]. In such, students engage in collaborative learning – continuously discussing, debating, and clarifying their understanding of concepts [12, 13]. Through online engagement, collaborative learning is not fixed to a physical location, but rather, is distributed to communities across the globe.

Online learning is defined as "learning experiences in synchronous or asynchronous environments using different devices (e.g., mobile phones, laptops, etc.) with internet access. In these environments, students can be anywhere (independent) to learn and interact with instructors and other students" [14]. Online learning is a tool that can make the teaching–learning process more student-centered, more innovative, and more flexible [15]. Research suggests online learning environments support learning outcomes comparable to face-to-face instruction [16-18], though this finding does not yet appear substantiated for online maker communities versus in-person maker communities.

Halverson and Sheridan's broad definition of the maker movement "the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others" accounts for the "digital" aspect of the maker movement [19]. Given the dramatic increase of technology as a means of social connection, it makes sense that the maker movement has spread online as well. Makers may share their experiences and projects through a variety of platforms such as video-host sites, online forums, or websites curated for makers such as Thingiverse creating online communities which extend making communities—our local academic makerspace communities included—to connect makers to makers around the world.

Digital maker cultures have created collaborative learning communities of many forms. Niemeyer and Gerber found the YouTube making community exhibits a collaborative, participatory learning environment to create new designs where all participants are highly engaged, work together to teach, learn from each other, and collaboratively reach common goals [20]. Platforms such as Thingiverse allow visitors to download publicly available files, reproduce them using local fabrication equipment, and reupload their "remixes" to the site to share with other makers. This creates a community of makers contributing to the development of new designs by iteratively remixing and refining one another's work [6]. Oehlberg, Willett, and

Mackay suggest this may also provide an entry point for new makers, who can dissect and build upon other's work to kickstart their own making practice [6].

3 Methodology

In this study, 31 semi-structured interviews with 14 different participants were conducted at two public U.S. universities (Big City U & Comprehensive U). Each university has campus makerspaces with rapid prototyping equipment (e.g. 3D printers) and typical manufacturing equipment. Interviews were conducted on the campuses in 2019 prior to the move to remote learning, and thus, reflect students' more "typical" use of online activities in their learning experiences. All interviewers were audio-recorded and later transcribed. There was a total of four interviewers, three from Big City U and one at Comprehensive U. All of the Big City U interviewers were mechanical engineering students. Two were white men and graduate students, and the third, also a white man, was a senior undergraduate student. The Comprehensive U interviewer was a white woman and a graduate student in the communication and advocacy graduate program.

The interview aimed to capture *how* students are experiencing learning in a makerspace. The research methodology was developed in previous work seeking to better understand women's experiences in a makerspace [Removed for Double Blind Review]. Irving Seidman's *Interviewing as a Qualitative Research* [21] outlines the in-depth phenomenologically based interviewing approach utilized. The method consists of three consecutive 90-minute interviews designed to evoke interviewees' lived experiences through an open-ended, semi-structured protocol. In order to gather more participants, a single-targeted modified interview protocol was developed from this and used as well. In both interviews—the three-series and the single targeted interview—the participants' lived experiences, meanings, and journeys as makers were the focus of the data collection.

3.1 Participants

In total, 14 students participated in the study. From Big City U there was four men and one woman participant, and from Comprehensive U there were 5 men and 4 women participants. Participants were predominantly upperclassman with the exception of one sophomore and one graduate student. From Big City U, four participants were mechanical engineering majors and one was industrial design. From Comprehensive U, all participants were undergraduate engineering majors. Comprehensive U does not have a distinction between the different disciplines within engineering.

The study sought out students who were highly engaged in the makerspace. To achieve this, snowball sampling was implemented—a method whereby current participants refer the researcher to other viable participants [22]. Students were recruited via the makerspace Facebook page, word of mouth, and mutual connections.

3.2 Interviewing Process

Big City U used the single-targeted interview and Comprehensive U used the three series interview. Interviews were conducted in an experiment room to ensure there were little to no distractions. After each participant's consent, interviews were audio recorded and transcribed. The respective interviewer edited the transcription to ensure anonymity and accuracy.

Big City U

The single targeted interview protocol used by Big City U is rooted in the findings and themes that emerged in previous work [Reference Removed for Double Blind Review]. This single interview adapts the original three series protocol to a more concise, single 60 to 90 minute session. The open-ended interview begins by asking participants to draw a timeline of their experiences as a maker and includes follow-up questions as appropriate. Table 1 provides a sample of questions included to help guide the interview. The interviewers aimed for the interview to feel more as an open conversation rather than a formal interview.

Table 1: Questions to guide single, targeted interview

Questions/ Topics to Guide Interview
Has your way of thinking through a problem changed? Could you walk me through an example?
How would you characterize *how* you learn in the makerspace?
What are some of the things that you have learned how to make in the makerspace?
Overall, how has your experience in the makerspace impacted your life?

Comprehensive U

The three series interview process used by Comprehensive U was comprised of three 90-minute interviews with each delving into different aspects of a person's lived experience. The first interview concentrates on the person's life history. The interview aims to understand *how* the participant became involved in the makerspace, capturing the context and history of their making experiences. The second interview details the person's current experience. Participants are asked to bring their own projects to the interview to provide a tangible reference. This provides a starting point for discussion as well as a means to understand the participants making experience in the project better. In the third interview, participants reflect on their experiences making and the meaning to them. The participants are asked to draw a timeline of their making experiences, same as in the single targeted interview.

3.3 Data Analysis

After all of the interviews were conducted, transcribed, and deidentified, qualitative data analysis began. In total 974 single-spaced pages of transcriptions were produced. Interviews were analyzed using N-Vivo qualitative data management software to manage the large volume of data. Three researchers took part in data analysis, an interviewer, an undergraduate researcher (UGR), and a faculty researcher. The faculty researcher trained both the interviewer and the UGR on qualitative research methods.

First, the two student researchers were trained to code the interview data using a makerspace learning typology that captures how and what students are learning in makerspaces, accounting for learning by doing, learning through others, content and cultural knowledge and skills, ingenuity, and self-awareness [Removed for Double Blind Review]. In order to determine the degree of coding agreement between the two researchers, Miles and Huberman's [23] methods for assessing interrater reliability were employed. The interviews were unitized by one researcher and agreement was established if both researchers coded for the same categories of the makerspace learning typology. An inter-rater reliability of 83.7% was established after coding four interview transcripts. The baseline for an acceptable level of agreement asserted by Miles and Huberman is 80% coding agreement on 95% of the codes. Thereafter, each researcher coded half of the remaining data. Importantly, the focus of this study emerged as the researchers consistently saw themes related to online learning appearing, thus updating the learning typology to address that form of learning in making and begging further exploration and analysis. The researchers revisited the data inductively and engaged in an iterative coding process through which they identified the nuanced themes discussed herein.

4 Findings

The in-depth phenomenological interview approach provides a deep look into the students learning in and out of makerspaces. As the interviewers were analyzing the data, the significance of online learning was apparent. Nearly three quarters (73%) of students interviewed mentioned online learning—even though the interviewer never prompted the subject. Through multiple cycles of coding, the learning model shown in Figure 1 was developed. The model aims to show how students are learning online and how this online learning supplements their in-person making.

The online learning cycle is experienced as "endless" to students. Makers discover information online, whether they passively came across it or actively sought it out, and then apply that new knowledge in their making. Then when approaching the next making project they repeat the cycle – returning to online sources as a means of learning.

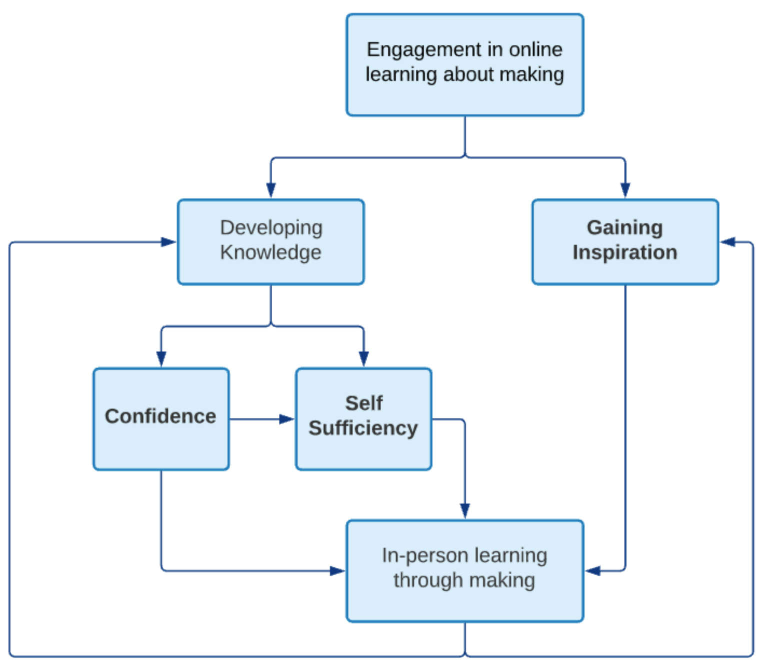

Figure 1: Online Learning Model

There are two main pathways in the model: (1) developing knowledge, and (2) gaining inspiration. As makers come across information online, they develop new skills and knowledge to add to their toolbox or find inspiration for a project—sometimes both. Through being able to develop maker-related skills virtually, students are able to develop confidence to apply that knowledge through physical making. Further, by having the confidence to try new tools, as well as having expert information at their fingertips, online learning appears to be fostering the development of self-sufficient makers. The following sub-sections describe the identified three important features of the model that were key to student experiences: confidence, self-sufficiency, and inspiration.

4.1 Confidence

Confidence is described by students as simply being comfortable to walk into the makerspace. For example, Liam, a Junior at Comprehensive U, recounts his first experience welding. Prior to first stepping foot in the makerspace, he watched videos to understand what to expect, common pitfalls, and the tips and tricks to a good weld. When he went to do his welding training, he impressed the instructor—his welds were good the first try. Liam recommends for any future makers who want to pursue welding to follow a similar process as him:

> I would tell them before entering the makerspace to watch as many YouTube videos on how to weld, different types of welding, the different nuances of welding. Like the feed speed, what kind of wire you use, how to weld with different materials because there's just so much information you can learn that way and even if you don't absorb all of it, even if you just have it playing in the background, just kind of being vaguely familiar with it even, for me at least, inspires a lot **confidence**, especially with something that can be as daunting as welding.

The significance of online learning for Liam's weld experience is clear. Through what appears to be a passive experience of watching a video about welding, the feeling of intimidation related welding is diminished. Thus, through visiting online platforms such as YouTube, students are able to know what to expect in the makerspace—without ever stepping foot in one. The sense of familiarity this brings can be profound for maker's confidence.

4.2 Self Sufficiency

Self-sufficiency was described by students as being able to teach yourself the fundamentals, at the very least, of what you're working on. Having instant access to expert knowledge is producing more well-versed, self-sufficient makers. For example, students working on a project using an unfamiliar material are not limited to seeking assistance during a materials professor's office hours; they can just search for the information online. In fact, oftentimes it's expected for students to take the first step of doing their own research before seeking out help from others. Through virtual communities and online resources, makers reap some of the similar benefits that one experiences through collaboration within the contexts of their independent work.

Confidence was also an important precursor to self-sufficiency in students' accounts. In the prior example, Liam was not required to weld himself; he could have instead dropped off his parts at the machine shop to have the weld completed by the shop. He had an interest in welding, though, and he built confidence through watching YouTube videos before taking the step of learning to weld himself. This experience developed his skillset and helped him to become a more independent maker.

Will, an upperclassman at Big City U, spoke of what he coined “creative confidence.” The belief that he could complete a project independently even if he never done it before.

> I'm going to go to look it up and watch some YouTube videos or something, and figure out how to do that other part, because I know I can do this. I know I can do 75%, 80% of that project without doing anything else, I'll look up the rest.

Will is confident that through his past experiences, even if not directly applicable, and the endless online resources, he can figure just about anything out by himself. Like Liam, Will’s experience and confidence was an important pathway toward self-sufficiency as a maker.

4.3 Inspiration

Beyond gaining new skills and knowledge, the internet was described as a phenomenal resource to find inspiration to apply to one’s own making. Students interviewed used words like effective, faster, simpler, and more viable to describe how the internet inspired their making. Whether it was watching their favorite makers new YouTube video and wanting to recreate the project themselves, or idea generating for a class project, students saw online inspiration as an important pathway to making.

Thomas, a Junior at Comprehensive U, asked his professor for help in improving his bike design and was suggested to use Google images. They pulled up the search engine on the projector and parsed through images.

> If you don't know specifically what you're searching for and you just look up on Google Images something that's related to it, then you might find something that helps with it. In this instance, we weren't looking for a redesign of that part specifically, but once we saw the picture of a bike that somebody had already made, then we knew that could be used for this.

Taking directive from the image found, Thomas was able to implement the redesign in his own work, improving upon an aspect of his design he had no intention of changing.

5 Discussion

Prior research has demonstrated the link between experience and confidence [24]. Though online learning is not a physical, “hands-on” learning experience, it is still an interactive and engaging learning experience. From the confidence developed through online learning, students in this study stepped out of their comfort zone and developed new skills within the physical makerspace. They were able to apply expert knowledge found online in their own work, extending their independent capabilities drastically. This suggests blending online, out-of-class learning with more active learning activities in the classroom (e.g., flipped classroom), as opposed to traditional lecturing, is an approach our students intuitively apply to their own personal making-focused learning.

To be sure, using the internet as a source of inspiration is nothing new. Take for example Pinterest, a popular social media site used to "discover recipes, home ideas, style, and other ideas to try." People are using online platforms to assist in all aspects of life, including making. With the abundance of projects posted online in making communities, it's an effective way for makers to find ideas and inspiration to apply to their own work. Using a search engine, such as Google, has proven to assist people in memory retrieval that may help improve their ideas [25]. Indeed, engineering educators can leverage student interest in such social media platforms toward creating a more connected classroom, enabling students to share ideas, questions, and feedback.

Given the relatively recent growth of the maker movement, coupled with relatively quick build-up of campus makerspaces, occurring alongside the growth of ubiquitous computing, it is not surprising that our digital-native students engaging in our makerspaces are turning to social-media and other community-based making websites and forums to learn about materials, electronics, tools and tooling as well as to find inspiration, methods, and procedures. Websites such as TinkerCAD and 123Design coupled with early desktop 3D printer such as the MakerBot brought digital design, modeling, and printing to the non-expert, while sites such as Thingiverse showed the non-expert what was possible. Beyond these simple making solutions, the internet provides extensive making and manufacturing knowledge and inspiration with instruction and projects for the laser cutter, vinyl cutter, lathe, CNC, waterjet – just to name a few. Everything from how to videos, pictures of projects, and project plans are available. Many of our students have grown up interfacing with this software and hardware using their laptops, tablets, and phones at their homes, in their primary and secondary schools, and now at their Universities.

And now, more than ever given the Covid-19 pandemic, there is urgency to understand how our students learn online—both independently as well as coupled to in-person, virtual, and hybrid communities. Our rapid shift from a traditional face-to-face course delivery system on most residential campuses to online instruction has left many grappling at solutions that accommodate our students, encourage engagement, and facilitate learning. And while it is unknown whether we will be able to return to "business as usual" in terms of in-person learning, findings such as ours show that there is promise for the effectiveness of e-learning even in making centered engineering programs and allow us to ask "should we return to business as usual?" Liam described his experience learning online:

> It's that informal background and theoretical knowledge, which is I think very similar to the knowledge you get in a classroom; I think it is paramount to really all education that you get that contextualized experience and that actual application of it. Cause they can teach me something in Mechanics and Materials and I'll take their word for it but it's not particularly intuitive right? The Young's modulus of steel, I get what that means, I get what it represents, but actually seeing it in, in action knowing that if you weld too fast on cast iron it will crack because of that. Getting that application is really useful, solidifies the information you learn and contextualizes it.

Connecting theoretical concepts with application: for Liam it is through YouTube, for the authors on this manuscript, it was through choreographed laboratory experiences. We ask, does it matter which channel is employed? What seems clear is that contextualized learning, such watching a YouTube video, facilitates both individual and collaborative processes of learning and knowledge building [26]. This promotes a rich, deeper understanding for students, and we believe that these online channels should be integrated and celebrated as critical component of one's development into a professional and an engineer.

6 Conclusions

In the work presented in this paper, insight is presented into how learning online supports students' experiences in makerspaces. Key themes identified through analysis of ethnographic interviews are presented as well as our initial model illustrating how students use online learning to supplement in-person learning and making in makerspaces. In essence, for our engineering students, makerspaces facilitate a hybrid learning environment. We believe that this online learning model shows promise for transferability beyond making as well. In other words, whether it's looking for a recipe for dinner tonight or learning how to weld a bike—we suspect that the process may follow the model created (Figure 1).

While maker communities are often thought of as a physical space, in reality, they extend beyond the limitations of one's local means. Online platforms are supporting makers confidence, developing their skillset, and providing a way of sharing and exploring endless projects from makers around the world. These digital spaces are furthering the development of competent, inspired makers.

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