Developing Makerspaces as Sites of Entrepreneurship

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ABSTRACT
Makerspaces are providing new opportunities for entrepreneurial development. Based on participant observation and a series of in-depth interviews in an entrepreneurial makerspace, we found that the socio-technical environment of a makerspace promotes entrepreneurship by leveraging community-based values of social support, transparency, exploration, and empowerment. The openness of a shared space, access to social technologies, and community of social support helped members develop entrepreneurial skills and self-efficacy. We add to CSCW literature on expanding the role of makerspaces as places of career development through entrepreneurship.

Author Keywords
Entrepreneurship; makerspace, hackerspace, social computing; learning; self-efficacy; collaboration.

ACM Classification Keywords
H.5.3. Information interfaces and presentation (e.g., HCI): Group and organizational interfaces.

INTRODUCTION
The demographics of makerspaces are expanding. Originally created for hobbyists who make for fun, makerspaces are now gaining popularity as sites of entrepreneurship [47]. While many still treat makerspaces as third places—spaces outside the workplace and home that foster socialization and greater creative interaction [58]—more people are starting to use makerspaces as places to launch new ventures.

If we visit a makerspace today, we might see a person building an LED lamp for his home, but we might also see a person building a series of clocks she intends to market on her personal website, an artisan entrepreneurship platform like Etsy [89], or a crowdfunding platform like Kickstarter [90]. Already, makerspaces have been the birthplace of some of today's most successful ventures, like the Pebble Smartwatch, Makerbot 3D Printer, Oculus Rift, and Nest Thermostat [25]. Yet, our understanding of this expanding professional role of makerspaces is limited.

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Figure 1: Makerspace members build a series of kitchen products funded by Kickstarter; openness of a shared space and community of social support helps to develop entrepreneurial skills and self-efficacy.

As such, CSCW scholars are calling for further research to understand how makerspaces become sites of entrepreneurship [46,47]. Previous work on makerspaces has primarily focused on how they serve social and civic needs, such as encouraging making activity among those who often lack access [9,12,21,30,48,62,64] and serving as places of personal empowerment [23,28,37,43,73]. However, an understanding of how makerspaces support development of entrepreneurs is needed to design makerspaces beyond places of just tinkering. In this study, we address the following research question:

How does the socio-technical environment of a makerspace support the development of entrepreneurial skills and self-efficacy?

We focus on skill and self-efficacy development because entrepreneurs must not only learn how to perform a wide range of tasks, such as manufacturing, publicity, and management, but also have the confidence to do so without extensive guidance or encouragement [69]. People who have greater entrepreneurial self-efficacy, belief in their ability to perform marketing, management, and innovation-type tasks, are more likely start their own businesses [14].

Makerspaces promote frequent testing and development of new ideas [51], activities critical to the early stages of fostering entrepreneurship [69]. This environment of exploration can be difficult to capture in traditional entrepreneurial

development contexts where people are often driven by competition and intellectual property protection [69]. We take a socio-technical perspective to understand how entrepreneurs leverage a makerspace's physical, technological, and online resources to promote social support, transparency, exploration, and empowerment—community-focused values previously observed in maker cultures [23,28,37,46,73,76,79]. These values, paired with socio-technical supports to observe and work alongside people of diverse skillsets, provides a unique opportunity to develop skills and confidence in an innovative and safe environment before launching larger-scale ventures.

Observing the progression of a makerspace from an empty warehouse to a place of thriving, social, shared entrepreneurial practice allowed us to study how relationships were formed, values established, and technologies adopted to facilitate skill and self-efficacy development in entrepreneurship. We performed a five week long participant observation of a new entrepreneurial makerspace in addition to 22 semi-structured interviews with members, informal observations of online communication channels, and follow-up observations and interviews with the makerspace founder a year later, to understand how people develop entrepreneurial skills in a maker setting, and the role of social technologies in this process. We build on prior research on maker communities, entrepreneurship, and social computing by performing one of the first studies identifying how people leverage the socio-technical resources in a makerspace to encourage entrepreneurial development, and how this entrepreneurial development benefits from community-focused values commonly observed in maker cultures.

RELATED WORK

In this study, we explore how individuals develop as entrepreneurs in an entrepreneurially-focused makerspace. We build on related work from entrepreneurship, makerspaces, and social technologies to understand how the socio-technical environment of makerspaces can provide unique development opportunities and challenges for novice entrepreneurs.

Learning in Entrepreneurship

Entrepreneurship requires strategic skills, such as building new products and services, marketing to distribute one's innovations, and controlling finances to manage costs and profits [14,39,54,69], as well as the self-efficacy to perform these skills under uncertainty [69].

Skill acquisition in entrepreneurship is experiential. Novices learn through trial-and-error, frequent testing of new concepts, and practicing skills in authentic, social environments [16,71]. Watching similar others and receiving validation while completing related tasks builds entrepreneurial skills and self-efficacy—belief in one's own abilities to succeed at entrepreneurial tasks [3,14,17], which influences subsequent attempts at entrepreneurial activity.

Apprenticeship—observing and working alongside an expert to learn new skills—is considered one of the most effective opportunities for experiential learning because novices learn-by-doing with longitudinal access to expert guidance [15,44]. For example, blacksmiths, printmakers, and carpenters traditionally train novices through apprenticeship as the work is complex and difficult to learn just by book or oral instruction [15].

However, there are limited opportunities for apprenticeship in entrepreneurship because, like with most areas of pedagogy, entrepreneurship experts have limited time and resources to provide long-term in-depth instruction to multiple novices [69,71]. While formal approaches to entrepreneurial skill acquisition, such as seminars, videos, and books [66] are still heavily used [87], more experiential sources like leveraging social networks and trial-and-error, have been argued to be more effective [38].

While accelerator and incubator programs often provide and scaffold networking and mentorship opportunities, they are inaccessible to most people, accepting between 1-5% of applicants [10]. Conversely, while Massive Open Online Courses (MOOCS) offer open access to entrepreneurial education, they are still limited in the range of authentic experiences and guidance that they can support [40]. Accessible apprenticeships are needed to support entrepreneurial skill acquisition, leading to greater levels of entrepreneurial activity [38].

Makerspaces as Sites of Entrepreneurship

Makerspaces offer a site for accessible entrepreneurship apprenticeships by offering hands-on manufacturing experience in supportive social settings [38]. While makerspaces may describe their set of activities (e.g. craft, repair [32,63], hacking [23,47]), these practices should be viewed as "shared family resemblances" where the differences between different makerspaces' particular activities and goals only adds deeper meaning to how we view making [45].

Toombs et al. argue that makerspaces rely on community-based values to survive and thrive [79]. Community-based values observed in makerspaces include the promotion of social support [76,79], transparency [42,46], exploration [28,75], and empowerment [23,28,37,43,73], all of which are useful for fostering apprenticeship activity. A more open and supportive community promotes observation, interaction, and self-efficacy development during early stages of entrepreneurship when novices often work alone and with little guidance [18,29,71].

Historically maker communities have been wary of supporting the goal of entrepreneurship, believing that it goes against principles to combat consumerism and profit-driven commercialization [23,45,47,63]. Yet, recent work have started to describe how entrepreneurially focused makerspaces are able to promote business development while fostering an open and creative atmosphere [45–47]. In a 4-year long ethnography of hackerspaces in China, Lindtner

et al. describe how these places help bridge China's emerging creative activity to the large-scale fabrication industry to help turn more ideas into a reality [47].

Entrepreneurially focused makerspaces are not yet widespread, providing a prime opportunity to study how these makerspaces are being designed and run to foster entrepreneurship in a way different from more established avenues like schools and business accelerators. Our study focuses on an entrepreneurial makerspace in the United States where people are interested in hands-on making and selling of one's products. This activity reflects efforts by U.S. President Obama who has promoted making as a way to encourage the creation of American-made products [91].

Skill Acquisition in Makerspaces

Makerspaces have already gained popularity as viable avenues for developing problem-solving skills and self-efficacy in engineering and science [5,42]. They provide a place for people to tinker with tools not often found in classroom environments [5] and facilitate increased communication between people with similar project interests [42]. Having access to a community of people with different skillsets, and who are motivated to help each other, provides opportunities for distributed forms of apprenticeship.

Novices can combine instruction and social support from multiple sources to acquire the diversity of skills and self-efficacy needed to perform entrepreneurial work. This distributed access to opportunities is particularly useful for novice entrepreneurs, especially underrepresented populations like women or older adults, who seek advice and other forms of support, but are most likely to lack access to adequate resources and training [18,29]. Makerspaces have been shown to provide a safe and empowering environment for a range of under-represented populations [9,12,21,30,48,62,64], including youth [21,48,70], older adults [64,73], and racial and gender minorities [23,56].

Social Technologies and Entrepreneurship Development

In addition to studying in-person interactions, we also seek to understand how social technologies used by makerspace members are changing opportunities to participate in entrepreneurship activities. We define social technologies as any type of online tool or platform that allows people to communicate, interact, and/or share information or resources with each other [41]. Together, the social technologies, physical space, and community make up the socio-technical environment of the makerspace [80].

Social technologies make it easier for people to share work processes [52], identify experts [31,53], and seek mentorship and help [11,19]. For instance, Rees Lewis et al. describe how an online community platform can facilitate project activity awareness between novice innovators and their expert coaches [60]. Already various social technologies that facilitate learning, resource sharing, and community development have been adopted in communities of distributed entrepreneurs [36]. However, we have yet to understand how social technologies are facilitating entrepreneurial skill and self-efficacy development in a physical makerspace environment.

For instance, crowdfunding platforms were originally created to financially empower entrepreneurially-inclined artists, designers, and makers by helping them raise funds without having to rely on the support of large corporations like banks and venture capital firms [24]. Crowdfunding, the practice of leveraging an extended social network to fund one's entrepreneurial endeavors [4,24], has been shown to be highly social in that the work relies on the combined and orchestrated efforts of supporters, peers, and mentors [36]. Many crowdfunding entrepreneurs have even reported that they crowdfund their work not just for the money, but to develop professional skills and a larger and more active community of social support [24,33,36]. Using social technologies in combination with membership in a physical makerspace may provide more avenues for building these communities of support around one's work.

Similarly, others have studied how novice innovators seek project feedback through social media [34,35] and have developed tools to facilitate higher quality feedback on creative [50,83,84] and entrepreneurial [26] work. While project feedback technologies have long been developed for enterprise contexts [67,68,85,86], entrepreneurs do not work under a shared company umbrella and lack access to built-in networks and company-produced knowledge sharing technologies. Therefore, it is important to understand how publicly accessible social technologies can be adopted to support entrepreneurial work and skill sharing outside the enterprise.

Social technologies provide access to distributed experts and expertise at a time when today's workforce desires greater independence and freedom in their careers than ever before [55,57]. One in three Americans identifies as a freelance worker [88], and the number of entrepreneurs continues to increase every year [20]. As today's professionals increasingly choose to lead independent professional lives, we see a concomitant increase in the number of co-working spaces [81], makerspaces and hackerspaces [49], and incubators [25], suggesting that people who work on their own ventures still desire regular social interactions with mentors and peers to develop professional skills and self-efficacy. It is imperative for CSCW researchers to understand how socio-technical resources, such as shared spaces and social technologies, can enhance skill and self-efficacy development in professions like entrepreneurship where the work is complex and often isolating [69].

METHODS

Research Setting

To address our research questions, we performed a 5-week long participant observation of a new Chicago-based makerspace from July-August 2015. Data collection took place

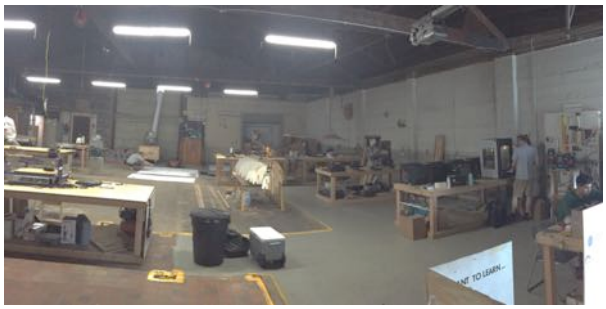

Figure 2: ORD1's open layout allowed members to maintain awareness of all activities going on inside the space.

at ORD1 (alias chosen based on Chicago's airport code), which launched in July 2015. The goal of ORD1 was to create a place where people could come together and have the tools and social resources to develop new products and services. ORD1 was unique from many existing makerspaces in that it encouraged entrepreneurial activity and was created as a 5-week long experiment to test the viability of developing a longer-term makerspace.

The space was a 4,300 square foot one-story building with an open floor plan located in an urban area at street level in Chicago. The space was previously a meatpacking warehouse and was scheduled to be torn down to build condominiums. Because the space was vacant during the months prior to teardown, the makerspace founder convinced the landlord to use the space for the experimental pop-up makerspace, leasing him the space for one dollar. Due to the success of this experiment, the setting of this community has been moved to another permanent location in Chicago. During data collection, ORD1 was typically open from 10am to 10pm, seven days a week.

Physical Resources

ORD included six 3-D printers, two table-top mills, one laser cutter, one table saw, one cabinet saw, one drill press, a plotter, soldering irons, and other basic tools (e.g. hammers). Because of the founder's connections and reputation in the entrepreneurship community, companies like Makerbot, Bosch, and Inventables, agreed to loan machinery. Gravel parking lots were located to the west and south of the building for outdoor and larger projects. A local company loaned their renovated airstream, which was parked in the adjacent lot and served as a "clean space" to work.

Social and Web Technologies

The founder created a group email list, Slack account, and Facebook Page to promote both community socialization and publicity before, during, and after the experiment. The email list was primarily used for announcements, such as public events. The Slack account was more commonly used for community socialization and included 14 channels, such as #general, #documentation, #events, #ideas, #maintenance, and #random. Each channel had its own unique purpose and allowed people to subscribe to different types of conversations. For example, #documentation was a place for people to post pictures of their work process, while #maintenance was used to announce when certain machines were in need of repair. There was limited wi-fi in the space provided by a portable Internet device lent by one of the ORD1 members. In addition, the ORD1 founder encouraged members to post photos of activity on social media, tagging the location of ORD1 and using the ORD1 hashtag. The public posts on social media and the Kickstarter page served as publicity material for the community.

People

Three months prior to opening, the founder of the makerspace invited 40 people from Chicago who represented a diverse range of skills and creative interests to join ORD1. Those invited included professional graphic designers, local community builders, design entrepreneurs, architects, teachers, and industrial designers. Ages ranged from 25-60 years old. Once ORD1 opened its doors, the founder invited friends-of-friends to join, as well as curious passerbys. By the end of the 5-week long data collection period, 103 people (27 female) were included on the email list as people who were welcome to work in the space. Based on a daily attendance sheet, 76 (20 female) of the 103 people visited the space at least once, while 35 (15 female) visited more than twice. In a Kickstarter campaign that raised $10,000 during the months prior, the founder encouraged contributions in exchange for makerspace access, but then decided to charge no fee to new members once the space opened.

Between 5-15 people would work in the space at one time. The founder gave a personal tour to each of the new members, but there was no certification process or official orientation as members were expected to reach out to each other if they had questions. Three local high school students served as "interns", taking attendance, keeping the space organized, and watching over the space when the founder was absent in exchange for a stipend and access to the space's resources and community.

The founder of the makerspace had extensive experience developing startups to support creative entrepreneurs. He invested $40,000 into buying some initial machinery and tools for the space. The founder was in charge of opening and closing the space, managing space facilities (e.g. electricity, water, wi-fi), giving tours, managing relationships with the press, and organizing events. While members of the space tried to help out when they could, the founder often described being overworked and low on sleep.

Data Collection

The first author performed the majority of observations, by visiting the space for 20 hours each week (total of 97 hours), performing field work through photographs, taking field notes describing member interactions and work processes, having informal conversations, helping with people's work when needed, facilitating member interactions, and leading community tours when the founder was absent or busy. Field notes were taken both in the space during free time and after being at the space each day. The second author conducted 20 hours of observation as well as manag-

ing the relationship with the founder whom she had met at a series of formal and informal meetings at different design and maker events.

The space was originally publicized through a Kickstarter campaign to raise funds for a zine, a small-circulation self-published magazine that would document the growth of the community. Similar to other participatory research approaches performed in previous makerspace studies [22], the researchers' roles also included documenting what was happening in the space in order to inform content for the zine. All members knew about the zine and research project and agreed to be photographed.

During data collection, our research question was not yet clearly formed, although we were interested in understanding how the social aspect of the makerspace supported entrepreneurial activity broadly. Therefore, we took particular note of how members interacted with each other, for what purpose, what tools were used for these interactions, and how these interactions informed their work. For instance, rather than just focusing on an individual's relationship with tools, as described in previous CSCW work on creative spaces [13], we sought to more deeply understand how an individual's work was informed by interpersonal interactions happening in the space and online.

Following observations, we also conducted interviews with 22 of the most active community members. Interviews followed a semi-structured format with questions around what skills they learned, who they came to know, how it affected their confidence, and their use of social technologies such as Slack, Instagram, Facebook, and the listserv. Interviews lasted for 30 minutes on average and occurred in person and by phone depending on the interviewee's availability. All interviews were recorded and transcribed.

We continued to follow up with the next iteration of ORD1, henceforth referred to as ORD2, by monitoring the social media channels (Slack, Facebook, and Instagram) and having informal conversations with the makerspace founder throughout the year as he prepared for and launched ORD2. We consider these conversations as secondary data to supplement our understanding of how activity in ORD1 informed the next version of the community.

Data Analysis

We performed a thematic analysis [6,8] to analyze the data over three rounds of coding. The data was first analyzed by two researchers who read over the interview transcripts and field notes, making a list of general themes that emerged, such as entrepreneurship, learning, self-efficacy, community development, and social technologies. This produced an initial list of 14 codes. In the second round of coding, we analyzed each theme more in-depth by identifying more specific codes. For example, under the theme "learning," we identified codes of "help-seeking," "mentorship," "workshops," and "observation." The first two rounds of coding led to the development of our research question—*How does the socio-technical environment of a makerspace support the development of entrepreneurial skills and self-efficacy?* In order to answer our research question, we performed a third round of coding informed by the *theory of cognitive apprenticeship* and *social cognitive theory* to identify mechanisms of skill acquisition and self-efficacy respectively. We used the categories within cognitive apprenticeship and social cognitive theory to further code the data around how ORD1 members developed entrepreneurial skill and self-efficacy in a social environment. All names have been changed for anonymity.

Cognitive apprenticeship

Cognitive apprenticeship outlines six mechanisms of skill acquisition: modeling, coaching, scaffolding, articulation, reflection, and exploration. *Modeling* involves an expert performing a task so that learners can watch and emulate their processes [2]. *Coaching* involves having someone provide feedback and advice as they see fit or as problems arise [15]. *Scaffolding* refers to the supports a coach may provide to facilitate learning, such as flash cards [61]. *Articulation* involves the learners explicitly describing their knowledge, reasoning, and problem solving processes as they perform the task [7]. *Reflection* involves the learner looking back at their finished work to identify opportunities for improvement [65]. Lastly, *exploration* is when the learner performs the skill in an authentic environment with few to no supports. Together, these mechanisms outline the multiple approaches to facilitating effective apprentice-like learning. We describe which of these mechanisms were most prominent in our observations and interviews to describe how entrepreneurial skill acquisition occurred in ORD1.

Social Cognitive Theory

Bandura's Social Cognitive Theory describes how self-efficacy is developed through experience of *mastery* (experiencing oneself succeed in tasks), *modeling*[1] (observing others perform tasks), *public validation* (receiving feedback and encouragement from others), and *physiological states* (physical and emotional response to a situation)[3]. We used these categories to further code the data around how ORD1 members developed entrepreneurial self-efficacy in a social environment.

FINDINGS

Developing an entrepreneurial makerspace goes beyond inviting people with entrepreneurial goals. It involves creating opportunities offline and online to develop skills and self-efficacy in a range of tasks, from manufacturing to marketing, all while engaging in a meaningful social con-

[1] Both cognitive apprenticeship and social cognitive theory use the term "modeling," but operationalize them differently. From now on, we will call modeling in cognitive apprenticeship as "modeling (cognitive apprenticeship)," and modeling in social cognitive theory as "modeling (social cognitive theory)."

text. Based on over 10 years of previous experience developing online tools for novice entrepreneurs, the ORD1 founder identified a need to create a physical community that included the benefits of social technologies (e.g. quick access to peers, distribution) with the benefits of a physical space (e.g. face-to-face interactions, manufacturing). He realized that novice entrepreneurs needed access to open participatory systems both online and offline to support their entrepreneurial development. We performed participant observation and interviews in order to understand how ORD1 members developed entrepreneurial skills and self-efficacy by interacting with people both in the physical space and using social technologies.

Developing Entrepreneurial Skills

We analyze entrepreneurial skill development through the cognitive apprenticeship framework [15]. Because there were no formal mentor-apprentice pairings as are typical in apprentices, we use this framework to understand how members of the space combined distributed instruction from multiple members online and offline to experience *modeling*, *coaching*, *scaffolding*, and *exploration*—the most prominent examples of cognitive apprenticeship methods represented in our data. We present the findings in order of prevalence. And while we present each mechanism individually, in reality, there were instances of overlap.

Modeling (Cognitive Apprenticeship)

We found that the transparency and exploratory nature of ORD afforded by the open floor plan and community use of social technologies provided opportunities to develop skills via modeling. Modeling in cognitive apprenticeship involves learning a task by observing expert behavior [15]. By observing experts offline in the space and online through social technologies, members were able to try out new skills and follow along with expert thought processes.

For instance, a self-described product designer, explained how being immersed in ORD1 provided greater exposure to new methods of making that he had not encountered:

"It's hard to find other people who are kind of the same way. So, it was an opportunity to be together with other people…You learn things that apply that you don't necessarily think to try to learn through normal channels."

For instance, Lee, a member who had launched over four successful Kickstarter campaigns wanted to learn better prototyping techniques. He then approached an art student who he saw using the 3D printer to print complex shapes. Lee worked alongside the art student at the 3D printers asking questions as needed, and eventually prototyped a new drinking product, which has since raised over $40,000 on Kickstarter. In return, the art student as was able to witness how a more experienced entrepreneur started his design process to turn his creative work into a viable product.

While modeling allowed people to observe more experienced others, we noticed a tension in terms of how people described the social and open aspect of the space. Members enjoyed being around other creative people, but it was sometimes distracting. The open layout provided a way for everyone to see what others were doing, but also sometimes limited social interaction and new member onboarding because the scattered presence of high-power tools were intimidating and limited conversations with their sound.

This dichotomy between freedom and structure created by the open layout seemed to both promote and inhibit skill sharing, especially when people were often tied to deadlines and client expectations. One professional furniture designer described this dynamic particularly well:

"I showed up at this space with some trepidation because of being drawn out into the world on a daily basis when I'm used to being head down working on things. Bouncing off different personalities throughout the day was a bit scary because one of the things that it does is it draws you away from what you're doing."

Many of the members are self-employed and typically work from home where there are few distractions, but also few opportunities to learn new skills from others. He then goes on to say:

"Ideally, that is sort of developed into more of a sharing process, where I can stop for a second … That little turn of concentration kind of, it's more fruitful in the end than just hammering nonstop with my head down. While it's a tradeoff of time, I think that in the end the bonus is there. It will eventually help develop what I'm doing."

This member became inspired by others' 3D printed work and prototyped ways to include 3D printing in the wood furniture that he sold.

While the social aspect of the space was sometimes distracting, members found that the transparency of the space and online channels provided an opportunity to observe the language and work processes of other members. When members could not be in the space, online conversation channels, such as Slack and a Facebook Page, provided an opportunity to peripherally participate [44] in conversations between community members.

"I wanted to know what everyone else was doing and wanted to see like what the dialogue was… There were people I never met, but I kind of knew what they were talking about on Slack and was able to find out about questions people had that may have helped me."

One member who was transitioning into a more entrepreneurial maker career passively watched conversations on Slack to better understand the range of tasks an entrepreneurial maker might participate in. This opportunity was particularly useful to those who had limited experience talking with more entrepreneurs in their field:

"It's really just this hive mind of information. There's people discussing things that you didn't think of until after

they've already gotten all the way through it, and all you have to do is look it up to see the entire conversation."

These online channels, which are more popularly used for team management, were particularly useful in this context for learning entrepreneurial skills that were rarely displayed in a makerspace environment, like fundraising. For instance, different members who were crowdfunding their projects would share links to their own and others' Kickstarter projects, which provided online models of how to run on online fundraising campaigns. These online examples of marketing were supplemented with offline conversations, which we further discuss in the Coaching section.

The ORD1 founder considered what he called "transparency" to be one of the best aspects of the space. By "transparency," he meant being able to easily see and watch what other members were working on. He encouraged transparency online by asking all members to upload a photo, introduce themselves, and share their projects on Slack. In the next iteration of the space (ORD2), he decided to maintain an open layout and use of social technologies, like Slack and Instagram, to allow people working on different projects to easily observe each other.

Scaffolding

We found that social technologies helped to scale and extend scaffolding—supports provided to learners to help them carry out a new task [15,61]—beyond the physical space. The scaffolding supported entrepreneurial skill development by providing step-by-step guidance in what sometimes felt like an unstructured environment.

By using Slack, people who had different schedules could share expertise with novices asynchronously. These online channels allowed members to share heuristic strategies (i.e. tricks of the trade) with each other even if they were not in the space at the same time.

"On Slack he had posted, I guess there were the setting parameters… So, like for instance, I cut magnet…I was able to look at the settings that were similar materials and kind of try to come up with the settings I would use when I was in the space. So it's kind of nice to have it as kind of the backbone or kind of the dialogue that was happening along with being in the space."

Because some members found visiting the space too time consuming or overwhelming, these online channels gave them an opportunity to keep track of knowledge being shared without having to physically visit every day.

Not only did scaffolding occur online, but also offline. Members volunteered to hold workshops on topics that they were particularly skilled at. The workshop leaders would scaffold the learning process by dividing up tasks step by step, providing practice projects, and allowing them to perform the skill on their own with support as-needed. Attendance at these workshops ranged from three to twelve people and provided an opportunity for members to gain experience with new tools and processes. While most workshops were on how to use certain tools, like the 3D printers and table saw, the success of these workshops has convinced the ORD1 founder to hold future entrepreneurial workshops on topics like crowdfunding and marketing in ORD2.

This effort to host workshops and document knowledge online spoke to a sense of mutual responsibility among community members. In order to foster this community culture, the founder posted community rules on the wall facing the main entrance: "Be helpful, Be fun, Be respectful". Scaffolding, together with opportunities to become aware of new methods through observation, helped members apply different skills to their craft, often with the goal of creating new ventures.

Coaching

We also observed various instances of members providing coaching to each other—giving advice and feedback on work in progress. The openness to help others was particularly useful for novices in the space who had limited experience developing and marketing products.

While some members were known to be more experienced than others on manufacturing or marketing, we observed bidirectional coaching activity. For instance, a family of three who developed a clay 3D printer together over the 5-week period partnered with one of the more experienced professional product designers in the space to turn their product into a Kickstarter campaign.

One high school intern in the space described how interacting with more entrepreneurially minded people helped him learn skills like marketing, quality control, and public communication.

"[Brian] has taught us a lot too, and points of, you know, business. He's taught us how you've got to talk to people, how you've got to sort of give them a tour of the whole place…You know, you learn something from everybody that's come in through this door whether it's something small or something big."

Novice members finishing up consumer products learned from others quality assurance practices, such as more efficient production processes or finding better materials. For instance, one member, James, was having difficulty finding high quality, environmentally friendly material for a Kickstarter product. Another member with over fives years of experiencing designing and manufacturing consumer-quality products offered some advice.

"[My teammate and I] would buy yoga blocks from Amazon for all of our projects. We didn't like doing that because it's super wasteful…I think Tyler was the one who suggested a company who will cut it to the thickness we need …which limited a lot of the waste too."

However, the 5-week long period of ORD1 limited the extent to which members could develop high-quality production skills as many were testing experimental ideas that may

or may not be further developed into a consumer product later on. For example, one member who built a canoe as an experiment is now working with a local organization to teach teens how to build their own canoe's for neighborhood rivers. Others developed experimental pieces of furniture that have so far just been donated to the ORD2 space.

In addition to offline coaching, we found coaching was also enhanced through social technologies, such as Slack. Because most members could not work at the space all day every day, people often turned to the community endorsed social technologies to see which members had certain skills. Messaging each other was an accepted practice and novice members found that social technologies helped develop more personal relationships with more expert members in the space. For instance, one of the interns described how he liked interacting with more expert members both offline and online to reduce communication barriers.

"I think [Slack] definitely creates a bridge for us…You're able to communicate a lot faster, get in touch with people and kind of know people, because I mean talking to people in person and through online I feel like, it's two different personas that you kind of learn from. So, it's unique, getting to know that person from social media and then in person."

In addition to providing advice on making products, members also encouraged each other to publicize their work on social media for entrepreneurial skill development. One member who runs a college summer engineering/maker program described how one of the most valuable pieces of information shared with his students was the importance of promoting one's work online to increase the number of people who know about your ventures.

"He said, 'You know, you really need to be on LinkedIn and you really need to have a professional presence. It's great you have a room of tools, but you need a place where you can put out the things that you are working on because there's communities at large that care…The more they know about you in advance, the better.' That struck with my students, and I got a good three or four of them who were like, 'So how do I post my code? And how do I get this stuff out there?'"

This emphasis on publicity further differed ORD1, an entrepreneurially focused makerspace, from other makerspaces that focused more on fostering self-contained environments of making [23]. Since ORD1, the founder has been brainstorming ideas for how to better help members document and share their new ventures and skillsets with each other and the public, such as encouraging members to keep online or offline public journals of their work.

Exploration

Complementary to coaching, ORD1 promoted exploration—using available tools and knowledge to perform a task with little guidance—by providing the resources to experiment with entrepreneurship tasks. At a public event, the founder described how he felt that there were few opportunities that provided the resources and community to support entrepreneurial skill development in an authentic, supportive environment.

This need was reiterated when he spoke with student members who explained how once they graduate, they would no longer have studio access to continue working on new ventures. They described how ORD1, plus various online entrepreneurial support tools, like crowdfunding platforms, provided a way for them to fund buying materials and test out ideas at a low cost. For instance, one member explained how ORD1 provided the resources to develop an initial low-run of his products for consumers before turning to large manufacturing plants:

"Manufacturers, they don't want to deal with us. We're making like 100, 200 at a time, and their setup for their lowest run is like 10,000. So why would they want to fit us in when they already have a client that they're going to make money off of? So it's that really low run use of machinery and equipment that I think is the most beneficial."

While manufacturing plants are a key part of product-focused entrepreneurship, novice entrepreneurs felt that they needed to test out their ideas on a smaller scale before investing in a large manufacturing order. Many others did not even want to use a manufacturer and preferred to handmake each of their products. However, because renting physical space and buying one's own tools, such as a table saw, can cost thousands of dollars, makerspaces can provide a cheaper way for entrepreneurial makers to use these tools for lower cost.

In addition to physical tool resources, ORD1 provided access to a diverse range of makers, artists, designers, and creatives, who are interested in forming project collaborations. Three members formed a project collaboration with each other to develop a series of products for a local education program. One member of the project collaboration, who had started his own adult design education program, approached two designers in ORD1 to create packaging for one of his modules. The final product was eventually promoted on Kickstarter and raised over $49,000 in a month. Most other members participated in short-term interactions, like offering brief help with each others' hands-on work, and expressed the desire to establish project collaborations for future projects.

The makerspace founder recognized that ORD1 was providing unique resources to novice entrepreneurs who did not have the tools, space, and community support to experiment in a social and safe environment. While the next ORD1 iteration involves a membership fee open to the public, the founder has been working with local colleges that have limited maker resources to develop potential partnerships around offering entrepreneurially-inclined students access to the space and community.

Developing Entrepreneurial Self-Efficacy

In addition to providing an environment for entrepreneurial skill development, ORD1 was also a site of building entrepreneurial self-efficacy, a trait particularly needed for novice entrepreneurs who are in most need of support, but have least access to social resources [18,29,71]. The two most prominent mechanisms of developing self-efficacy that we observed were *modeling* and *public validation*.

Modeling (Social Cognitive Theory)

Similar to modeling for skill development, modeling in self-efficacy development involved observing similar others to build one's confidence. Novices felt comfortable watching and conversing with more expert members of the space, which helped build confidence in their own abilities and goals. For instance, one member described how the space helped him believe that it is possible to have a career as an entrepreneurial maker one day.

"I think it gave more validity to what I've always imagined me doing in the future… So, I think being part of [ORD1] kind of made me more aware of the possibility of that and gave it more hope."

This belief was also shared among the interns at the space who were all high school students trying to figure out their future careers. Many of the more novice members described how they initially had a limited idea of what types of careers they could pursue in involving making. Participating in the space provided career role models and motivation to pursue entrepreneurial careers in making by watching others work (Figure 3). For instance, one intern described how watching a product design entrepreneur motivated him to want to build products as well.

"Tyler just came in here and I was like, "Hey what are you making?" And I think he was working on a boat or something like that. And that's really cool. I want to watch him build a boat. I want to be able to build a boat too, that sounds really cool."

Participation in the space not only benefited novices, but also the more expert members. One member who has had over 20 years of experience making and selling products described how being at the space boosted his confidence.

"I tend to downplay my experience and abilities and I was probably a little on the older side compared to a lot of people who were there, and it made me realize how many different projects, materials I've worked with, and how many techniques I've tried that didn't work, and successes I've had. And so it made me realize I have a lot to offer."

Members also described how working in parallel with others helped them stay motivated in their own work. This type of transparent work environment was particularly useful for members who often felt isolated when working alone. For instance, one recent design graduate described how he liked working in parallel with others to keep him motivated.

Figure 3: Visiting students from a college summer engineering program watch a member of ORD use the CNC router. Many expressed that they had few opportunities to meet people who have developed a business for their hand-made work.

"One thing I really liked was all the activities going on…It was really awesome to see [other] collaboration[s], and maybe we weren't necessarily collaborating with someone, but we were watching and inspired. I guess, in a general sense, it's like the same as working out at home versus working out in a gym. You're not working out with someone necessarily, but you're motivated when you're next to people who are doing the same activity."

Similarly, an intern described how he was excited watch a range of team forms.

"I think so far what we learned is that people from different backgrounds and different kind of, like job areas can work together, which is something that you don't see too often. For example, you have artists who specialize in doing murals and people like Tyler who do more like hands-on work working together, you know, come up with creative ideas and problem-solving."

Being able to form and work in ad-hoc teams without managerial guidance is a key part of entrepreneurial work [69]. Both experienced and novices felt that watching others work provided motivation for their own entrepreneurial development.

Public Validation

ORD1 also provided a way to receive public validation both in the physical community and through online social media channels. Within the space, members found that the expectation of social support helped new members feel included and confident in trying out new skills. One entrepreneur with her own design firm described how she thought the supportive environment was a key asset to ORD1.

"Everyone has to feel comfortable within that space to actually ask the questions, create a very safe environment. And also new people who are coming into the space also don't feel like they're a novice and at a handicap. So it's the community building was exceptionally strong."

Others described how they liked the open layout of the space because their work would be on display for other members and visitors to see. While there were two public

Development Type	Mechanism	Examples from ORD1	Impact on ORD2 Design
Entrepreneurial Skill Development	Modeling	*Offline:* Watching others use certain machines. *Online:* Reading others' project process on Slack.	- Open space layout maintained - Social media for project sharing still encouraged (e.g. official Instagram, Facebook Page, and hashtags) - Public offline or online project "journaling" to be encouraged
	Scaffolding	*Offline:* Attending community-member run workshops *Online:* Reading community-posted tutorials in online communication channels	- Further workshops to be held on entrepreneurial-focused topics (e.g. crowdfunding) - Work area organized in order of most to least approachability (e.g. laptop area to table saw)
	Coaching	*Offline:* Seeking informal advice from members working nearby *Online:* Using online channels to ask questions and advice to other members	- Open space layout maintained - Loudest machine tools kept farthest away and sound-dampened from conversational work areas - Social media use still encouraged for Q&A
	Exploration	*Offline:* Manufacturing small product runs for a crowdfunding campaign *Online:* Using social media to promote one's ventures	- Membership marketed to soon-to-graduate and recently-graduated creatives and engineers - Partnerships being developed with other entrepreneurial education non-profits - Designated photo and video production area added to support publicity efforts - Social media use for marketing encouraged
Entrepreneurial Self-efficacy Development	Modeling	*Offline:* Observing others work who exemplify one's entrepreneurial career goals *Online:* Viewing others' online webpages, portfolios, and community conversations	- Open space layout maintained - Social media use still encouraged to share project progress (e.g. Slack #Documentation channel) - Public offline or online project "journaling" to be encouraged
	Public Validation	*Offline:* Sharing one's work at public events *Online:* Sharing photos of one's projects through social media	- Open space layout maintained - Social media for project sharing still encouraged (e.g. official Instagram, Facebook Page, and hashtags)

Table 1: The impact on the design of ORD2 was informed by observations from running ORD1.

events during the period of data collection, various members described how they hoped there would be more opportunities for public displays of their work.

Because ORD1 was a publicized place, with a public Facebook Group, Instagram, and articles printed in the local city newspapers, members used these online materials to associate themselves with the act of entrepreneurial making. One member described how being a maker entrepreneur was often not well understood among members of the public. Being part of ORD1 allowed him to pull out his phone and show people the type of work and community he was involved in. These multiple ways of associating with this publicized community gave him more professional legitimacy. Similarly, others described sending Facebook links to their parents and friends whenever they asked for a life update.

"You have this reason to talk to someone whereas if I'm just a guy sitting in my apartment as a designer, you know, people aren't as open to listening to what you have to say. So it really did provide a platform, an excuse to talk to people and reason to talk to people."

Overall, we found that the opportunities to share one's work within the space and online helped build entrepreneurial self-efficacy through public validation.

DESIGN OF ORD2

ORD 2 opened about a year later in a more permanent location about 1 mile from the original ORD1 site. To further support entrepreneurial development, ORD2 includes a larger open space with designated work areas, a wider range of entrepreneurial-focused workshops, a photo/video area for marketing, and continues to promote social media activity for publicity and project documentation. A summary of how activity in ORD1 influenced the design of ORD2 can be found in Table 1.

Located relatively near the center of the city of Chicago, the location of ORD1, and hence ORD2, was chosen to be accessible by all areas of Chicago. Similar to ORD1, ORD2 is located at street level and is accessible by public transportation and car, and is located near a local city college with public bike rental options.

The ORD1 space (Figure 4a) had an open 4,300 sq. ft. layout, which allowed for *modeling* and informal *coaching* opportunities, but sometimes limited conversations and novice onboarding because the space was loud and unstructured. The new ORD2 layout (Figure 4b), which is 10,000 sq. ft. with a 15,000 sq. ft. storage area, has an updated open layout, designed in a way to better facilitate *modeling*, *coaching*, *scaffolding*, and *exploration* (Figure 4b).

Rather than having all tools spread out, ORD2's updated open layout is staged where the entrance is closest to the clean-work area and farthest from the high-powered tools. This allows novice members to work in a designated "safe" or "clean" area while watching a range of activity around

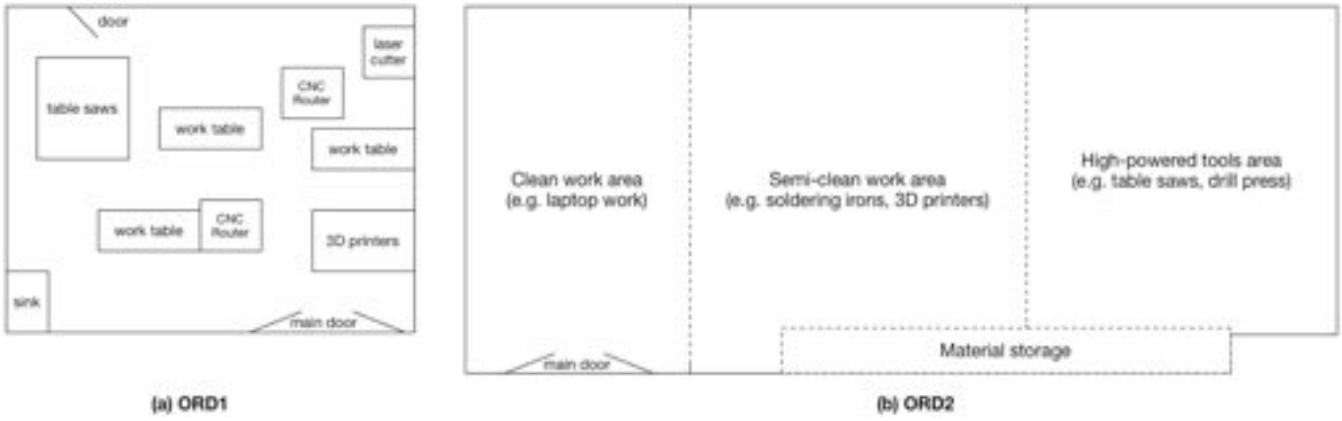

Figure 4: (a) ORD1 had high-powered machine tools placed throughout the workspace, which limited where peope felt comfortable performing non-building work needed for entrepreneurship (e.g. budget planning). Extra outside space not shown. (b) ORD2 is larger, has an open layout, and stages the work areas from less intimidating (clean laptop area) to more intimidating activities (high-powered tools). Extra storage space not shown. Images are relatively to scale.

them before deciding to move onto a potentially more challenging set of tasks. As the workshops from ORD1 demonstrated, novices liked learning complex tasks with structured guidance and at their own pace. The ORD2 open, yet staged layout, combined with available workshops, builds on the cognitive apprenticeship concept of *scaffolding* where novices can work up to more challenging skills.

To further support entrepreneurship, ORD2 includes a designated photo and video production area, and will begin to offer workshops on a wider range of entrepreneurial skills, such as fundraising and financial planning. The existing social media channels of Facebook, Instagram, and Slack, are still used by members after ORD1 closed, and have been adopted for the new ORD2. This continued use of online communication tools highlights the value of social media in extending the benefits of community activity beyond the physical space.

DISCUSSION

By understanding how makerspaces support entrepreneurial skill and self-efficacy development, we can further expand makerspaces as sites of career empowerment through entrepreneurship. While CSCW research on makerspaces has increased over the past five years, few have studied 1) entrepreneurially-focused makerspaces explicitly, and 2) how these makerspaces leverage socio-technical tools to promote community-focused values [79] for entrepreneurial development. We study how novice entrepreneurs leverage the openness of a shared space, access to social technologies, and community of social support to develop entrepreneurial skills and self-efficacy in a new environment.

ORD as an Entrepreneurial Makerspace

We decided to study ORD1 because of the founder's expressed commitment to supporting entrepreneurial activity in a makerspace beyond providing "just a room with tools". ORD1 was not the first makerspace to support entrepreneurship [45–47], but it is one of few that clearly promotes entrepreneurship as part of its platform. On the community website, alongside promoting "exploring ideas," and "kinship," it also calls itself place where people can go to "start a business." Many consider ORD1 a hybrid between a business incubator, machine shop, and co-working space because it aims to provide access to machine tools, social learning, and entrepreneurial support in one space.

Similar to other makers [47], ORD1 members were wary of the connotations associated with the word "entrepreneurship" because it is often associated with privilege and competition. In fact, most did not describe themselves as entrepreneurs despite performing entrepreneurial work—creating new products and services, marketing one's work, and managing finances [14,39,54,69]. Rather, they defined themselves by their craft (e.g. designer, artist), where the entrepreneurial part of their work was seen more as means of acquiring funding. In agreement with previously uncovered values of resistance to authority [79], members were motivated to make and sell their work as a way to combat consumption of mass-produced products. This was exemplified early on during the development of the space when members came together to build the makerspace tables and chairs, joking about the worst-case scenario–buying furniture from IKEA.

Unlike other makerspaces, where communities were described as more inwardly focused [23], a core practice in ORD1 was developing professional reputations outside the space by publicizing one's work online and offline. Publicizing one's work is a key aspect of entrepreneurship, and members were intrinsically motivated and encouraged to share photos and updates of their projects. While communities of practice literature describes how one's identity with a community is primarily developed through interaction with community members [82], we found that interactions with people outside the community also played an important role. This behavior is similar to those described by psychologists as reflective appraisal theory, which states that people develop impressions of themselves based on how they think others perceive them [72]. This finding adds

to social cognitive theory by highlighting how public validation can serve multiple purposes for building entrepreneurial self-efficacy. In the context of ORD1, members not only liked being praised for their work, but also felt that associating themselves with ORD1 in others' eyes made their identity as an entrepreneurial maker more legitimate.

Democratizing Opportunities to Entrepreneurship

It is important to understand how to develop entrepreneurial makerspaces because few entrepreneurial communities promote exploration and social support over competition [69]. Consistent with research on creative work environments [1], we found that a community backbone of social support and exploration made it easier for novices to reach out for help and be open to failing early and often as part of their entrepreneurial process.

Expectations of transparency and social support were embodied in both the open layout space and frequent use of community social technologies. The physical space provided greater opportunities to observe others working, a key aspect of learning via cognitive apprenticeship [15], and develop personal relationships for public validation, a key aspect of self-efficacy development [3]. Consistent with extensive work on collocated work [59,77], we found that the strongest bonds were developed in person.

However, social technologies played an important role in facilitating relationship and trust development. Other entrepreneurial support tools, like crowdfunding platforms, have made it easier for novice entrepreneurs to acquire financial resources [24,36], but are still limited in the extent to which members could receive advice and feedback [26,36], especially after public failures [27]. Similarly, accelerators and incubators provide mentorship and funding, but often have competitive acceptance rates. Being able to frequently interact both offline and online with peers and experts in a makerspace creates greater opportunity to develop entrepreneurial skills and self-efficacy in a transparent and supportive environment. Consistent with literature on trust development online [78], frequent interactions online and in person helped members feel more comfortable reaching out to others even though they had never met before.

However, while our findings uncovered how cognitive apprenticeship and social cognitive theory mechanisms instantiated themselves in the ORD1 environment, we were primarily only able to observe the sharing of heuristic knowledge (i.e. best practices) rather than more complex knowledge, such as metacognitive and learning strategies [15]. For example, knowing how to attach a CNC machine to a vacuum (heuristic knowledge) is a different skillset from knowing why one should seek feedback (metacognitive knowledge). Identifying how and when members are acquiring other types knowledge would take further research and is a goal for future studies.

Our findings not only apply to entrepreneurship and makerspaces, but professional development in general. The following section considers how our findings can inform the growing CSCW discussion on computer-support career development.

Computer-Supported Career Development

Efforts to understand, improve, and develop tools that support career development have started to move to the forefront of CSCW. For instance, Suzuki et al. describe a system that pairs novices with mentors for "micro-internships" on how to perform paid crowdsourcing work [74]. Similar to our findings, they find that cognitive apprenticeship in an online environment helps novices absorb best practices. Others describe how seeing models online can influence designers' professional practice [52] and student's college information seeking efforts [19].

Unlike online micro-internships or MOOCS, where novices have access to a long-term instructor, entrepreneurs in makerspaces typically have to self-direct their efforts to identify and connect with a range of potential mentors. Because the more expert members of a makerspace are often busy working on their own projects, our data finds that a distributed approach to skill acquisition is more feasible. By distributed, we mean combining small amounts of instruction from multiple sources to mimic long-term expert guidance. This method of using social technologies to combine instruction from different sources, previously described in contexts of online fan communities [11], is particularly suitable for makerspaces where one has physical and online access to multiple knowledgeable peers and experts.

Of course, democratizing avenues to entrepreneurship is not possible if we do not take into account social and political forces [45]. We hope to further address these issues of access to entrepreneurship in future work.

LIMITATIONS

We acknowledge limitations to our study. First, the founder recruited specific people to participate. While this creates selection bias, the positive outcome of the community suggests that initial selective recruitment is a design consideration when developing a new makerspace culture. Second, ORD1 was only a temporary makerspace, which may change how people interact with each other. However, we found that the relationships developed in ORD1 extended beyond the end of the 5 weeks as people continued to keep in touch through social technologies, and other Chicago-based creative groups and events. Finally, we did not explicitly measure learning outcomes, but rather studied the presence of learning mechanisms through interviews and observations. While this limits our findings on whether people actually learned entrepreneurial skills and self-efficacy, we find initial evidence that the presence of these mechanisms (e.g. modeling, coaching, public validation) have created viable opportunities for entrepreneurial development.

CONCLUSION

Through participant observation and interviews, we found that the socio-technical resources of the makerspace supported the transparency and social support beneficial for entrepreneurial skill and self-efficacy development. Drawing from cognitive apprenticeship and social cognitive theory, we describe how makerspaces support entrepreneurial skill development, such as using makerspace technologies to build and market new products, and self-efficacy development, such having the confidence to develop new ventures.

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