Together at Last:
How Makerspaces Simultaneously Support Exploration and Exploitation

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Abstract

The innovation and strategy literatures identify both explorative and exploitative activities as important, yet conflicting, aspects of organizational learning. The inherent tension between these activities arises from issues related to the costs and benefits of resource allocation within organizations—and, as a result, explorative activities are often marginalized in favor of exploitative ones. Given this theoretical backdrop, organizational designs that support both explorative and exploitative activities raise an interesting theoretical puzzle. Based on both primary source qualitative data collected through interviews and observation, and on archival data we seek to understand the factors that allow "innovation communities"—organizations comprised of voluntary participants— to support both exploration and exploitation. We study a particular set of innovation communities—makerspaces—that provide participants with access to a variety of tools, materials, and knowledge resources. Our research finds evidence for three characteristics—resource availability and sharing, heterogeneous participant expertise and goals, and fairness norms—that simultaneously facilitate both explorative and exploitative activities. Implications for research on innovation and organization design are discussed.

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INTRODUCTION

> *"A hacker takes nothing as given, everything as worth creatively fiddling with, and the variety which proceeds from that enricheth the adaptivity, resilience, and delight of us all." Stuart Brand, cited in The Economist, January 2014*

Innovation and entrepreneurship are critical drivers of economic growth. Novel products and services improve the quality of life for consumers. Historically, the management literature has focused on understanding the role of for-profit firms in creating and commercializing innovative products (e.g., Schumpeter 1934). For-profit firms spawn innovation and entrepreneurship by investing in the creation of new products and services, as well as by developing human capital that spawns the creation of new firms (Agarwal et al. 2004; Klepper 2001).

The challenge that corporate organizational forms face in balancing exploration and exploitation is well documented (March 1996; O Reilly and Tushman 2004). In a firm innovation context, exploration implies firm behaviors characterized by search, discovery, experimentation, risk taking and innovation, while exploitation implies firm behaviors characterized by refinement, implementation, efficiency, production and selection (Cheng and Van de Ven 1996, March 1991, He and Wong 2004). March (1991) posits that "tradeoffs [between exploration and exploitation] are affected by their contexts of distributed costs and benefits and ecological interaction." As a result, explorative—that is, innovation-centered—activities tend to be marginalized in many corporations. Compounding the organizational issues that can impede exploration is the fact that new product development is inherently a difficult and challenging task (Brown and Eisenhardt 1995; Clark and Fujimoto 1991). Numerous studies document the high failure rates of corporate product development projects (Cooper 1979; Cooper and Kleinschmidt 1995; Taylor 2010). Given this backdrop, the emergence of non-corporate forms of organization that appear to successfully support both explorative and exploitative activities raises an interesting theoretical puzzle. Moreover, while firms are an important and critical component of the economic landscape, alternative organizational forms are playing an increasingly important role in seeding innovation and entrepreneurship (Davis 2013).[1]

The past decade has brought unprecedented shifts in prototyping, communication, supply chain, and production technologies. These changes in technological capabilities and platforms support the emergence of organizational forms centered on local or virtual collaborative production. Open source software communities are perhaps the best known example of this fundamentally different organizational model—a model referred to as collective invention (Allen 1983), private-collective innovation (von Hippel and von Krogh 2003), and community-based innovation (Franke and Shah 2003). This model has generated key innovations across many product domains. Innovations developed within communities are diffused within and beyond the community through a variety of mechanisms, including the sharing of designs and production instructions, as well as commercial distribution through both established (von Hippel 1988; Winston Smith and Shah 2013) and entrepreneurial (Shah and Tripsas 2007; Shah, Winston Smith and Reedy 2012) ventures. Particularly striking are the many examples of innovative new ventures that have emerged from innovation communities. Academic and practical interest in such communities has risen greatly over the past fifteen years, and a great deal about their organizational design and remains to be understood: "The technology is already here; what are needed are better-documented organizational models of local collaboration" (Davis 2013: 304).

[1] Scholars have even suggested that "The twilight of the public corporation in the United States" may be at hand (Davis 2013): public corporations are becoming less concentrated, less integrated, shorter-lived, and less prevalent. Since corporations invest significantly in R&D, their decreasing number and size might lead to declines in investments in U.S.-based R&D and innovation. If the significance of the modern corporation dwindles, understanding alternative sources of innovation and economic growth becomes increasingly relevant.

Innovation communities provide an intriguing organizational setting in which to study the factors that support exploration and exploitation in that they represent a unique organizational form—one in which there are few organizational-level goals or objectives for product development, individuals are able to self-organize, and neither hierarchy nor pecuniary benefits provided by the organization motivate participants' time and effort. Makerspaces are one such type of innovation community. Our objective is to understand makerspaces as social structures where innovation occurs: we aim to identify the resources and social mechanisms that support the coexistence of exploration and exploitation in makerspaces, including those that help balance the tensions that arise between the two sets of activities.

Based on primary source qualitative data, collected through interviews and observation, as well as archival data, we seek to understand the factors that allow some makerspaces to support both exploration and exploitation. Our research finds evidence of three core characteristics. First, sharing norms and resource availability act to enable the sharing of knowledge and resources that facilitate exploration, as well as early stage entrepreneurship. Second, heterogeneity of expertise and professional interests amongst participant is central: participants' unique utilization of existing resources——for different purposes and at different points in time—allow for the coexistence of exploration and exploitation activities both by limiting direct competition and enhancing resource and knowledge flows amongst participants. For example, participants routinely shared material and social network resources, as well as knowledge pertaining materials, tools, techniques, and commercialization. As a result, makerspaces that seek to attract diverse participants have an easier time balancing exploration and exploitation. Finally, concern for a fair balance between the use of individual time and makerspace resources, together with practical constraints ensure that exploitative activities do not detract resources and attention from explorative ones, such that as fledgling firms grow, they move out of the space. In this regard, we observed a number of entrepreneurs engage in production outside of makerspaces, yet return to the space to engage in explorative activities such as designing and prototyping. These findings appear to be consistent across non-profit and for-profit community-based makerspaces and across geographic locations.

BALANCING EXPLORATION & EXPLOITATION

Prior literature shows that balancing exploration and exploitation presents a challenge for organizations , yet the importance of these activities necessitates we understand how to encourage them. At the crux of this challenge is sustaining support for exploration (March 1991). That is to say, activities that advance commercialization tend to take precedence over innovative activities. Several reasons have been posited for this: organizations quickly establish routines, explorative activities are inherently riskier and more uncertain than exploitative activities, and exploitative activities have a higher likelihood of generating a profit. For these reasons, many organizations have a difficult time establishing and maintaining processes and structures that balance these two activities (Tushman and O'Reilly 1996).

The existing literature highlights two broad sets of conditions for enabling exploration and exploitation: architectural and contextual conditions. Architectural conditions pertain to the design of the organization's formal structure, and scholars suggest the use of ambidextrous organizational forms to allow for exploration and exploitation within the same organization (Kleinbaum & Tushman, 2007; O'Reilly III & Tushman, 2008). This solution effectively cleaves the organization into two relatively independent subunits in order to support explorative activities. In contrast, contextual conditions include the use of normative and cultural mechanisms to encourage both exploration and exploitation activities. Such conditions have received less attention in the literature than have architectural conditions (Gibson and Birkinshaw, 2004). Our examination is open to examining both architectural and contextual conditions in the context of user innovation communities.

User Innovation Communities: A Social Structure for Exploration & Exploitation

Innovation communities are distinguished from corporate organizational forms in both structure and culture, and in their focus on collaborative innovation processes. Participants in innovation communities share information and resources related to common interests. Innovation communities have been influential in fields as diverse as automobiles (Franz 2005; Kline and Pinch 1996; Lucsko 2008), industrial equipment (Allen 1983; Nuvolari 2004), personal computers (Freiberger and Swaine 2000), and sports equipment (Franke and Shah 2003).

The community-based model represents a fundamentally different organizational model for innovation. In contrast to the proprietary and academic models, the community-based model relies neither on exclusive rights nor on hierarchical control. The model is instead based on the open, voluntary and collaborative efforts of users—a term that describes enthusiasts, tinkerers, amateurs, everyday people, and even firms that derive benefit from a product or service by using it. [2]

Many innovations have been developed within user innovation communities (Shah and Tripsas 2007; Shah and Mody 2014). A rich research stream documents that the innovations

[2] While paid positions occasionally exist in such communities, they are ordinarily related to infrastructure maintenance or administrative functions that need to be attended to in order for the community to survive and they are not located in the core of the community.

generated by users are important,[3] frequent,[4] and distinct from those generated by firms.[5] In addition, users and their communities have seeded many entrepreneurial ventures (Baldwin, Hienerth and von Hippel 2006; Mody 2006; Shah 2005; Shah and Tripsas 2007). Recent research finds that over half of innovative U.S.-based startups that survive five years or more are founded by user entrepreneurs (Shah, Winston and Reedy 2012). Many user entrepreneurs benefit from participation in user innovation communities: community participation provides feedback for improving the innovation, diffuses knowledge of the innovation (often through word-of-mouth), and information regarding whether or not a customer base for the product exists (Shah and Tripsas 2007). Innovation communities appear to be a fountainhead of innovation and

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[3] Numerous studies find that users—in contrast to manufacturers or suppliers—developed a large fraction of key innovations across a variety of product classes (von Hippel 1988).

[4] A number of studies measure the fraction of users in particular fields who innovate, generally finding that between 20% and 40% of users create innovative prototypes. For example, 19% of users of Apache security software (Franke, Nikolaus, and Eric von Hippel. 2003. "Satisfying Heterogeneous User Needs via Innovation Toolkits: The Case of Apache Security Software." *Research Policy* 32:1199-215.), 26% of users of library information systems (Morrison, Pamela D., John H. Roberts, and Eric A. von Hippel. 2000. "Determinants of User Innovation and Innovation Sharing in a Local Market." *Management Science* 46(12):1513-27.), and 38% of consumer sports enthusiasts (Franke, Nikolaus, and Sonali K. Shah. 2003. "How Communities Support Innovative Activities: An Exploration of Assistance and Sharing Among End-Users." *Research Policy* 32:157-78.) report innovating for their own use. In addition, user innovation is common across the general population: 6.2% of consumers in the United Kingdom report innovating for their own use (von Hippel, Eric A., Jereon de Jong, and Stephen Flowers. 2010. "Comparing Business and Household Sector Innovation in Consumer Products: Findings from a Representative Study in the UK." *Management Science* September 2012 (58):1669-81.)

[5] A handful of studies show that the knowledge generated by innovative users is distinct from that generated by other sources of innovation (Chatterji, Aaron, and Kira R. Fabrizio. 2012. "How Do Product Users Influence Corporate Invention?" *Organization Science* 23 951-70, Riggs, William, and Eric von Hippel. 1994. "Incentives to Innovate and the Sources of Innovation: the Case of Scientific Instruments." *Research Policy* 23:459-69, Winston Smith, Sheryl, and Sonali K. Shah. 2013. "Do Innovative Users Generate More Useful Insights? An Analysis of CVC Investment in the Medical Device Industry." *Strategic Entrepreneurship Journal* 7(2):151-67.) These distinctions arise due to the nature of the user innovation process: as users, individuals are exposed to different contexts and information than they would be as product developers (von Hippel, Eric. 1994. ""Sticky Information" and the Locus of Problem Solving: Implications for Innovation." *Management Science* 40(4):429-39, Winston Smith, Sheryl, and Sonali K. Shah. 2013. "Do Innovative Users Generate More Useful Insights? An Analysis of CVC Investment in the Medical Device Industry." *Strategic Entrepreneurship Journal* 7 (June)(2):151-67.) As a result, user innovations are distinct in character from innovations from other sources: user innovations were found to embody altogether new product functionality, whereas producer innovations tended to improve existing product functions along dimensions known to be important to customers (Riggs, William, and Eric von Hippel. 1994. "Incentives to Innovate and the Sources of Innovation: the Case of Scientific Instruments." *Research Policy* 23:459-69.)

entrepreneurship. How they manage to support both explorative and exploitative behaviors is an open question.

How Do Innovation Communities Balance Exploration & Exploitation?

While research has extensively documented the pervasiveness of user innovation communities, little is known about *how* user communities manage to support both the enthusiastic exploration of new ideas and the exploitation of prior designs. This question is particularly salient, given the importance, as well as the complexity, challenge, and resource-intensity inherent in both innovative and entrepreneurial endeavors (Brown and Eisenhardt 1995; Schoonhoven, Eisenhardt and Lyman 1990).

Several unique organizational characteristics of user communities—centering around issues of knowledge sharing, the availability of heterogeneous solution knowledge, and individual motivation—may allow user communities to balance exploration and exploitation. To date, little or no research examines the connection between these characteristics and the ability of communities to balance exploration and exploitation, but these unique characteristics do provide a starting point for our study. Knowledge is generally freely shared within innovation communities: empirical studies find that participants provide assistance to one another by providing feedback on novel ideas and prototypes, offering advice and knowledge, and by introducing individuals in need of particular knowledge resources to participants who might possess such resources (Franke and Shah 2003; Raymond 1999). Heterogeneous knowledge synthesis is one of two key components of innovative knowledge; the other is need-related knowledge (Alexander 1964). By encouraging "legitimate peripheral participation" by individuals with diverse needs, interests, and knowledge bases, innovation communities may be especially effective at making heterogeneous knowledge available (Jeppeson and Lakhani 2010; Wenger 1998). Finally, the issue of motivation has received a great deal of attention, with empirical studies supporting the idea that individuals with diverse motives participate in innovation communities and that the motives of some individuals are shaped and altered through participation over time (Ghosh et al. 2002; Hertel, Niedner and Hermann 2003; Shah 2006).

By and large, each of these characteristics of innovation communities has been studied independently; they constitute pieces of a puzzle that has yet to be fully assembled. Research has yet to devise an explanation for how these—and other—organizational characteristics shape the ability of communities to engage in the exploratory learning activities that result in innovation and entrepreneurship. The grounded-theory based approach employed in this study will help illuminate these patterns.

In this study, we examine how the social structure of innovation communities supports explorative and exploitative learning activities, and seek to understand the social structure of innovation communities as a cohesive system, rather than focus on any single factor. Individual innovation communities may possess unique social structural characteristics, social structures may evolve over time, and different sets of characteristics may result in diverse outcomes. These possibilities are recognized in the design of the study. The study also pays attention to the knowledge, skills, and motivations of various individuals participating in the community, since each participant's resources are likely to influence the surrounding social system and be enriched by that system as well.

DATA & RESEARCH METHOD

Study Setting: Makerspaces

Makerspaces "serve as gathering points where communities of new and experienced makers connect to work on real and personally meaningful projects, informed by helpful mentors and expertise, using new technologies and traditional tools" (Maker Media 2013, p. 7). Within these spaces, makers—hobbyists, tinkerers, amateurs, professionals, and others—gather to invent, build, replicate, and take things apart. Makers tend to value new and unique applications of technologies and skills, and encourage invention and prototyping (MacMillan 2012). There is often a strong focus on using and learning practical skills and applying them creatively.

In addition to serving as physical forums for individuals to "make things", these spaces also function as social forums and are increasingly being heralded as natural incubators of entrepreneurial activity (Stangler and Maxwell 2012): "ever-accelerating entrepreneurship and innovation with ever-dropping barriers to entry (Anderson 2012)." For example, Pinterest, the social networking site, used HackerDojo—a famed makerspace in Silicon Valley—as their primary workspace for several years and hired their first two engineers from the Dojo's membership. Similarly, Square, the credit card reader for mobile phones and tablets, was designed in the Commercial space A makerspace located in Menlo Park (Vance 2012).

Makerspace participants are engaged in a wide range of exploration and exploitation activities—with explorative activities ranging from learning about tools and techniques to invention and innovation, and exploitative activities including kit-making, production, and the founding of firms. Spaces vary in the extent to which they support explorative and exploitative activities. This variance enables us to begin to identify the factors important in balancing exploration and exploitation within a single organization.

We chose makerspaces as the ideal organization to study innovation communities and, in particular, exploration processes in a physical, collective setting for several reasons. First, makerspaces represent a local solution for producing, distributing and sharing" (Davis 2013). Second, makerspaces are becoming increasingly visible as a source of creative activity, innovation, and entrepreneurship in the U.S. economy. And lastly, the diversity of makerspace attributes allows us to examine the conditions under which makerspaces are able to foster exploration activities and give birth to entrepreneurial ventures.

Our examination of the social structure of makerspaces has been informed by several phases of data collection. We conducted preliminary fieldwork; assembled background data on all U.S. based-makerspaces; detailed data pertaining to the history and current state of the maker movement; and comprehensive case-study data on four makerspaces. Such "layered" data collection provided us with rich and detailed knowledge with which to analyze a form of organization that has developed relatively recently.

Data collected through interviews and publicly available project information are analyzed using an inductive and qualitative methodological approach based on the principles of grounded theory building. This approach avoids layering preconceived theoretical concepts onto a novel social structure and "makes room for the discovery of the unanticipated (Van Maanen 1998)." Individual makerspaces were the focal unit around which both data collection and analyses were structured.

Data Sources: Interview & Archival Data

Preliminary Fieldwork

We began developing an understanding of makerspaces as an organizational form by reading widely, visiting several makerspaces, and consulting well-known experts such as magazine editors and book authors. These actions (1) allowed us to develop a basic understanding of the social structure of makerspaces, (2) provided us with a preliminary history and background of makerspaces as an organizational form, and (3) provided us with a basis for designing the survey used in Stage 1.

We systematically collected primary source and archival data from multiple perspectives. Multiple data sources are critical to grounded theory development as they enable triangulation and validation of theoretical constructs (Miles and Huberman 1984).

Interviews

In-depth interviews allow us to collect data pertaining to the characteristics of individual makerspaces, as well as the evolution of the maker movement over time. Such information is irregularly reported in archival data. Sixty interviews were conducted in three stages. Stage 2 overlapped with both stages 1 and 3; stage 1 was completed prior to commencing stage 3.

Stage 1. We assembled background data on all known U.S. based makerspaces. Since systematic data on makerspaces are unavailable, this data collection effort was designed to provide us with knowledge pertaining to the characteristics of a large number of makerspaces, and specifically on the commonalities and differences amongst makerspaces (see *Findings*). These data provided us with a basis to select specific makerspaces to be analyzed in Stage 3, as well as knowledge regarding the prevalence of innovation and entrepreneurship in makerspaces.

We began with the online listing of makerspaces on the HackerspaceWiki site hackerspaces.org. We added spaces to our list by asking interviewees for the names of other spaces in their state; we identified spaces that were planned, but not operational; and we removed the names of spaces that were no longer in operation. We concluded that roughly 240 spaces were operational in the United States in 2013. The number of makerspaces is fluid, with new spaces emerging and existing spaces disappearing on a regular basis.

We contacted each space and requested to speak to a founder or representative of the space. A survey-instrument was designed to collect information about the founding history; resources; norms, rules, and governance structure; number and type of participants; and existence of innovation development and firm founding within each space. Questions were closed-ended, and time was left at the end of the interview for open discussion and identification of salient characteristics about which we had not inquired. Several such characteristics were identified in the first half-dozen or so interviews conducted and added to the survey instrument.

Stage 2. In this stage, we sought the perspectives of a wide variety of actors involved in makerspaces: founders; members (including hobbyists, entrepreneurs, and business owners); suppliers and partners (including community development organizations, venture capitalists investing in firms founded within makerspaces, and government officials involved in funding makerspaces); and other related actors.

The 24 Stage 2 interviewees were asked a series of open-ended questions, augmented by follow-up and clarifying questions (Spradley 1979). Because of the wide variety of individuals interviewed in this stage, questions differed from one interview to the next—focusing on issues surrounding how innovation and entrepreneurship emerging from makerspaces, as well as the role of the interviewee/the interviewee's organization in supporting, facilitating, or engaging in these processes.

We engaged in snowball sampling by asking interviewees to suggest names of others involved in innovation or entrepreneurship within makerspaces//they considered experts or deeply knowledgeable participants. We continued interviewing until the information collected in subsequent interviews was largely repetitive of that collected before; at that point, the names that were being recommended to us were also largely the names of individuals who we had previously been in contact.

Stage 3. Next, we selected four makerspaces to study in-depth. We visited each space multiple times to observe practices and interview participants. We began by taking a formal tour of each space or asking a representative or employee of the space to show us around. This provided us with an overview of the resources and culture of the space, as well as introductions to participants who were using the space at the time. We typically spent four hours to a day at each space during each visit. Spending time at the space made us "familiar figures" and facilitated introductions to additional participants.

We interviewed a total of 34 individuals familiar at least one of the four spaces: hobbyist members, entrepreneurial members, non-members who used the space from time-to-time, founder(s), employees, and—when possible—a former member whose cancelled their membership. Stage 3 interviewees were asked a series of open-ended questions, augmented by follow-up and clarifying questions (Spradley 1979). Questions addressed the following issues: (1) decision to join the makerspace, (2) past and ongoing projects in the makerspace, (3) tools used, assistance given and received, and collaboration within the makerspace (4) norms related to sharing and fairness in the space, (5) (for entrepreneurs) origins of the business idea, and support and hindrances to developing it within the makerspace, (6) advantages and disadvantages of being part of the makerspace, and (7) the interviewee's socio-economic and educational background.

Interviewees across all three stages were guaranteed anonymity to promote candid responses.[6] Interviews were either conducted by telephone or in-person and were recorded and transcribed to facilitate data analysis. Interviews ranged in length from 30 minutes to over two hours, with most stage 1 interviews lasting 45-60 minutes and stage 2 and 3 interviews lasting from 60 to 90 minutes.

Archival Data

Archival data corresponding to each stage of data collection described above was collected. Archival data was collected from a variety of sources, including newspaper and magazine articles, a variety of online sources (e.g., blogs, LinkedIn), and the websites of individual makerspaces. This documentation provided a basis for understanding the history of the maker movement, the career histories of individual respondents, as well as the organizational design and goals of individual makerspaces. In select cases, online discussion forums provided insights into participant interactions within particular makerspaces. Archival data was also used to verify and provide context for information collected during interviews (Denzin and Lincoln 1994; Van Maanen 1979; Webb et al. 1966).

Case Selection

Our choice of case study settings was shaped primarily by our desire to develop a framework for understanding how some makerspaces balance exploration and exploitation. Additionally, we

[6] A few in-text quotes relating to specific innovations have been attributed to particular innovators when previously published materials also document the same story. All other quotes are included anonymously in order to respect the privacy of interviewees, many of whom spoke very openly with us about their decisions and experiences.

aimed for a replication logic, whereby the analysis of each case can be used to confirm or disconfirm inferences derived from prior cases. In this manner, identifying commonalities and distinctions across contrasting cases allows for the development of a more robust framework (Glaser and Strauss 1967). This method for selection of cases is consistent with the recommendations that illustrative cases may be chosen based on theoretical criteria rather than statistical sampling criteria (Eisenhardt, 1989).

We explored two dimensions of contrast: the culture/governance model of the makerspace and the accessibility of tools within the space. The extant literature suggests that culture/governance models are likely to shape organizations' ability to balance exploration and exploitation; however these factors have not been examined in depth at organizational level (Gilsing, 2005). We therefore chose to examine makerspaces whose culture/governance models differed. We used whether the makerspace was operated as a non-profit or profit entity as a marker for this difference. We also located a space whose policies towards the accessibility of tools differed: in most spaces, participants can use tools themselves, in others participants must communicate what they want done to employees who then run the projects. Finally, because the availability of particular tools might shape the ability of individuals to both innovate and produce copies of their innovations for others, hence we sought out makerspaces that had similar tools. We chose to limit contrast on this dimension in order to make comparisons across the experiences of individuals working in different spaces more clear.

Study designs based on multiple-case studies produce more generalizable, grounded theories than single case studies (Yin 2003). The number of cases we examined was largely shaped by practical sampling concerns regarding the number and distribution of spaces in the United States. During Stage 1 phone interviews we identified 12 cities with more than two established makerspaces and only three cities with a pair of makerspaces endowed with similar tools. In city A, two for profit and two non-profit spaces had similar tools. We chose the pair of makerspaces studied in city A as the for-profit and non-profit spaces most spatially proximate to each other (less than two mile walking distance). In City B, one for profit and two non-profit spaces had similar tools. We chose from the two possible non-profit spaces in city B based on the spaces' physical proximity to the for-profit space, by selecting the closest space. We therefore chose to conduct detailed case studies of four makerspaces in Cities A and B. The study of four makerspaces with distinct governance structures/norms and policies regarding tool accessibility but similar tools allows us to investigate how such differences affect outcomes pertaining to innovation and entrepreneurship.

The Case Studies

Open since 2006, Commercial space A Inc. in city A is a facility designed to provide professional quality resources to makers, hackers, hobbyists, small businesses, and entrepreneurs. Commercial space A Inc. offers training on any equipment in the facility and has a full-time employee team for assisting members on their projects, and also for equipment maintenance and repair. One can attend classes without being a member, or purchase a membership on a monthly basis.

Community space A in city A is a space that provides infrastructure and collaboration opportunities for people interested in programming, hardware, robotics, science, art and technology. Community space A was modeled after European hackerspaces. Anyone can access the space and its tools; membership is needed only for voting rights, as the space stresses a consensus-driven approach to decision making. Founders estimate that the space currently has about one hundred paying members and several other hundreds of participants visiting the space every month.

Commercial space B is a for-profit space located in a central location in city B, in a commercial district. Commercial space B is staffed by approximately six employees who are in charge of executing customer projects using tools available in the space. With the exception of a few machines, making at Commercial space B entails creating virtual design files for tools such as laser cutters and 3D printers. Due to being an open space with no membership fee that is open to manufacturing on demand, Commercial space B attracts freelancers, enthusiasts and innovators seeking to work in the space, as well as small businesses interested in ordering custom designs (for example, signage, electronics, and furniture).

Community space B is a non-profit space located in a residential neighborhood in city B. This organization was started by a group of makers and tinkerers seeking work space for their projects, and it does not offer a regular stream of classes. Tools in the space are partially shared, such that members may bring tools from home and color-code them as personal use only, public use, or ask-for-instructions-before-using. In contrast to the other makerspaces, Community space B members work collectively on art and technology projects targeted towards display at the Burning Man festival, and subsequently donate these projects to museums or for public art installation purposes.[7] The two dimensions of contrast among the four chosen case studies are illustrated in **Table 1**.

Insert Table 1 here

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[7] We considered studying City C as well, but one of the makerspaces closed as we were conducting our study. We did however interview the founder of that space, as well as founders of the other two spaces in City C regarding the structure and culture of these makerspaces as well as the types of participants they attracted.

Data Analysis

We constructed categories based on the principles of grounded theory building. The technique involves comparing and contrasting specific findings from our interview notes to construct theoretical categories that serve as the basis for analysis (King, Keohane and Verba 1994; Strauss 1987). The construction of categories is an iterative process intended to create a common meaning that captures the essence of multiple observations (Locke 2001).

For example, we noted a number of instances where individuals were freely sharing information regarding entrepreneurship and production. We therefore created a preliminary category, “commercial advice” to describe this practice. After a category was created, we systematically examined the data and looked for other examples that supported or contradicted the category. As more examples were examined, categories were refined by adding or altering specific descriptors. If no other relevant examples appeared, the category was abandoned or revised.

As we identified and refined categories, we tried to understand how the different categories formed a coherent picture. In doing so, we made a series of comparisons at two levels. We investigated and compared participants’ views of each individual makerspace. This allowed us to identify the social mechanisms at play within each makerspace and bring our framework into focus. We then compared and contrasted social mechanisms across makerspaces, as well as the ability of different spaces to successfully support exploration and/or exploitation. This allowed us to further refine our framework, ensuring that it was robust to commonalities and differences across practices within different makerspaces. Data analysis required intensive work and iteration, and continued until a coherent framework was developed that matched the patterns in the data.

FINDINGS

Makerspace Attributes

During first stage of our research, we learnt that there are currently over 250 makerspaces in the United States (hackerspaces.org 2013). The formal structure and resources of these organizations vary across multiple dimensions. Some makerspaces are organized as for-profit businesses, while others are non-profits; yet others are formally for-profit businesses run purposefully with a non-profit ethos. Some makerspaces focus exclusively on particular technologies (for example, electronics, robotics, food, or biotechnology)[8], while the majority are generalist spaces, offering access to tools and knowledge pertaining to a wide range of interests, such as 3D printing, electronics, robotics, the use of CNC (computer numerical control), as well as more traditional skills such as metalworking, woodworking, sewing, and arts and crafts.

Makerspaces vary in their membership policies: some allow non-members to participate in classes and work in the space (often charging for storage space or for tool usage), while other spaces are accessible to members only. While there is substantial variation in membership fees, fees tend to range between $50 and $125 per month, and many spaces offer discounts to students and the unemployed.[9] Makerspaces also vary in the extent to which they provide formal training: some provide only cursory tool training focusing on safety, others provide extensive tool training, and yet others offer an array of courses pertaining to both skill development and the creation of particular projects. Classes vary in price, ranging from free to materials fees only to

[8] Biotechnology-specific makerspaces are relatively rare due to the more stringent restrictions placed by the U.S. government on working with biological agents.
[9] Some spaces call this the "starving hacker" rate.

hundreds of dollars (in such cases, equipment and insurance costs tend to be high or the skills required to teach the class tend to rare and specialized).[10]

Maker Attributes

Makerspace participants vary widely in the length of their membership, their interest and experience with using various tools, and their uses of the space. For example, in terms of uses of the space, a person may join a makerspace in order to gain access to a tool for a particular project, such as repairing an old clock mechanism, or sanding and repairing a piece of furniture; this would be a transient, or short term member. Others may be permanent members or even founders who helped set up the makerspace and who are long term members, working on various hobby projects or commercial products.[11]

We have found that although many makerspaces were created for use by hobbyist working on “garage projects”, they have also become valuable resources for the owners of small businesses and prospective entrepreneurs because makerspaces offer affordable access to expensive, high quality equipment on a flexible basis (see **Table 2**). For example, theatre costume makers can access industrial sewing machines; furniture restoration businesses can access a wide range of metal and woodworking tools—some of them too large, expensive, or demanding in terms of safety to be housed within one’s home or small business location. By

[10] Some spaces allow instructors full discretion in setting pricing (e.g., Community space B, in Seattle, Ace Monster Toys in Oakland), while others adopted consistent pricing policies for classes: some offer free classes only (e.g., Community space A in San Francisco), whereas others embrace set pricing (The Crucible in Oakland, Commercial space A in San Francisco, and Artisans’ Asylum in Somerville, MA).

[11] Makerspaces also vary in their acceptance of children and teenagers, mostly due to safety reasons, ranging from the very open Mothership Hackermoms in Berkeley, CA, which provides discounted childcare services and a play space for parent members, to Commercial space A which allows children over 12 in the makerspace provided that they are supervised by a “sponsoring” adult member. Some makerspaces have initiated children’s programs—such as HackerSprouts in Berkeley, and HackerScouts in Oakland—and several makerspaces exist and are being founded expressly for the purpose of exposing children to science, analytical reasoning skills, and tools.

being open to participation from small business owners, makerspaces often benefit from the latter's contribution of knowledge and skills to the community in the form of informal advice regarding business practices, or formal teaching of technical skills.

Insert Table 2 here

Similarly, makerspaces serve a very important role for prospective entrepreneurs. They represent places were the latter can prototype their product ideas and start collaborations with potential business partners. Membership in the makerspaces allows these proto-entrepreneurs to grow at their own pace, without pressure from landlords or investors, and avoid making large fixed capital investments before building a customer base.

Our Stage 2 analysis has revealed three characteristics of makerspaces that foster exploration activities in collaborative innovation spaces. Among these three characteristics, we have identified resource availability, participant heterogeneity, and two types of norms—pertaining to sharing and fairness in use of shared resource and in interaction with other makerspace participants.

Resource availability and sharing

Prior literature suggests a distinction between architectural and contextual conditions for enabling exploration and exploitation, whereby the organization is not only structured such that its architecture allows for both these processes to strive but also designed to allow a favorable context to flourish. While the innovation literature focused in-depth on organizational structures that enable the coexistence of exploration and exploitation (Kleinbaum and Tushman 2007), contextual conditions, and, in particular, the conditions for exploration, have received less attention. Our analyses reveal the importance of two contextual conditions: physical resources of space, tools and scraps and norms regarding sharing—and how the interaction between resources and sharing norms facilitates exploration activities.

Space. The characteristics of physical space in makerspaces are important for participants' activity and for casual interaction. Space as a resource is often marginalized in organizational research (Gieryn 2000), but we find that space is at least as important as time, tools and material resources in creating the conditions for exploration. A founder of a design firm working out of Commercial space A explained the value of access to the space:

> "Somebody had to have… maybe quarter-million dollar to start this [business independently] because I'm making up about forty-two different designs. So, … I'm thinking about not only just design it but also manufacturing it. [We] have Commercial space A, … I do my [work here] about how to start the business, own the business, and buying [materials]." (Eric)

Non-entrepreneur members and entrepreneurs alike expressed interest in physical space as a place to find social connections and technical support. Non-entrepreneurs explained that "hanging out" often results in serendipitous interactions and learning experiences. This was echoed by member / entrepreneurs who explained how they found advice groups, employees, and co-founders for their businesses within the space: support; employees; and co-founders.

Moreover, interviewees explained that they were often the recipients of technical advice from other members as a result of casual interactions within the makerspace. Members advised each other on the use of materials and tools[12] within the space, and often offered feedback on both aesthetic and technical quality of prototypes.

Having a space that is neither too large, nor too small compared against the number of frequent participants in the space results in close proximity among people. According to our data, close proximity to others facilitates "eavesdropping" to observe what and how others are working with a particular tool or on a particular product and results in faster and better incremental prototyping. This process is particularly salient to physical products, where people can visually examine how parts fit together and use tactile senses to explore textures and feel (Nicolini, Mengis and Swan 2012). In contrast, a software-oriented makerspace we have visited in the greater city A area did not facilitate similar eavesdropping and incremental prototyping due to the absence of visible boundary objects in programming.

Tools and materials. At Commercial space A, low-cost access to tools and tool training provides an important incentive to become a makerspace member, both from the perspective of members who are there to acquire new skills, and from the perspective of entrepreneurs. An employee of a firm working out of Commercial space A explained that they grew large enough that they would need to relocate outside the space, but they will also keep their existing rented area within the makerspace:

> "the two major reasons are the capital equipment [and exposure to media]. So, A. knows how to use a lot of the machines down here, and if he wants to build a new part, he just pops down here and he does it. He comes upstairs and he tests it. So, the capital equipment is the one sort of first most important issue."

[12] Especially due to the fact that some maker technologies such as desktop 3D printers are still in their infancy, being able to mitigate the idiosyncrasies of shared tools provides an important contribution to successful exploration in makerspaces. A testimony to this issue are the 3D printer owner meetings in many makerspaces such as Community space A and Commercial space B, where owners bring their tools in order to learn together about them and tweak tool performance.

Many other entrepreneurs have noted that cheap tool access enables them to iterate rapidly and efficiently on their projects. For example, an accessory designer at Commercial space A explained:

> "if I had bought a laser cutter, and also … wood-shop stuff [that I used]. Also the welder, you know, all of those things. If I bought all of those things, it would be a hundred thousand dollars, and I'd have to maintain them, you know? That's not what I want to do."

In contrast to Commercial space A, Community space B provides selective access to tools and equipment whereby member can rent a premium personal space (a table) and tools and equipment are labeled according to their degree of publicness. This was done following a simple and intuitive color code, such that "green" tagged items are free to use, yellow tagged items can be used only with prior approval and / or training, and red items are the personal property of a member and they are not for public use despite being housed within the space. Such restriction effectively limits the types of tools that are available and shared, reducing the usefulness of the membership for participants who do not possess their own tools. Indeed, while we have noticed that this makerspace generated a number of collective art projects, exploratory, innovative activity was severely limited in this space, and participation in the makerspace more scarce.

The other city B makerspace, Commercial space B encourages computer-aided design and virtual idea exploration despite the fact that it houses a wide array of electronics, crafts, and industrial arts tools. According to the founder, this space was founded as a makerspace without membership fees so that it does not place any financial burdens on those who are interested in contributing to the community. At the same time, this business earns revenue by having participants pay for all materials, tool usage and employee time, because participants are not allowed to directly interact with the tool due to safety concerns. This has led to a community space oriented towards social interactions, where participants hang out for the “free wifi and coffee, and smart people” (as told by an interviewee). The founder explained: “I have awesome people hanging out here. That is the greatest thing, is that I've built a trap for all these cool smart people… I no longer have to go out and find them... It's self-selection. There are [other] people that won't even walk in the door.”

At the same time, another set of participants behave as “customers” who routinely place virtual orders for employees to laser cut or 3D print their designs. An employee (Maria) explained that “a lot of people just send a job in and then come in a pick it up. So a lot of times there aren't very many people in the shop. That doesn't necessarily reflect how busy we have been… customer members don't use the tools aside from hand tools or a soldering station or the soldering machines. We're running the machines.” Thus although Commercial space B has been setup as a for-profit space, the culture has not given rise to many entrepreneurial ventures by participants – much innovation within this makerspace comes from the ranks of employees who have direct tool access and the ability to rapidly prototype their designs without all the tool access costs that the other participants in the space have to incur. Commercial space B employees benefit from “access to a lot of machines and tools and equipment … [One employee, John said that it] would be prohibitively expensive for me to build out in my own shop, basically, for [the cost of] a very cheap membership fee. I get access to a ton of stuff that I would, basically, need to be part of a very big organization like a big, internal, corporate, R&D arm, or part of a design firm, or part of an engineering and R&D firm, or something to get access to tools like that."

Evidence suggests that many members regard membership costs as "sunk cost" which gives them the freedom to explore and iterate their ideas within the limits of tool availability. For example, an interior-designer turned accessory maker at Commercial space A confessed that he shied away from working in another makerspace located closer to his home because that space charges a fee per minute of tool use. Iterating designs and exploring alternatives are important to him, and having a variable operating cost would result in financial difficulties for his business (whereas a fixed membership cost becomes negligible when he attains a good monthly volume for his products).

In addition to enabling hobbyists and entrepreneurs alike to cheaply prototype their designs, shared tools generate "social glue," for two reasons. First, people schedule consecutive appointments to use the tools, and, in the process of waiting are able to observe one another's designs and learn about each other's expertise and interests. Second, by virtue of being common goods, tools become the object of shared expertise; everyone has a stake in maintaining the tools in good functioning and helping others reduce their machine-time needs, so they teach each other ways to use the tools more effectively and correctly. For example, one Commercial space A entrepreneur explained:

> "a year earlier when I took a laser class, somebody was doing wine glasses as a Christmas gift, and one of the things that they shared was that you put wet newspaper on the glass in order to get a better result… And that was not in any manual anywhere. I could not have gotten that in a master's course or something." (Matt, Commercial space A)

Along the same lines, another Commercial space A participant stated: “[o]n the laser machine, somebody showed me just some trick to do the job faster. … You could press the button again without re-printing it again from the software.”

Space and tools are closely tied to yet another important but marginalized resource, material scraps. The time when nascent entrepreneurs engage predominantly in exploration activities is before creating a brand, which is paradoxically also the time when they are most constrained in terms of resource access. In addition to providing access to space and tools, many makerspaces provide a designated space to house donated and discarded but potentially reusable materials. These materials are used as slack resources by members, leading to experimenting with new materials and material properties, and offering a low-cost avenue to learning. For example, in many makerspaces one is expected to buy a “kit” with materials in order to take a course such as electronics. However, Community space A and Commercial space A have nicely organized bins with excess materials that one can “rummage” through to extract components needed for participating in the class, should they be unwilling or unable to cover the cost of a kit. Similarly, Community space B provides members with some electronics and textile areas where they can freely choose materials they can work with. Commercial space A has a few such items as well, such as for example vinyl for experimenting with laser cutting patterns. In Community space A, scraps were explicitly offered up for use to those in need, as an explicit time-money tradeoff:

> “If you want to forage through that pile for parts, because you don’t have $20 for the electronics kit we use in the class, you’re welcome to! You may need to desolder some of them to salvage what you need, but that’s up to you.”

We have observed that the presence of these scraps allows participants to experiment with prototyping, and becomes a self-perpetuating resource in the organization, whereby others donate materials they have, or contribute other scraps for their own projects once they have advanced in their mastery of the tool and move from scraps to purchasing new materials.

Participant heterogeneity in expertise and goals

A second key to the success of balancing exploration and exploitation within a makerspace is participant heterogeneity. While few interviewees explicitly discussed heterogeneity as such, we found that heterogeneous expertise allowed project collaborations to naturally emerge. All makerspaces we have studied relied on formal and informal means of forging such connections, from bulletin board posts in common areas or emails on the member list, to information brokered by acquaintances, employees, and central participants in makerspaces. Overall, many interviewees articulated the idea that peer makers were a rich trove of information about materials, tools, and techniques. For example, James from Commercial space A participant explained:

> “You run into a problem on the machine. What do I do? Well, most people go onto Google and they say, "This is happening. What do I do." The benefit of having someone here is that the insight is so much - it's not necessarily more rapid, but it's a little bit finer. Think of shooting an arrow. Google can get you really close to the answer, but a person can get you even closer. A person can get you to the target because they can see what you're working on. Whereas Google will say, "Here are eighteen answers. Weave your way through and maybe you'll make an answer from this eighteen." … the people that are using the space … there's a

good chance they ran into your problem as well. Whether it's using the same material that you're using, if you're [making] a bag and say it's not sewing correctly. Well, there might be a different type of leather or a different type of application you can use on the leather that you've been looking for…It just so happens that there is a guy in here who has been working on leather that you can ask… So those are the kind of things that happen here because it's people. People forget that computers are brains and the best brains on the planet are the ones that humans have."

Fairness norms

Three types of fairness norms appeared particularly salient within the makerspaces studied: fairness regarding assistance, intellectual property, and use of common spaces or hiring peer makers for exploitation / manufacturing purposes. These norms affected the extent to which participants were able to engage in exploration and exploitation.

Fairness when in need for assistance. One fairness norm concerned the extent to which one can expect others to "help out" with a project. Several interviewees in Commercial space A and Community space B expressed dissatisfaction that sometimes people would come to the makerspace with ideas, but no concrete skills or plan to execute on them, and proceed to bother others repeatedly for detailed advice. While all interviewees were committed to some extent to the idea of providing feedback and guidance to their peers, many felt that using their time and social capital for someone else's project should come at a cost—either financial or in terms of favor exchanges. For example, a woman running a tailoring and theatre costume business out of Community space B explained that she is happy to share her knowledge of particular sewing machines in the space, provided that people have some skill and are able to manage on their own after that. However, she confessed that there had been times when someone came in and "expected me to sit by them and help them make a skirt" so she then posed a price list by her work area, in half-hour increments of her time. Another member of the same space told us more about what had happened:

> "[The seamstress is] fine if you ask her like one or two questions. But there was one woman who… really frustrated [her] because … she was looking at the pattern and putting the pieces out on the fabric and just acting like she wanted someone to come and help her a lot. If you ask, sure, but I don't want to sort of give into your theatrical sighs!... I don't want to give you the impression that people are like mean or anything because they're totally not but people are here to work. They'll help you if you need like a little bit of help to get started. But if you want to have someone like teach you what they know, the way to do that is probably to approach them about a lesson."

Similarly, an architect from Commercial space A explained how he draws a line between tool-related sharing, and sharing of supplier information:

> "if you're just, like, here on a weekend, and it's for fun, and somebody asks you, "Oh, man, that's awesome. How did you cut that?" You're like, "Oh, I used the band saw"…"That's great." Some people ask me, like, "Where do you get that stuff?" I'm like, "Well, it kind of costs me about a thousand dollars. I'm paying my employee to research." You know, and, like, I kind of start asking, like, well, who is it? If it's somebody who I exchange with a lot, who gives me ideas – [yes, but], sometimes the people who are consulting for somebody, have asked me, "Would you care to share your sources?" I'm like, "Well, how about sharing the, like, money that that tech start-up is paying you to do

this?" … It's give-and-take….I'll tell people what it is and where they can get it. I'm not going to tell them my sourcing. Like, I'm like, one fabric I'm using, you can get at Jo-Ann Fabrics. I'll say, "This is this kind of felt. Go to Jo-Ann Fabrics. They have it." I won't say, "It's made in New Hampshire by thus-and-such a company. Here's the contact. The company is a pain-in-the-butt to deal with. It took me many hours to get that. And, like, you know."

Intellectual property and fairness. Concerns with intellectual property have the potential to stifle information sharing and collaboration, which means that exploitation and the potential material rewards can stifle exploratory activities. Interestingly, we have found that such concerns were less prominent than expected in the makerspaces we studied. Multiple people expressed a lack of concerns for idea theft; Jimmy, a Commercial space A entrepreneur, stated that:

> "I think generally not just in the makerspace but also in the community in the world right now, in the [city A] community as well as beyond, that there are just too many good ideas out there. It's actually really never about having an idea. The chance is that somebody else is going to have a similar idea or even if somebody else does have your idea, it's all about execution. That's something that can't be stolen."

While some spaces like Commercial space A offer support for intellectual property filings, others like Community space A, Community space B and Commercial space B and are explicitly supportive of an innovation model that forsakes intellectual property and generates public knowledge in the interest of accelerating innovation at industry level or democratic access to knowledge:

> “We don't believe in patents as like the ‘be all end all’. We also feel strongly about open source and the fact that you can still make money on open source. You don't have to hoard it and patent things. It's that ability to make a profit off things. There are many other ways that sort of leave you with a much better product.” and “, if you can stand on my shoulders, if you can avoid the lessons that I had to painfully learn, please do so because all of humanity will be better if we spend less time doing the same mistakes over and over again. Similarly, with the amount of litigation and the amount of legal activity surrounding patents, it's very much curtailing innovation. I cannot tell you how many people I talk to that say, "I've got this idea, but I'm scared to launch it because I'm afraid I'm going to get sued for patent infringement, or somebody, a troll, is going to come after me." (Martha, Commercial space B)

The third facet of fairness norms was defined by people attempting to use more than a “fair share” of resources for business-related purposes, or seeking to employ other creative makers from the makerspaces as skilled labor for mass production. With the exception of Community space B, which allows members to rent long-term table space for their projects, the makerspaces we have studied rely heavily on the use of common spaces by different groups of people throughout the day and the week. Thus someone occupying a large space with a “production line” is bound to attract negative evaluations, leading to exploration activities being moved out of the space. In this manner, makerspaces organically encourage innovation in the space, while allowing nascent entrepreneurs to “graduate” as their designs converge and their work focuses on exploitation of a particular product or product line.

Makerspace members are passionate about learning and exploration. They usually either rent their own workspace when moving into exploration mode and the makerspace does not afford them to produce a sufficient volume, or outsource their production while keeping the design and prototyping capabilities of their business within the makerspace in order to flexibly address changing customer demands. For example, the co-founder of a now large tablet accessory business in City A explained: “we wanted to start this project with no budget, and we wanted to … do it with our own two hands. Therefore, all the prototyping was going to be done here [at Commercial space A]…We saw that the product was going to evolve, maybe not at the onset, but certainly within the first few weeks … We wanted to make sure that we were going to be able to iterate quickly and improve upon the product in real-time.” However, once prototyping concluded and the entrepreneurial team focused on a particular set of tools and skills needed in producing their goods, they locally sourced them:

> “the [production] side of things was never an issue for us. What was the issue …, was the [material]. Obviously, working overnight at Commercial space A wasn't going to work. So we went out and basically scoured San Francisco for anybody who owned a shopbot [machine] or something similar. That led us to a lot of furniture makers and different types of entities that had that machine. Ultimately we found a guy in the Mission … We were able to first get him to produce large volumes than we could previously produce on his shopbot, and later we entered into an arrangement with him where he would produce some based on his man hours, but he would also let us use the machine overnight and we would train operators to basically use his equipment to make our parts. Once the pieces came off the machine, we rented a little part of a shop next door to his shop where we would do all the finish sanding that was required for the parts.”

When some makers have attempted to mass-produce in the space, this was reported as an undesirable and rather temporary state. For example, Mike, a member of Commercial space A explained:

> "[An entrepreneur] actually tries to produce products here. This is more of a prototyping place if you ask me, there isn't enough space to mass-produce. I mean you can make a product line but if you're really trying to like mass produce something [then] go into a factory."

Mike was hired by this entrepreneur to mass-produce a line of kitchen accessories. He reported being very disappointed with the experience, stating that:

> "If you want make [your products] here in America. .. this [Commercial space A] really isn't like a factory. You can produce large numbers I guess. That's what he does. He really tries to do that here. I'm sorry. I'm not like mocking him in any way but I just didn't have a very good experience working with him. He wanted like a sweat shop worker or something. I just seriously wasn't into doing that for him because there was nothing in it for me…So just copying his designs …A thousand times … I'm a designer so I can't really do monkey work like that. I just can't do it."

In contrast, another Commercial space A participant shared a positive experience hiring his peers in the space to help reproduce a design, because he gave them freedom to participate at any point in the manufacturing process and to make enhancements as they saw fit:

> "I found that the quality and the creativity and the intelligence of people at Commercial space A meant that even though we were sort of just doing simple tasks of assembly or making electronic boards like this, that there was always innovation. When you have creative people and your goal is to move faster or ship more units or make the product cleaner, there is always room for innovation. I found that we were making changes and tweaking things all the time" as a result of their input.

Interdependence of Enabling Characteristics

We found that these three characteristics operate interdependently (see **Figure 1**). For instance, the types of resources available to participants, or norms against tool and information sharing, limit the type of participants active within the makerspace. In the case of Community space B, limits on tool availability constrained the extent to which participants explore and innovate despite the fact that the space hosts a wide variety of scrap materials that members could experiment with. Relatedly, the limited exploration is connected to the lack of vibrant new entrepreneurial ventures in the space, limiting small business participation to a few arts and crafts businesses (see **Table 3**). Conversely, Community space A has encouraged open tool and information sharing, and a wide offering of scrap materials, which in turn has fostered a creative, innovative atmosphere in the makerspace, and maintained a high level of interest in exploratory activities and learning. At the same time, Community space A interviewees reported no considerations of "fairness" in terms of limits on information sharing, meaning that participants often help substantially on developing other's projects or voluntarily take on "community" projects. Additionally, the free tool sharing at Community space A has historically led to a high rate of machine breakdowns, which is bound to raise concerns for people involved in commercial production or on the path to entrepreneurship. Both of these have arguably led to less exploitation activity in the space and have limited the proto-entrepreneurship pipeline.

Insert Figure 1 here

In our sample, Commercial space B and Commercial space A were most likely to produce entrepreneurial ventures. As discussed above, in the case of Commercial space B this ability was severely constrained by limited access to tools, which in turn affected the diversity of participants active in the space. Many of our interviewees reported that they liked the makerspace as a "place to hang out with smart people," while many of those engaged in "making" at these space created computer designs off-site and sent them in as production orders to Commercial space B employees. We observed that the lack of shared tools limited social interactions within the space as well, and reduced the likelihood of entrepreneurs visiting the space once they were engaged in exploitation mode, thus diminishing the likelihood of future ventures developing in the makerspace.

Lastly, Commercial space A provided the most successful example of fostering innovation and balancing exploration and exploitation. The space provided shared tools and space for scrap materials, and encouraged a culture of sharing, and fairness in use of tools and peer participants' knowledge and expertise. The space also offered ample course offerings, and a wide variety of tools, which attracted a heterogeneous group of participants in terms of type and level of expertise. Lastly, the physical space provided and the makerspace norms encouraged participation by hobbyists and proto-entrepreneurs alike, but also allowed several small businesses to foster within the space. The richness of tools available in the makerspace was partially responsible for small business and entrepreneurial participation in the space; as several interviewees suggested, the combination of heterogeneous expertise in the space and the expensive equipment (sometimes necessitating special permitting and space-consuming safety precautions) resulted in many entrepreneurs returning to the makerspace for design and feedback purposes, even as they had relocated their business off-site. We found that this heterogeneity of goals enabled a vibrant entrepreneurial community oriented towards exploitation of innovative designs, in a symbiotic relationship to ongoing exploratory activities.

Insert Table 3 here

Limits to the Proposed Model of Exploration and Exploitation in Makerspaces

As described above, the development of an innovation and a new venture by an individual partially relies on the local makerspace creating a context that facilitates product prototyping and quick iteration of designs and business model with help from the community. In this regard, we have found that the physical location of the makerspace affects the range of expertise and occupations present in each space, such that we see architects and designers in San Francisco's SoMa, software developers at HackerDojo in Silicon Valley, industrial engineers and machinists in Menlo Park, true "hackers" at Community space A, a mix of engineers and craftsmen in Boston and Seattle, automotive engineers and artists in Detroit, and aerospace engineers around the Mojave Air and Space Port industrial district. Additionally some makerspaces' commitment to open access and the acceptance of the fact that members engaged in a passionate pursuit of creativity and innovation may work at non-traditional hours has led to some problems with homelessness, or members living on the premises. This was particularly the case for spaces where members receive unlimited access to the space, in contrast spaces where the owner or employees monitor building access and often restrict it to daytime and evening hours.

Another often-invoked limitation of the makerspace organizational model that frequently came up in our interviews was the public good dilemma regarding use of public areas in the makerspace. Makerspaces such as Community space A function as a "do-ocracy" ('if you see something that can be done to improve the shared space, do it'), and are often subjected to cycles of tidying up and disorganization and to free riding behaviors. A central participant in Community space A explained to us:

> "we have his storage area for members only, and it's separate and well-organized. Someone recently came up with the idea of sort all the library books and clean up the social space, and he did it without asking anyone, now it's nice. Everyone knows that Friday is trash day but nobody is in charge of taking it out, and these storage boxes at the entrance need to be periodically emptied because random people throw stuff in here."

A participant in an East Coast makerspace explained to the first author: "there is just infrastructure that bothers me. I think we can be a lot more professional. … I'd like them to clean up after themselves…Just take some personal responsibility." Similar complaints were voiced in other spaces such as Community space B and Commercial space A: "clearly, someone had been using the seam ripper and just didn't put it back." In other spaces people have complained about free riders who "visit" often but do not pay membership fees taking advantage of the open culture in some spaces, and of irresponsible behavior surrounding proper use of equipment and tool storage in their designated space.

Related to the problem of the commons, space or machine limitations were often cited by interviewees as reasons to move either entirely or mass-production activities out of the space. One interviewee explained: "machine time [is the pain point]. I mean with lasers it was just [a] terrible [constraint]. You could not book [them ever!]. Two hours [slots] is never enough time to do anything. These [3d printers] you get four hours because these take [f]orever. Four hours isn't even enough with these. Honestly they need to be okay with letting us print overnight or something… I barely got this case out in time." (Mike, Commercial space A)

Study limitations

There are limitations to be considered when interpreting and using the results of this study. The use of in-depth, qualitative data offers the opportunity to gain understanding and build theory in areas that we understand little about, however such theory runs the risk of being idiosyncratic and not generalizable to the entire population (Eisenhardt 1989). In this case, the makerspaces studied are generally accepting of a wide-range of activities, with the exception of Community space B in which non-entrepreneurial applications of projects pursued within the space appear to be preferred—although existing small businesses are welcome. Makers in other makerspaces might have might have different motivations for participating, both stemming from and resulting in different structural arrangements. For example, one might observe that groups comprised primarily of entrepreneurially-driven makers—in their effort to create successful commercial products—will channel their efforts toward creating spaces where advice on how to form and run a start-up is shared, but where it is acceptable to hold-back product-related information or where new members are accepted only when their start-ups are pursuing product paths different from those of existing members. Care should be taken when using findings from this paper to better understand social practices in makerspaces with different missions/objectives.

DISCUSSION AND CONCLUSION

This paper contributes two key findings to the literature on entrepreneurship, innovation, and organization design. First, it highlights the conditions under which entrepreneurial know-how and advice occurs in makerspaces, and the process through which initial entrepreneurial occurrences appear to stimulate subsequent ones. Second, it indicates that shared resources and the presence of participants with time and heterogeneous skills and motives affect the ability of the makerspace to support both explorative and exploitative activities simultaneously. We consistently find data in support of these factors across non-profit and for-profit spaces and across cities. Below we engage in a discussion of each of the key findings, focusing on contributions in relation to the literature on innovation and entrepreneurship.

Key Theoretical Point 1: Sharing Entrepreneurial Know-How

Many of the makers we have interviewed have a background in engineering, technology or arts. We possessed entrepreneurial know-how, and none of the spaces we have examined provided systematic support for venture launching. Therefore, participants relied heavily on peer experience with entrepreneurship, crowdfunding, and production outsourcing. As a consequence we expect that venture founding within the space has a strong effect on subsequent foundings, provided that the entrepreneur continues to participate in the space. In one of the makerspaces studied, Commercial space B, we became privy to two entrepreneurial success stories thanks to the employees showcasing these successes to us. However, due to limited tool access within the space, the entrepreneurs had stopped participating in the space and therefore their experience was not readily available to other potential innovators and entrepreneurs.

In addition to sites for information sharing, we found that makerspaces contribute to the success of entrepreneurial ventures by allowing proto-entrepreneurs to use physical and human resources on a flexible, low-cost basis until they are ready for take-off (crowdfunding, angel investment, etc.) In doing so, potential entrepreneurs are not constrained by fixed capital investments, space rental or costly loans, and can explore a wide variety of production paths, materials and designs without the pressure that external constraints impose on start-up ventures.

Lastly, the wide range of entrepreneurial ventures in makerspaces also indicates that, despite the original ethos of the makerspaces being connected to the social movement of the “makers,” these physical settings are open and accepting of a wide range of entrepreneurial interests, ranging from social entrepreneurship and educational ventures to commercial products companies.

Key Theoretical Point 2: Shared Resources, Heterogeneous Participants, and Implications for Balancing Exploration & Exploitation

While resource constraints and heterogeneity of goals have previously been suggested as impediments to balancing exploration and exploitation, our findings suggests that, in the right circumstances, resource and space sharing may contribute to collaboration among participants with heterogeneous goals. Contrary to expectations that heterogeneity in participant goals would lead to divisiveness and conflict, we find that makerspaces foster an “ecosystem” of innovation and entrepreneurship, where experienced entrepreneurs are willing to mentor proto-entrepreneurs and new ventures and share their business process experience; experienced “makers” voluntarily share information about tool operation and help inform material choices; and all participants openly engage in conversations about their skills, knowledge and goals. Thus the heterogeneity of expertise within each space, coupled with the heterogeneity of “career” trajectories of inventors and entrepreneurs provided social capital in the form of feedback and advice, and legitimate peripheral participation in maker communities was encouraged within the limits of perceived fairness in sharing time and resources. In spaces where we did not observe this relationship among makers with heterogeneous goals, and where connection to the physical resources was curtailed, exploration or exploitation activities were severely impaired.

This work contributes to research at the junction of user community and innovation research by extending and refining the exploration-exploitation framework to innovation communities. Moreover, these findings contribute to our understanding of community-based forms of organizing by highlighting the benefits of heterogeneous participation and the role of shared space and (participant) time for the success of these communities. While March (1991) suggested that organizations cannot do exploration and exploitation simultaneously because of limited resources, we find that certain resources such as information do not pose the same limitations, such that exploration and exploitation may easily co-exist in the same organization, and that user communities where participants are subjected to a different set of constraints than firm employees can thrive under resource and space constraints.

Conclusion

Makerspaces, and innovation communities more generally, represent a novel model for innovation development and entrepreneurial seeding. While pour knowledge of this novel organizational structure and the societal benefits it creates is growing, many questions and issues remain to be explored. In this paper, we investigate issues pertaining to how the needs of both exploration and exploitation are balanced within four makerspaces. We find that the ability to freely and inexpensively "tinker" with shared tools and materials is a key contributor to innovation and to fostering proto-entrepreneurship in makerspaces. In addition, participation by individuals with a variety of motives and expertise are a key element of creating and maintaining a balance between exploration and exploitation. Finally, issues of fairness—regarding both the availability and use of community resources and returns to the sharing of information—appear to be at play in limiting the extent of exploitative activities within makerspaces.

Table 1. Case selection based on governance and tool access characteristics

	Restricted tool access	*Open tool access*
Governance: for profit	Commercial space B	Commercial space A
Governance: non-profit	Community space B	Community space A

Table 2. Participant Motives in Makerspaces

Participant Type	Motives for Participation
Hobbyist	• Access to tools and/or resources to tinker and build • Enjoyment • Self-efficacy (producing something by oneself) • Social engagement, ability to interact with others and build relationships • (Limited learning – for many, learning was a beneficial by-product)
Small Business Owner	• Access to tools and/or space to produce product or service • Limited social interaction and learning Note: often engaged in creation of custom products
Early-Stage Entrepreneur*	• Access to tools and/or resources to refine and produce a product or service • Learning (skills, tool use, entrepreneurship) Note: generally creating a specific product or product line (not custom products)
Late-Stage Entrepreneur*	• Access to tools and/or resources to create new or refine existing products or services; occasionally to produce a product or service • Access to expertise, ideas, perspectives of others Note: generally creating a specific product or product line (not custom products)

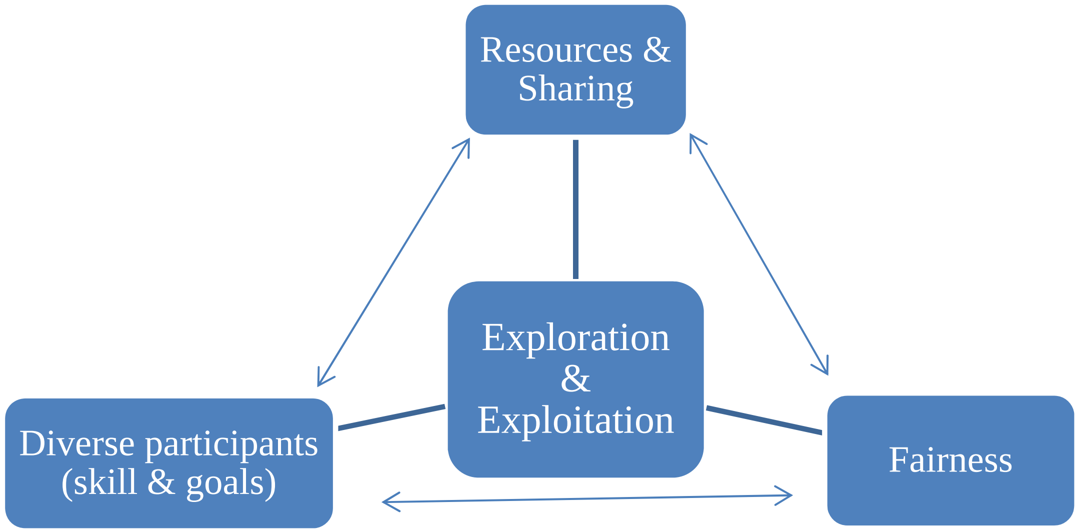
* We interviewed hobbyists who became early stage entrepreneurs in the space; early stage entrepreneurs who became late stage entrepreneurs

Table 3. Enabling Characteristics and the Four Makerspaces

	Commercial space A	**Community space A**	**Community space B**	**Commercial space B**
Resources/ sharing	Yes	Limited	Limited	Limited
Diverse participants	Yes	Limited	Limited	Yes
Fairness	Yes	No	Yes	Yes
Exploration	**Yes**	**Yes**	**Limited**	**Limited**
Exploitation	**Yes**	**No**	**Limited***	**Yes**

* “Exploitation” only in the form of pre-existing businesses such as photography or sewing.

Figure 1. Interdependence of Enabling Characteristics



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