# Impact of Makerspaces on Cultivating Students' Communities of Practice Abstract

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# Impact of Makerspaces on Cultivating Students' Communities of Practice

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Abstract

*The Richard L'Abbé Makerspace at the University of Ottawa-Ontario, opened its doors to students in 2014 aiming to offer a creative environment that fosters interdisciplinary collaboration and innovation. Since then, the Makerspace was incorporated in 10 courses offered at three faculties, held 250 workshops, 3 design challenges, and was used by more than 3000 students. This paper describes how Makerspaces help cultivate students' communities of practice (CoP). We interviewed 19 engineering students with different participation levels in the Makerspace, from different engineering disciplines to understand how they became participants in the makers' community of practice at the Richard L'Abbé Makerspace. We found that the Makerspace provided engineering students with a platform for forming a CoP that shares a common interest in making, by providing them with access to equipment, workshops, competitions, and by connecting engineering students from various disciplines to work on hands-on engineering projects that allowed them to translate theories learned in classroom to practice. The paper also describes the lessons learned from the interviews and challenges that face the Richard L'Abbé Makerspace.*

Keywords: Makerspace, Engineering Education, Community of Practice, Maker Movement.

## Introduction

Makerspaces are informal sites for creative production in art, science and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products; Participants in these Makerspaces are of all ages, and levels of experience (Sheridan et al., 2014).

Engineering schools are opening Makerspaces to provide creative spaces, and bolster design and prototyping activities on campus by providing students with access to prototyping technologies, and encouraging collaboration between diverse teams of students (Forest et al., 2014). As well, they complement design courses, and answer the need for more practice-based engineering that compliments existing theoretical class structure (Barret et al., 2015). Barret noted that the key benefits of Makerspaces to its users in engineering schools are building physical models, and the benefits inherent of informal learning environments and communities. Those benefits include enhanced academic performance, integration of academic and social experiences, gains in multiple areas of skill, competence, and knowledge, and overall satisfaction with the college experience (Zhao, D. Kuh, 2004). Makerspaces also work to strengthen community ties by offering a space for the community that facilitate and foster broader community life (Moilanen, J., 2012).

## Communities of Practice

Wenger (2002) defined Communities of Practice as "groups of people who share a passion about a topic, interact on an ongoing basis to deepen their knowledge and expertise, share information, insight, advice, and help each other to solve problems. He also recognized that CoPs, despite the variations among them, all share a basic structure: A domain of knowledge, that the group shares interest in; A community of people, that represents the social fabric of learning and encourages a willingness to share knowledge among participants; A shared practice, that represents the knowledge the community develops, shares, and maintains (Wenger, 2002, p. 27-29).

CoPs allow their participants to develop professionally, remain at the forefront of their discipline, and gain confidence in their own expertise (Millen, Fontaine, & Muller, 2002). Student CoPs provide a unique opportunity to engineering schools by allowing students to form networks to exchange knowledge and skills, engaging students on campus, and creating a collaborative learning environment that provides students with access to authentic activity, and situative learning environment. Lave and Wenger (1991) argued that learning is a process that takes place in situated contexts of practice through participation and group activities. They also argue that the acquisition of knowledge is social process in which people participated in communal learning at different levels depending on their authority in a group, whether they were a new or an active participant. Lave (1991) argued that knowledge and skill develop in the process-and as an integral part of the process-of becoming like master practitioners within a community of practice. She also noted that apprenticeship learning provides learners with a broad view of the material to be learned from the very beginning, and a broad exposure to ongoing practice.

This work is informed by the definition of knowledge as a product of the activity and situations in which they are produced, and that concepts continually evolve in the learner's mind with each new instant of practice, and every chance of new practice allows for an opportunity to transfer knowledge to new situations (Brown, Collins, & Duguid, 1989, P.33). They have also argued that when students observe and practice as part of a culture they are exposed to the use of a domain's conceptual tools in authentic activity.

## The Richard L'Abbé Makerspace

The Richard L'Abbé Makerspace opened its doors to students and the public in September of 2014. The Faculty of Engineering intended to create a space that fosters innovation, promote interdisciplinary projects, provide access to prototyping facilities, encourage and facilitate students' entrepreneurship, and provide a space for students to realize their designs and acquire and practice new skills, and knowledge.

The Makerspace adopted a model that granted free access to all students on campus, and dedicated Sundays to community engagement. The space was directed by Faculty but the day-to-day operations are managed by students. The Richard L'Abbé Makerspace's management model is an integrated employee-volunteer model with 9 employees and 10 volunteers per semester.

The Makerspace started with very limited resources, and the Faculty of Engineering covered the initial operating costs. By the second year of opening the Makerspace had doubled in size, offered more advanced tools and equipment and secured more funding from a variety of sources including philanthropic donations and government funding.

Today 3000 students have used the Makerspace, 250 workshops have been held, and 3 design challenges have been organized.

A survey was previously administered to the users of the Richard L'Abbé Makerspace; The survey asked students about the impact the Makerspace had on their engineering skills: Problem analysis, design, team work, communication, use of engineering tools, life-long learning, and entrepreneurial skills (Galaleldin, Bouchard, Anis, & Lague, 2016). After analyzing Ninety-three responses to the survey, the study revealed that the Richard L'Abbé Makerspace helped engineering students gain more confidence in their engineering knowledge through hands-on experience, prototyping, and continuous iterations of their designs. Of the survey sample, 62% reported that the Makerspace increased their confidence in their problem solving skills through the use of prototyping equipment available in the Makerspace, and the Maker environment and community in the Makerspace; 72% reported that the Makerspace helped them to increase their confidence in their design skills through visualizing and iterating their designs using the prototyping equipment in the Makerspace, it has also increased students' experience with CAD and modeling software, and helped them learn how to design for manufacturability; While 66% said the Makerspace helped them feel more confident in their communication skills as they feel more able to communicate their designs and ideas with their peers; Moreover, 67% of the engineering students who completed the survey used the Makerspace for extracurricular projects, while 40% used it as part of a course related requirement. 50% of the students reported using the Makerspace at least once a month (see Fig-1).

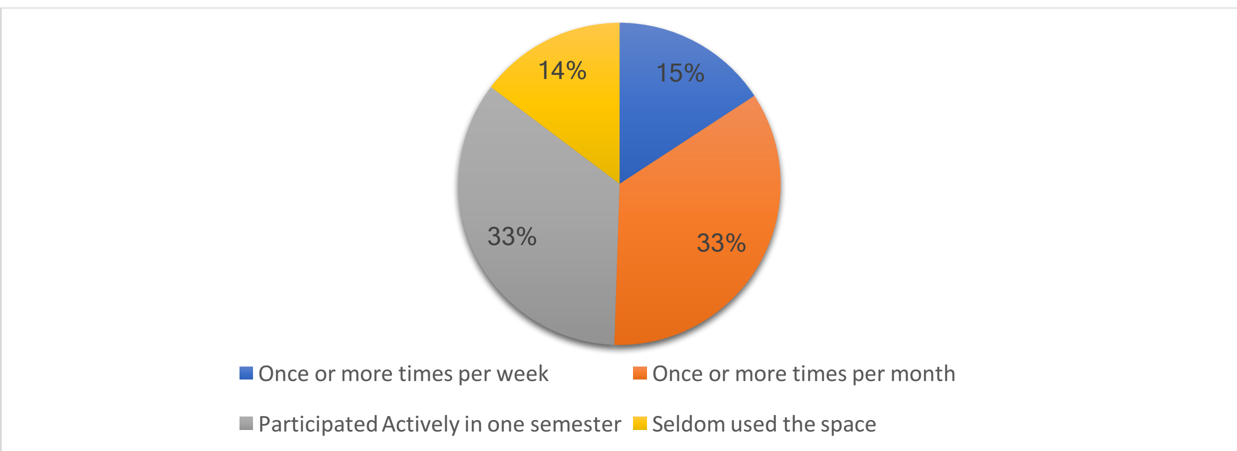


*Figure 1 - Frequency of participation/use in Richard L'Abbé Makerspace*

The focus of this paper is on understanding the impact that Makerspaces have on cultivating student CoPs in engineering schools. We argue that Makerspaces can provide an environment on campus that facilitates the growth of student CoPs. For this study, by "cultivating" we are referring to Wenger observation that even though CoPs are usually self-organized configurations and participation within one is voluntary and organic, good community design can invite, and evoke aliveness. We hypothesize that establishing a resourceful, student run, free access to all, on campus Makerspace would enable students to form a student CoP.

## Research Question

The purpose of this research is to identify the role that Makerspaces play in cultivating engineering students' CoPs.

## Methods

### Participants

We purposefully invited users who represent the diverse student population. Some users had answered the survey conducted in 2016, but this is not true for all interviewees. To gather broad perspectives, we invited students from both genders and from a variety of engineering disciplines as well as both undergraduate and graduate programs. Moreover, we ensured that we include frequent users, and those who used the space only when they needed to achieve something.

We used purposeful sampling to maximize the variation and representativeness of the sample of engineering students who use the Makerspace. Maximum variation (heterogeneity) sampling insures detailed description of the phenomenon, and helps in identifying shared patterns (Patton, M, 2002); Moreover, the strength of heterogeneity sampling is that common patterns that emerge from great variation are valuable in capturing the core experiences and central, shared aspects or impacts of a program (Patton, M, 1990). Students were invited to participate in the interview via email or in person at the Richard L'Abbé Makerspace.

Table-1: Demographics of the students interviewed

| **CHARACTERISTIC** | **POPULATION (N)** |
|---|---|
| Gender | |
| Male | 9 |
| Female | 10 |
| Engineering Discipline | |
| Mechanical | 7 |
| Civil | 2 |
| Electrical | 6 |
| Biomedical | 2 |
| Computer Science | 1 |

### Data Collection & Analysis

Aiming to understand how the Makerspace cultivated the makers CoP, we conducted semi-structured interviews with 19 users of the Richard L'Abbé Makerspace at the University of Ottawa. Interviews took place in various locations, based on participants' availability (e.g. cafés on campus, the Makerspace). Interviews took approximately between 15 to 30 minutes.

We asked the interviewees what the Makerspace meant for them; How they came to be a participant of the makers CoP, and the frequency of their participation. We also assessed students' feeling of inclusion in the community, and how they would describe this community. Also, we assessed the existence of an apprenticeship learning model in the Makerspace and the exchange of knowledge, skills, and expertise between students - participants of the CoP-.

Interviews conducted based on the principles of (Kvale, S, 2009). Interviews were then transcribed and analyzed using definitions from Wenger's CoP model to clarify and verify how the Makerspace impacted the cultivation of a makers CoP on campus. We looked for evidence of idea units that emphasized domain, community and practice.

**Results**

Participants shared a common interest in "making", tinkering, and realizing their designs. There were five categories of reasons for participation in the Makerspace: accessibility to resources, professional development, self-efficacy, Networking, social interaction and engagement, and learning opportunities.

Making use of Wegner's structure of CoPs, we present in this section the results of the study. Wegner noted that CoPs are based on three elements: A Domain, a Community, and a Practice. The Domain represents the main topic that the Community shares an interest in, and the Practice is the knowledge the Community shares through a set of frameworks, tools, information, and stories.

(a) Domain

For the participants of this study, the Makerspace represented a space where they can explore their creativity, acquire different skills, and socialize with a diverse group of engineering students. Moreover, the makerspace represented a source of inspiration to students by providing a space where they can showcase their projects to other engineering students.

We identified five categories of reasons why the participants of this makers CoP use the Makerspace and what are the benefits they receive from their participation. The first, Accessibility to resources, such as rapid prototyping equipment and workshops helped students to realize their designs; The second, Professional development opportunities through the application of knowledge acquired in classrooms, and the practice and improvement of students' design skills by learning and practicing CAD software; The third, self-efficacy, as the makerspace helped students to gain confidence in their engineering skills, and abilities to realize projects as future engineers; The fourth, networking, social interaction and engagement reasons, as the Makerspace dismantled disciplinary boundaries and connected engineering students from different disciplines to work together on projects in a fun environment, and connected junior students with their seniors which helped them to learn from their seniors' experience; The fifth, learning opportunities reasons, since the makerspace provided students with free access to resources to work on curricular and extracurricular projects, which allowed for the exchange of skills, and knowledge between students in a creative environment.

*"You meet other engineers who are very excited about their projects, and you get more inspiration"*
- Quote from a second-year mechanical engineering student.

Table 2: Summary of the students interviews on the role of the Makerspace in developing a CoP

| Category | Reason |
|---|---|
| Accessibility to Resources | - Free access to equipment and prototyping facilities<br>- Workshops and training opportunities |
| Professional Development | - Application of knowledge acquired in classroom<br>- Practice of design skills |
| Self-efficacy | - Empowered students with confidence to transform their ideas to reality |
| Networking, social interaction and engagement | - Interdisciplinary space within the engineering faculty<br>- Fun environment<br>- Access to other participants' projects and allowed students to participate in extracurricular projects<br>- Introduced students to peers in upper classes which allowed them to share academic experiences. |
| Learning opportunities | - Extracurricular projects<br>- Exchange of skills and knowledge between peers<br>- Access to a creative environment that provides inspiration |

(b) Community

Participants described the community as a welcoming community, that offered a family-like environment on campus. Initially when the Makerspace opened, the makers CoP was composed of the employees and volunteers of the Makerspace but quickly the Makerspace started to gain popularity on campus, and participants invited their friends to use the resources available in the makerspace. The student-run management model of the Makerspace also helped in fostering a creative and positive space, that welcomed a diverse group of participants, with various interests, and skills, who shared a passion for making, exchanged ideas and worked to improve their engineering skills.

Employees and volunteers of the Makerspace, and frequent participants of the Makerspace had the same level of participation in the CoP, while it took new participants some time to familiarize themselves with the environment and with identifying the right people to ask for direction and help whether with the use of equipment or with their own projects.

> *"what Makerspace did for me is that it made me realize, the first day I came here, and this is my first reaction, these people are playing, these are like grown adults who are playing, and then the more I sat here, for the first three days that I was here I sat and watched"*
> - Quote from a first-year electrical engineering student.

Programs offered by the Makerspace such as workshops, volunteering and work opportunities, design challenges and engineering courses hosted at the Makerspace played an essential role in scaffolding students to participate in the CoP. Also, providing students with free access to tools and prototyping facilities emerged as the principle reason in encouraging students to prototype their designs without considering the cost of their activities which allowed them to iterate their designs as much as they needed.

> *"I am more capable of doing things now, I can almost do anything now, and I don't have to worry about money, that's always my concern, how much is it going to cost me!"*
> - Quote from a fourth-year biomedical engineering student.

(c) Practice

Participants of the makers CoP acted as mentors to each other, and played a key role in welcoming new participants, introducing them to the use of tools available in the space, exchanging ideas, advice, and help in relation to projects, and providing inspiration to each other through their various interests, talents, achievements and projects.

> *"You come here and you are actually shocked by the skills some of these people have, the other week I met a first-year student, here he was soldering circuits like there is no tomorrow and he ended-up being a hobbyist, like his whole life he has been working on circuits, he is like 17! so I learned from him. I come in here set up my circuit, and I am like you have to teach me"*
> - Quote from a first-year electrical engineering student.

Employees and volunteers gain significant knowledge and experience while working in the Makerspace, which they transfer to other students in a workshop or when an advice is sought privately. Workshops are accessible to all students across campus, from different faculties, and on Sundays to the public. Many of the participants from outside the University are makers who come to tinker, use the equipment and exchange ideas with engineering students. This opportunity facilitates another form of apprenticeship between students and external community members and is enabled by the free access of the Makerspace.

Interviews showed that participants who viewed themselves as a part of the COP often came to the Makerspace to work on personal projects. Students who didn't see themselves as participants of the CoP came to the Makerspace only when they needed to use the equipment, or when they had a course that required them to use the resources available at the Makerspace.

Interviewees expressed the need for more advanced workshops to enable them to tackle more advanced projects. Existing workshops offer introductory sessions to different equipment, programming languages, and CAD software.

Participants showed a clear desire and interest in helping other students which in turn provided them with more networking opportunities with the campus community. Engineering students cited the desire to meet new friends as one of the drivers of their participation in this community. We also found that the Makerspace helped first year students to be more engaged with the university's environment and connected them to senior students and allowed them to participate and explore engineering projects.

> *"I got my first job through the makerspace with the Adventures in Sciences and Engineering summer camp, and that's because I sort of knew the people who were at the makerspace community, and through that they were like this guy is really good, maybe we could give him a job. I actually met a lot students through the engineering student society, I met them through the makerspace, and I integrated things from the makerspace to their society and this year I am actually part of the EES, It gave me a lot of connections to different places in the faculty, and definitely if I wasn't involved at the makerspace I would have been just a regular engineering students. In high school, I wasn't also involved in activities in the school, but thanks to the makerspace, I am more integrated to the campus university"*
> - Quote from a second-year, electrical engineering student.

Discussion

In this paper, we hypothesized that student run Makerspaces with free access to equipment, facilitate the growth of students, increase engineering students' confidence in their engineering knowledge and competencies by providing them with creative environment, and most importantly allowing for the formation of a community of creative students.

We found that the Makerspace enabled the creation of a COP by allowing students who share a passion for hands-on engineering, to expand and develop their knowledge and expertise in various areas of engineering practice through applying theories learned in class, and creating an informal, resourceful, learning environment for students on campus that provides training and free access to equipment in order to allow students to exchange creative ideas, and work on engineering projects. It has also helped students to explore extracurricular interests and work on their personal projects while supporting engineering education through providing means for experiential learning opportunities.

Workshops, courses, design challenges, volunteering and work opportunities offered in the Makerspace help in scaffolding and integrating students in the COP.

In addition, the Makerspace also contributed to providing a venue that allows and supports interdisciplinary projects, which helped students explore other engineering disciplines and learn how to communicate their engineering ideas to others from diverse backgrounds.

## Lessons learned

Although our Makerspace played a key role in connecting engineering students from various disciplines, we need to take a more proactive approach in connecting engineering students with other disciplines to increase multidisciplinary collaboration across campus. It was found out that designing multidisciplinary workshops and training opportunities is an excellent venue to facilitate this collaboration.

In the first few years of the Makerspace launch, the focus has been on offering introductory level workshops. However, as the community grew, there is more need to offer opportunities for continuous educational programs.

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## References

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32–42.

Galaleldin, M., Bouchard, F., Anis, H., & Lague, C. (2017). The Impact of Makerspaces on Engineering Education. *Proceedings of the Canadian Engineering Education Association*.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: strategies for qualitative research*. Aldine Pub. Co.

Heller, R. S., Beil, C., Dam, K., & Haerum, B. (2010). Student and Faculty Perceptions of Engagement in Engineering. *Journal of Engineering Education*, *99*(3), 253–261.

Hildreth, P., Kimble, C., & Wright, P. (2000). Communities of practice in the distributed international environment. *Journal of Knowledge Management*, *4*(1), 27–38.

Hotaling, N., Fasse, B. B., Bost, L. F., Hermann, C. D., & Forest, C. R. (2012). A Quantitative Analysis of the Effects of a Multidisciplinary Engineering Capstone Design Course. *Journal of Engineering Education*, *101*(4), 630–656.

Kimble, C., & Hildreth, P. (2004). Communities of practice: Going one step too far? In *9e colloque de l'AIM*. Evry, France.

Kvale, S., & Brinkmann, S. (2009). *Interviews: learning the craft of qualitative research interviewing*. Sage Publications.

Kvale, S., & Brinkmann, S. (2009). *InterViews : learning the craft of qualitative research interviewing*. Sage Publications.

Lave, J., & Wenger, E. (1991). *Situated learning: legitimate peripheral participation. 1991. Man* (Vol. 29).

Lave, J. (1991). Situating learning in communities of practice. *Perspectives on Socially Shared*.

Martin, L. (2015). The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *5*(1).

Millen, D., Fontaine, M., & Muller, M. (2002). Understanding the benefit and costs of communities of practice. *Communications of the ACM*, *45*(4), 69–73.

Moilanen J. (2012) Emerging Hackerspaces – Peer-Production Generation. In: Hammouda I., Lundell B., Mikkonen T., Scacchi W. (eds) Open Source Systems: Long-Term Sustainability. OSS 2012. IFIP Advances in Information and Communication Technology, vol 378. Springer, Berlin, Heidelberg

Patton, M. Q. (n.d.). *Qualitative research & Evaluation Methods : Integrating Theory and Practice*.

Patton, M. Q., & Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Sage Publications.

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the Making: A Comparative Case Study of Three Makerspaces. *Harvard Educational Review*, *84*(4), 505–531.

Trochim, W., Donnelly, J., & Arora, K. (2015). *Research methods: The essential knowledge base*.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*.

Wenger, E., McDermott, R., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Harvard Business Press.

Barrett, T. W., & Pizzico, M. C., & Levy, B., & Nagel, R. L., & Linsey, J. S., & Talley, K. G., & Forest, C. R., & Newstetter, W. C. (2015, June), *A Review of University Maker Spaces* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.234

Zhao, C.-M., & Kuh, G. D. (2004). Adding Value: Learning Communities and Student Engagement. *Research in Higher Education*, *45*(2), 115–138.

## Appendix
## Interview Questions

1- What does the Makerspace mean for you?
2- What invited you to participate at the Makerspace?
3- How often do you come to the Makerspace?
4- What's the main activity/passion you have in the Makerspace? Why?
5- Do you feel included at the Makerspace? Do you feel a sense of community at the Makerspace?
6- If yes, how would you describe this community?

7- Did you invite friends to the Makerspace? or other students'/Makerspace users who you thought can contribute to your community?
8- Did you meet a mentor here in the Makerspace?
9- Has anybody ever shared a tip or an idea that has allowed you to expand your skill set in the Makerspace? Can you describe that situation?
10- Have you ever shared your own knowledge in the Makerspace if so tell us about that?
11- How did participating in this community affect your experience at the university of Ottawa?
12- Did participating in this community affect your academic performance at all?
13- Did you use the Makerspace for any course work?
14- What constitute a good learning environment for you?