College Settings That Promote Innovation and Entrepreneurship: A Comparative Case Study

Jonathan Spiegel[1], Amanda L. Becker[2], Judy Randi[3], Ed.D.,
Maria–Isabel Carnasciali[1], Ph.D.

[1]Department of Mechanical and Industrial Engineering
[2]Department of Industrial and Organizational Psychology
[3]Department of Education

University of New Haven

Many colleges are developing innovation centers to promote entrepreneurial ideas and products that contribute to societal change. University-based entrepreneurial ecosystems are rapidly evolving because they are creating "makerspaces" that offer design and problem solving courses, provide resources and space, and sponsor events to promote awareness of the "Maker Movement." This research investigates the characteristics of university-based innovation centers that were established to promote innovation and entrepreneurship among the university community and its partners. This case study focuses on two university-based innovation communities: Yale Center for Engineering Innovation and Design (CEID) and the innovation ecosystem at Rensselaer Polytechnic Institute (RPI). Data were collected from observations, document analysis, and interviews with organizational leaders. Common themes that emerged from the data included diversity, educational purposes and methods, community building, and the innovation process itself. Cross case analysis revealed similarities as well as distinct differences in purpose and views about innovation and the design process. The ultimate goal of this research was to inform the design of a stronger innovative and entrepreneurial ecosystem at the authors' own institution.

Corresponding Author: Maria-Isabel Carnasciali, mcarnasciali@newhaven.edu

Introduction/Background

The nationwide "maker movement" is a means of uniting people who are interested in creation, fabrication, design, and innovation. Makerspaces are physical locations where "makers" can come together as a community, learn new skills, work on projects, and collaborate with other makers [17]. Typically, these spaces offer a variety of tools, materials, equipment, and training sessions to provide makers the resources to create what they imagine. Makerspaces aim to promote entrepreneurship and provide the impetus and resources for the development of new products. Schools, colleges, public libraries, and communities are now starting to capitalize on this movement by structuring environments for students and others to develop entrepreneurial ideas and products [10]. Universities have joined the maker movement establishing makerspaces for students of all disciplines to come together and create products that can potentially benefit society worldwide.

In higher education, within the last three to five years, there has been a shift from students as passive learners to students as creators who engage in active, hands-on learning experiences such as those offered in makerspaces [9]. As learning communities, colleges and universities are ideal venues to develop entrepreneurship in young people and to spark creative ideas that can lead to tomorrow's innovations. Currently, colleges across the nation are rapidly evolving their entrepreneurial ecosystems by creating makerspaces, offering product design courses, and sponsoring events to promote awareness of the

maker movement. The need to infuse opportunities for creativity and innovation into the education of engineers is especially salient in order to keep pace with the demands of a rapidly growing global society [4]. Although university makerspaces have been viewed as opportunities for learning by creating, little research has as yet investigated the impact of these makerspaces in college communities.

Thus, one overarching goal of this research is to study in depth how universities structure makerspaces as learning environments that contribute to an entrepreneurial campus ecosystem and promote a culture of innovation. This research can potentially inform the development and structure of innovative and entrepreneurial university ecosystems, including here at the University of New Haven.

Literature review

Makerspaces have been perceived as a new way to promote and disseminate innovation, "one project at a time" [11]. Yet, the dissemination of innovations has a long history in education and in other fields [12]. Three related areas of literature provide context for the study of makerspaces as a means of promoting innovation and entrepreneurship. First, we provide some historical context for the study presented here, including descriptions and definitions of innovation and entrepreneurship in different disciplines. Second, we review existing research on academic makerspaces to identify gaps in the literature. Finally, to provide context for studying how academic makerspaces promote innovation, we briefly review the literature on creativity in organizational settings.

Innovation and entrepreneurship

Historically, the value of innovation has been much debated. The study of innovation traces back to Plato who considered innovation as a dangerous force that interrupted the status quo; on the other hand, innovation has been viewed as necessary for progress [12]. At one time or another, in virtually all fields, innovation has been encouraged along with the dissemination of innovative products. For example, Rogers [14] described how the dissemination of agricultural tools and practices supported the growth of developing nations. Although such tools were not "new" in industrialized societies, they were "new" in the countries that adopted them and thus contributed to their economic growth and progress.

According to Drucker [6], innovations are tools of entrepreneurs who capitalize on the need for change to develop new products, businesses, and services. Thus, innovation begins with the analysis of opportunities. Drucker advised entrepreneurs not to sit around and wait for the "big idea" but rather, Drucker explained, successful entrepreneurs go to work immediately, try to create "new and different values" and make a contribution (p. 34).

In Creating Innovators, Wagner [16] offered his views on how young people should be brought up in order to become successful innovators. He provided examples of young and successful innovators who had mentors in their lives who fostered their creativity and encouraged them to use their imagination. These adult figures also helped the younger individuals learn from their mistakes and taught them to never give up. Wagner then described how the education system might best develop young innovators by implementing innovative curriculum that revolves around collaboration, multidisciplinary problem solving and motivation.

Wagner [16] described the characteristics of educational environments that are likely to promote innovation; but, in practice, how are such educational environments established and managed? The next section reviews the literature on academic makerspaces designed to establish the kind of educational environment Wagner described.

Academic makerspaces

The characteristics and specific purposes of academic makerspaces vary widely across universities. Barrett et al. [4] conducted a review of university makerspaces. The researchers collected information about 35 American colleges that had established one or more makerspaces and identified whether or not the spaces were on or off campus, and whether or not the spaces were designated only for engineering students, for students of all disciplines, or open to the community. These researchers also investigated

how the spaces were managed and what resources they offered. This research was conducted through an Internet search and, therefore, could not provide a "first-hand" description of the makerspaces and the impact they have on the university innovation ecosystems.

In an ASEE conference paper, Wilczynski [17] reviewed academic makerspaces established on seven college campuses: Arizona State University, Georgia Institute of Technology, Massachusetts Institute of Technology, Northwestern University, Rice University, Stanford University, and Yale University. The data collection methods were not described but the stated purpose of the review was to characterize the unique attributes of each makerspace, rather than describe the equipment, programs, or policies. The seven centers represented the wide variety of makerspace models that exist. Drawing examples from these models, the author suggested the following "best practices" that contribute to the success of makerspaces:

- The mission of the academic makerspace must be clearly defined from the onset
- Successful academic makerspaces ensure that the facility is properly staffed
- Establish open environments to promote collaboration
- Aligning access times with student work schedules promotes usage
- Provide user training
- Establish makerspaces as a contributing component of the campus community

Wilczynski [17] called for more reviews of academic makerspaces practices, including training, programming, financing, and staffing models so that best practices can be shared and accelerate the impact of the academic makerspace movement.

It is also useful to review research on academic makerspaces in pre-collegiate settings. Colleges have begun to adopt many educational practices that long been implemented in secondary schools, such as collaborative learning problem-based learning, and other pedagogies of engagement [9]. Kurti, Kurti, and Flemming [10] described the practical implications of a makerspace in a school library setting. Drawing on the research base for engaged learning, the authors emphasized "shared expertise" where students learn from their peers as much as from their mentors, are encouraged to learn from their own mistakes in creative spaces, and enjoy a sense of ownership over their own learning. Thus, students are more likely to be engaged in learning and without the need for as much formal instruction. In these environments, learning is facilitated by mentors who provide the guidance that students need to develop a deeper sense of confidence. As Wagner [16] advised, mentors are important catalysts for innovation.

In addition to engaged learning opportunities, such as working with peers and mentors on projects, it is likely that successful university makerspaces provide organizational support that encourages creativity and innovation. The next section reviews the literature on features of the organizational setting that have been found to promote creativity.

Contexts that support creativity

Contexts that support creativity have been extensively studied by Amabile and her colleagues [2, 3]. In one interview study, Amabile [2] described how individuals interact with their environment. Amabile found that individual creativity and organizational creativity were integrally related. Amabile distinguished individual creativity from organizational innovation, which she defined as the successful implementation of creative ideas within an organizational setting. Organizational characteristics that supported creativity included freedom or sense of control over one's work, good project management, sufficient resources, encouragement, collaborative climate, recognition, sufficient time, challenge, and pressure, such as competition with outside organizations. Amabile and her colleagues [3] called for further research on these organizational features across a variety of organizational settings. The advent of the maker movement provides an ideal opportunity for studying the organizational features of academic makerspaces that support innovation and creativity.

Thus, the research reported here investigated the question: "How do university innovation centers promote innovation and entrepreneurship within

their organizational settings?" The research design is a comparative case study that explored in depth how two different universities established academic makerspaces that encouraged innovation and entrepreneurship and offered opportunities for engaged learning experiences, each within the context and constraints of their particular organizational setting.

Research Methods

The case study reported here provides a rich description of how makerspaces impact the university innovation ecosystems. Case study research is appropriate for studying phenomena in depth [19]. The unit of analysis for this comparative case study is the organization, i.e., the university-based center for innovation. Two different universities were selected to provide a contrast between a single makerspace operated out of an engineering school and a university innovation ecosystem with makerspaces spread throughout its campus. Specifically, the researcher studied the Yale Center for Engineering Innovation and Design (CEID) and the innovation ecosystem at Rensselaer Polytechnic Institute (RPI), the nation's oldest technological research university.

Data collection procedures and instruments

Data collected for this case study were triangulated using three different methods: document analysis, semi-structured interviews, and observation checklists. First, the researcher reviewed each university's website to obtain information about the makerspaces, including the mission, history, and organizational structure. Next, the authors identified a point of contact at each of the two university centers and made arrangements for a guided tour during which the observation checklist was completed, and the interview conducted. The authors asked the point of contact at each center to identify an individual affiliated with the center who was most likely to be able to provide an elaborated description of the center, including examples of its programs and projects. In the case of the Yale CEID, one administrator was identified who provided the tour and participated in the interview. At RPI, three administrators were identified, one of whom provided a tour of the campus ecosystem, and two of whom provided interviews. Of the two administrators who were interviewed, one provided information on the RPI Emerging Ventures Ecosystems (EVE) and the other described the Multidisciplinary Design Laboratory. Informed consent (which included permission to take photographs) was obtained from the administrators, who were interviewed and/or who provided tours; interview participants' identities are protected by research confidentiality.

As the second data source, the first author conducted semi-structured interviews (see Appendix for Interview Protocol). The interview participants were provided with one of the interview questions prior to the interview to increase the likelihood of a rich description of the innovative products and processes originating at the center:

- *Think of some of the most innovative ideas that have come out of your center, some of the success stories. Which one would you consider the most innovative? How would you describe that success story?*
- *Include in your story as much detail as possible: How did that idea come about? Who was involved? What was the final result or outcome? How long did it take from start to finish? What makes this particularly successful?*
- *Think of some of the least innovative ideas that have come out of your center. Which one would you consider the least innovative? Tell a story about one of the least innovative ideas or projects.*
- *Include in your story as much detail as possible: How did that idea come about? Who was involved? What was the final result or outcome? How long did it take from start to finish? What makes this innovation so different from the innovations that you considered success stories?*

Third, the authors developed an observation checklist to note features of the environment and the activities occurring in the space (i.e., facility/physical space, equipment, resources, consumable materials, users, and projects). The

checklist was grounded in the research base on optimal work environments for supporting innovation [3].

Data Analysis

First, document analysis consisted of a search for background information on each university's innovation centers: mission or purpose, organizational structure, guidelines and policies, user statistics, financial structure, and the history or establishment of the center.

The second data source was observational data collected during an escorted tour of each center. The observation checklist itself proved difficult to use during the tour. Instead, notes were taken recording all observations and comments provided by the tour guide. In some instances more than one author participated in the tours and also contributed notes. Therefore, observation notes were triangulated, which facilitated recording as many observations as possible, so that these notes could subsequently be coded with the categories on the observation checklist.

The third type of data collected consisted of semi-structured interviews with a selected organizational leader at each center. Interviews were recorded and transcribed. Because the unit of analysis for this study was a center for innovation within a university setting, the coding scheme began with searching the data for factors that are associated with universities, as opposed to business enterprises. That is, businesses are for profit organizations, whereas universities are traditionally places for learning. Moreover, universities are considered educational organizations, whose purpose is to offer "more experiences of a certain type than nature might offer" to facilitate learning [5 p.79].

In contrast with the observation codes derived from research on creativity in organizational settings [3], the interviews were intended to explore the academic innovation centers as places for learning. Therefore, interview codes were derived from literature on educational outcomes [1]. Three codes were applied to interview data using analogies from instructional design: (1) *why* (2) *how*, and (3) *what*. By analogy, these data are similar to planning educational experiences by identifying goals, objectives, and proposed outcomes. Data coded as *why* included data related to the purpose of the center. Data coded as *how* included data that described how the center's goals were met, such as planned activities, resources, and other supports. How data also included how the center promoted itself, how the center was staffed, and how the center trained users. Finally, the data coded as *what* included the actual outcomes, such as the number of users, the products generated by the center, testimonials of users, and other data that documented whether or not the center achieved its goals.

Next, coded data from all three sources were reviewed to identify themes that emerged across data sources. Themes included: diversity, educational purposes and mission, instructional methods, community building, and the innovation process itself. Finally, a cross case analysis was conducted to compare how each university established a culture of innovation and entrepreneurship with its campus community.

The Cases

Yale Center for Engineering Innovation and Design

The Yale Center for Engineering Innovation and Design (CEID) is housed in the Becton Engineering Center. The mission of the CEID is to "empower its members to improve human lives through the advancement of technology, . . . to launch high-impact projects and develop visionary leaders by bringing together people from diverse backgrounds and giving them resources to learn, create, and share." According to one CEID administrator, "engineering, innovation, and design are three approaches toward the same goal: the advancement of humanity."

The facility is equipped with workstation and conference space, a variety of "maker" equipment including 3D printers, hand tools, sewing machines, shop equipment, and electronics, as well as consumable materials. Courses and orientation training sessions are offered. There are both faculty and peer mentors.

The CEID is an interdisciplinary innovation center that invites the entire campus community to come together in one space to collaborate, to

generate ideas, and to create new products that will benefit society. For example, innovations developed at the CEID included a cancer-screening device, and an identification necklace containing a chip coded with a child's medical records. The CEID values diverse perspectives and skills as vital to identifying, defining, and solving real world problems.

Although the CEID is an interdisciplinary community, one implicit goal is to promote engineering, as defined on its website as "the application of scientific and technical knowledge to create functional materials, devices, and systems. This is what engineers are classically trained to do," [18]. The CEID seeks to infuse design experiences into student learning through an array of classes and activities. Creativity and novel solutions "beyond the boundaries of invention" are encouraged, such as a student project that resulted in the creation of a medical product company.

It is important to note, that although the CEID serves as Yale's centralized makerspace, innovation, entrepreneurship, and collaboration are encouraged and supported in a variety of programs throughout the campus. Notably, a makerspace has a natural home in engineering, where innovation and design are central to the discipline, but at Yale, the CEID is one of many programmatic efforts to promote innovation. Indeed, such other programs may themselves contribute to the popularity of the CEID and account, in part, for the wide range of disciplinary participation beyond the engineering school.

RPI Ecosystem

In contrast to Yale's central facility, RPI has several facilities spread throughout its campus community. The O.T. Swanson Design Lab is an open space where small groups work together in "pods." Grey and blue hexagonal walls or cube-like pods divide spaces. Walls have white boards, markers and posters. The Design Lab aims to " engage engineering students in open-ended, technically challenging, real-world design projects that are important to sponsors and partners and to provide a valuable return on investment in ideas, innovations, and potential employees to our sponsors and partners."

Another component of the RPI ecosystem is the Emerging Venture Ecosystem (EVE). EVE extends RPI's innovation ecosystem beyond the campus and into the community. EVE is a distributed incubation program focusing on the process of business development appropriate to the unique needs of each client. This venture partnership incubator program operates under the belief that new businesses need a concrete plan to succeed. A Board of Advisors established from community resources or alumni provides guidance. Peer coaching is accomplished through monthly peer review meetings where the CEOs of the incubated companies get together to talk about topics and issues of importance to them. EVE client companies are invited to networking opportunities within the local business and academic community to expand professional networks and increase exposure to decision makers. Presentations of all EVE participating companies showcase the companies to the Rensselaer community, venture organizations, news media, and the community at large.

The Rensselaer Innovation Hub (RPIHUB) aims "to establish and facilitate better linkages for communication and collaboration between academia, entrepreneurs and industry innovators affiliated with Rensselaer Polytechnic Institute." Rensselaer's Technology Park and Business Incubation Programs are innovations in and of themselves and are among the first technology-driven economic developments within a university ecosystem, with the Incubation Program founded in 1980, and the Tech Park shortly after in 1981 [13].

Results

Despite the apparent differences between the two institutional settings, each university purposefully established an innovation ecosystem consistent with its mission. They seemed to do so in similar ways, i.e., by building community, by considering what diversity had to offer, and by providing learning experiences of a certain kind. How each university promoted innovation and entrepreneurship was revealed through its mission, its approach to community building, its attitude toward diversity, its strategies for providing learning opportunities, and ultimately its perception of innovation itself.

Yale's approach to innovation and entrepreneurship embodied in the CEID

The humanitarian and inclusive mission of the CEID was explicitly presented on its website; it was also lived in every aspect of the CEID. Consistent with its mission, the CEID promoted the interdisciplinary use of the center, as revealed in the following data:

- "So it provides an environment where people of different disciplines can quite literally come together at 1 in the morning and work on something" (CEID interview).
- There was an interdisciplinary project on one of the workbenches: project on display on one of the workbenches in the center of the studio area: a music-physics interdisciplinary project generated in one of the "dozen or so" formal design-based courses offered in the CEID space. This particular course, team-taught by music and engineering faculty, culminated in a student project in which students created new instruments of their own design (Observation notes).
- The tour guide described the electronics station as the "most used space" and likened it to user-friendly technologies and interfaces that "democratized" the use of computers. Its users include non-engineering students, such as Divinity students (Observation Notes).

Important, although housed in the School of Engineering and Applied Science, the makerspace was open and accessible to the entire university community, including faculty and both graduate and undergraduate students in diverse schools and programs, e.g., divinity, medicine, law, architecture, and music, as well as other areas in the sciences and humanities. It is reasonable to assume that the collaboration between musicians and physical scientists led to the development of the innovative musical instrument on display at one of the work stations.

Not only did the CEID open its space to a diverse audience, but it deliberately established a collaborative community in which individuals from different disciplines worked together, in collaboration, not competition. The data show that shared ownership was established as the norm:

- "And I think that that is something that when you walk through the space and you see students working hard, working late or laughing or having a good time, all of those are the types of things that I want to see when we are here" (CEID interview).
- The Center hosted a party at beginning of year (Observation notes).
- "So when (a member) refers to the community as 'we' instead of saying 'do you' or 'does the CEID,' I think that is a really big success in my mind" (CEID interview).

This space was not only structured for collaboration, but for learning. One important strategy the CEID used to establish the learning community was mentoring:

- "But they also have access to working alongside their friends, engineers" (CEID interview).
- "Materials are replenished every night by undergraduate student employees, who also help users with projects, primarily in the evening hours" (Observation notes).

The way in which Yale established its diverse, collaborative learning community was integrally related to the innovation that happened there. Innovation was viewed as a continual process that took time and was rewarding in and of itself:

- "And I think creating those types of environments where students can be creative is extremely important. And you never know what they will come up with" (CEID interview).
- "The humanitarian ID necklace project took about a year and a half for them to get to having all those necklaces out in India. I mean the course started in January of a year in a half ago. So they didn't come up with the idea until 4 weeks into the course" (CEID interview).
- "They generated hundreds of concepts of how to create an innovation that would help

in that space. And then this is where they landed" (CEID Interview).

- In sum, the establishment and management of the CEID tells a story that begins with a mission or purpose and ends with certain innovations or outcomes. Educators might conclude that the CEID was designed like an instructional innovation, with a goal in mind, and planned learning experiences leading to outcomes.

RPI's approach to innovation and entrepreneurship

At RPI, diversity and experiential learning were intertwined and embedded in the implicit purpose of the RPI ecosystem. At EVE, makers included student entrepreneurs from engineering and business: "Some of them, about a third of them are student entrepreneurs, who are currently pursuing an academic degree in engineering or in business and who come up with an idea through their course work or through their college experience" (RPI EVE Interview). The interdisciplinary venue was described as "another advantage that affords students the opportunity to work with students from other disciplines that they possibly otherwise may not have had an opportunity to do" (RPI EVE Interview). At the Design Lab, multidisciplinary and experiential learning opportunities were described, but at the Design Lab, multi-disciplinary meant disciplines within engineering: "It's an experiential based learning laboratory. A big part of it too is that it's multidisciplinary. So we are for the most part all engineers but the different disciplines within engineering, mechanical, electrical, computer, systems, industrial, materials, and a few biomeds and others as well. But that's the main population" (RPI Design Lab interview). An interdisciplinary component was introduced when "the sponsors and some of the students might have a minor in management or minor in economics or some other areas, or when dual degree students come to us" (RPI Design Lab Interview).

The contributions of a diverse membership were perceived in different ways, possibly stemming from an entrepreneurial, business mindset: "From a financial standpoint, on one side it's good to have a lot of ideas. But then you have to move forward and implement the solutions and you need to focus. So if you work with, for example, with my colleagues from the social sciences, with political scientists and pathologists, they are usually more inclined to focus on the problem, which tends to be a diversion. You know, you're expanding the problem. You're making it bigger. And that's good at defining the problem perhaps. In the early stages, it's necessary to identify a problem. But as you move on, you have to get going and solve that problem, which means you have to converge" (RPI Design Lab Interview).

Community and collaboration were valued at the RPI Innovation Hub, where students were encouraged to make connections and develop a sense of student ownership in the space. Collaboration and ownership promote innovation. RPI established a collaborative community that encouraged networking in a number of ways:

- "A third of the entrepreneurs are alumni from RPI who have graduated and have recently created a new venture and need assistants with growing it. And then the other third of the folks are from the general business community, entrepreneurs that live here within the capital region" (RPI EVE Interview).
- EVE client companies are invited to networking opportunities within the local business and academic community to expand professional networks and increase exposure to decision makers. Also, local companies and their employees will be part of the Rensselaer community. In that regard, the companies will also be invited to participate in campus events and workshops as they occur (RPI EVE website http://rpihub.org/eve-services/).
- "When people work together, they are certainly in a design environment and everybody talks about diversity and ideas but on the other side of design, there is an interest of getting something done and they need to focus" (RPI Design Lab interview).
- "We show students what it means to be an engineer and how engineers help people and contribute to society" (The Design Lab Document website http://eng.rpi.edu/mdl-about).

Mentoring is apparently an important component in RPI's innovation ecosystem.

Fundamental to its educational mission, mentoring was seen as critical for developing entrepreneurs. Mentors included faculty, alumni, and business partners. Numerous examples of mentoring were found in the data:

- "We are constantly coaching our entrepreneurs to stay on top of the latest trends in the industry and in the marketplace they are operating in. And always to be future thinking about their intellectual property strategies, which involves constantly turning out new innovations to stay on top of the game" (RPI EVE Interview).
- "We do a lot of mentor matches between the alumni and undergrad entrepreneurs, as well as the graduate/post-grad entrepreneurs" (RPI EVE Interview).

Another strategy for promoting innovation and educating innovators at RPI was engaged learning: "One very important one for us is that this a learning lab. This is an academic laboratory where students come in and they learn about design and they practice engineering skills. So one definition of success is if they learned" (RPI Design Lab Interview). There was a distinct career focus advertised on the website: "The Design Lab process provides a culminating experience intended to prepare students to enter the workforce. The projects are open-ended, technically challenging design problems that encompass a broad array of important contemporary issues. In addition to defining an important problem, sponsors provide a significant grant and interact directly with the students, faculty and staff who work to provide design solutions" [13]. The career focus was confirmed in interviews: "I think what we do, in terms of engaging students, is… the experiential learning process is very hard to do. As a result, in most universities, most teaching environments rely primarily on lecture, and on written tests. We don't do any of that here. So from that standpoint and given the number of students that we work with, and amount of outreach we have, you know other universities and so on, I think what are you doing in terms of learning and engaging engineering students and preparing them to be engineers is what's truly innovation" (RPI Design Lab Interview).

At RPI, innovation and entrepreneurship were viewed as intertwined. The purpose of innovation was to produce marketable products and business partnerships were encouraged. Products were developed "after validating that there actually is a market need for it, and a third of the entrepreneurs are alumni from RPI who have graduated and have recently created a new venture and need assistance with growing it" (RPI EVE interview). Product promotion was also deemed important: " Presentations of all EVE participating companies will be used to showcase the companies to the Rensselaer community, venture organizations, news media, and the community at large" (RPI EVE website: http://rpihub.org/eve-services/). The RPI innovation ecosystem encourages business start-ups, such as the start-up company that developed a system for measuring balance very accurately (RPI Design Lab interview). The Design Lab includes "prototyping facilities and workshops configured adjacent to the conference area to allow students to build and test their designs and turn their ideas into reality" [13].

Thus, the RPI innovation ecosystem, which spread throughout the campus and beyond, was firmly rooted in the college's identity as the nation's oldest technical college, and its commitment to preparing engineers.

Cross Case Analysis

A cross case analysis was conducted to compare the ecosystems of Yale and RPI. Table 1 summarizes the comparison of themes across the two cases.

The ways in which Yale and RPI promote innovation and entrepreneurship are somewhat different from one another. First, the physical structures vary across universities. Yale established a central facility (CEID) where the entire university community gathers and practices parts of buildings innovation and entrepreneurship. Observations provided evidence of an open atmosphere where anyone in any discipline is encouraged to participate. There were many

Table 1: Summary of themes across the two cases studied.

YALE CEID	RPI Innovation Ecosystem
Diversity	
"We are a very interdisciplinary space; there isn't a single user category." 2000 current members spanning over 50 different academic disciplines	"We are all for the most part engineers, but in different disciplines." Broad diversity of technologies Business partners as sponsors
Community	
"You see students working hard, working late, laughing, having a good time."	"We use that space as a venue for people to get together."
Guided Learning Experiences	
"Students have access to working alongside their friends, engineers." "We just informally walk around and support projects. We have faculty from other disciplines come in and have office hours a couple times a week."	"What's innovative is the education process. We teach them about the design process and engage them in activities." "A good mentor has connections and a wealth of knowledge for your venture."
Innovation Process	
Time > Idea Generation: "They didn't come up with the idea until 4 weeks (into the course)." **Process**: For a humanitarian project, "they generated hundreds of concepts of how to create an innovation that would (document children's medical records)." **Innovation**: "We provide tools, space, programming, and staff for them to develop the innovation they come up with, and do what you want to do. That's how we foster innovation."	**Time > Problem Solving**: "You have to get going and solve the problem." **Product**: "You translate ideas into a complete unambiguous unique description, with artifacts that can be used. " **Entrepreneurship**: "When it catches on, that's when it is an innovation. . . .From a financial standpoint, on one side, it's good to have a lot of ideas. But then you have to move forward and implement the solutions."

multidisciplinary projects on the tables that displayed diverse and collaboratively designed products, several of which were produced in courses. The interdisciplinary nature of the CEID may be due, in part, to the structure of the university as a comprehensive liberal arts college. Notably, although the CEID served as a central facility equipped as a makerspace, innovation is encouraged throughout the campus, and this may have accounted for the apparent popularity of the CEID. RPI's ecosystem, on the other hand, included individual facilities, e.g., the Student Sandbox, the O.T. Swanson Multidisciplinary Design Laboratory, and EVE. RPI's ecosystem is named the "Innovation Hub", which is scattered throughout the university. Second, the mission and purposes vary. Although both universities support student learning in academic makerspaces that encourage innovation and experimentation, Yale emphasizes the process of innovation as a learning experience, RPI, on the other hand, views emphasizes the products that result from engaging in the design process. At RPI, innovation leads to business start-ups and partnerships. At Yale's CEID, innovation included a humanitarian perspective, which improves society. While Yale's center is affiliated with the School of Engineering and Applied Science, its impact extends beyond the engineering community to include students and faculty in all disciplines. RPI, a technological college, includes a less diverse population, and its ecosystem includes primarily engineers. RPI extends its ecosystem beyond the university, to the business community to increase its diversity.

Discussion

Both Yale and RPI appear to have established university-wide cultures supporting innovation and entrepreneurship. At Yale, the CEID provided a centralized multidisciplinary facility for "hands-on" innovation but programs throughout campus fueled innovation. At RPI, facilities for different types of "making" were distributed throughout the campus. As shown in Table 1, each university went about promoting innovation and entrepreneurship in different ways. It is interesting to note that Yale, which has campus facilities integrated with the New Haven community established a centralized innovation center while RPI, which is sited on one large campus, has a

distributed ecosystem, with several separate facilities throughout its campus. One striking difference was each university's perception of diversity. The CEID welcomed diversity and interdisciplinary work as a catalyst for innovation. RPI had a narrower view of diversity (e.g., the engineering disciplines), perhaps because of its history as a technical college. Community members from other disciplines were viewed as distractions from "moving forward and implementing the solution," rather than as catalysts for innovation. At RPI, the product was important; at the CEID the process of innovation was viewed as an important, providing for optimal learning experiences as well as incubators for ideas.

Clearly, the missions and perceptions of innovation and entrepreneurship are somewhat different at each institution. Yale's mission is humanitarian -- to improve the quality of life. RPI, on the other hand, aims to integrate entrepreneurship and collaboration into their programs. The missions of Yale and RPI are distinctly different; yet, each drives the development of the university's innovation and entrepreneurship ecosystem.

Conclusions and Implications

The results of this study can potentially inform the development of innovative and entrepreneurial ecosystems at other universities. Qualitative data cannot be generalized. Nonetheless, this description of how two different universities went about establishing innovation and entrepreneurial ecosystems within the particular contexts can serve to guide other institutions in working within their settings. For example, each university established innovation systems consistent with their particular institution's mission. It is also noteworthy, that each university established a university-wide learning community, whether by inviting different disciplines both within and outside of engineering, or establishing different "hubs" throughout the campus. The lesson here is that both universities capitalized on interdisciplinary work is a catalyst for innovation [7].

Universities are first and foremost, centers for learning. This case study of university-based innovation systems not only identified different approaches for promoting innovation and entrepreneurship but also examples of classes, workshops, events and activities designed to promote engaged learning in a collaborative setting. Learning and innovation occurred simultaneously, not in a classroom per se, but in a learning community where mentors and apprentices worked side-by-side in meaningful work. These are the kinds of low risk and high support "optimal learning environments" and "flow experiences" thought to characterize creative individuals [15].

The themes identified in this comparative case study may be important to consider and address when designing innovation centers. Case study research is useful for studying particular contexts. In other contexts, other themes may emerge as critical for the success of innovation centers. One important lesson from this research is that what is considered successful innovation in one context may be considered less so in another context. This research, however, provides a place to start and a way to learn from the success of others.

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Appendix: Interview Protocol

Thank you for agreeing to participate in this interview. As you know, the purpose of my study is to learn about university-based centers for innovation. Although the center will be identified in my research report, your identity will be kept confidential. May I have your permission to audiotape this interview?

1. How would you define innovation?
   - What is the connection between innovation and design?
   - What is the connection between innovation and entrepreneurship?
2. What defines success in your center? (Rephrase, if necessary. What makes your center successful?)
3. What are some of the ways in which your center encourages innovation? What is it that your center does that especially supports users?
4. Let's talk about individuals, the "innovators" who participate in the activities or use the resources your center offers. Tell me about the individuals who use your center and how they use the center.
   - Prompt (if not mentioned): Do all the students use the center at some time during their program? Do they come on their own, with faculty, as part of a class assignment, or for other reasons?
   - Prompt: Who else uses your center (e.g., faculty)?
5. Let's talk about resources. What kinds of external support does your center have, such as partnerships or funding? What about internal resources and support?
6. How does the Center involve other disciplines and individuals not associated with engineering? What do you see as the advantages and disadvantages of extending the center opportunities beyond the school?