An Exploratory Case Study of Cross-Disciplinary Project-Based (i.e. Maker) Curricula as a Catalyst for Entrepreneurship

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ABSTRACT

Universities employ a number of strategies to support entrepreneurship. We examine several of these factors, and compare them to the role of cross-disciplinary courses hosted in our makerspace in promoting entrepreneurship. By looking at the startups arising both from these courses, and those arising outside of a course, we see the the relative merit of cross-disciplinary courses as promotors of innovation and entrepreneurship. By looking at 10 startups founded at James Madison University X-Labs (JMU X-Labs) we demonstrate how innovation and entrepreneurship are more effective when given an academic framework based around 3 ideas: multidisciplinary problem-solving, Design Thinking approaches, and a lean startup methodology.

INTRODUCTION

Since 2015 James Madison University X-Labs has hosted a series of cross-disciplinary courses in the lab and has seen an unexpected rise in the numbers of businesses formed from people using the lab space. Our hypothesis is that the combination of a Design Thinking approach and a lean startup methodology in project-based learning is particularly effective in generating entrepreneurial outcomes because of this interdisciplinary approach. This results in creating a culture of makers within the courses who are both frequent makerspace users as well as more likely to engage in entrepreneurial ventures.

Looking at the number of students forming businesses out of classes hosted at JMU X-Labs, we were curious:

- Is the rate of entrepreneurship higher with participants in JMU X-Labs programming than the rate of that for the university as a whole?
- Is the rate of businesses formed higher after taking these unique cross-disciplinary classes than the rate after taking traditional courses?
- Does the Design Thinking / lean startup methodology which focuses on solving problems also contribute to this rise in entrepreneurship?

It is important to note that the JMU X-Labs space is not a typical collegiate makerspace that focuses primarily on casual or even discipline specific making. The mission of the space is targeted primarily at fostering interdisciplinary cooperation and innovation as part of the statewide 4-VA initiative (http://4-va.org/), while also serving a secondary role as an interdisciplinary campus makerspace. The courses that we offer at the space are project-based and cross-disciplinary.

We use the term cross-disciplinary here to denote a difference between an interdisciplinary course, where typically one topic spans multiple fields, and a cross-disciplinary course where multiple distinct fields of study are brought to bear on a single problem or project. These courses are likewise listed separately in the course catalogue under multiple majors (i.e. Topics in Technical Communication).

We hope to show that these courses, combined with access to a makerspace, lead to improved entrepreneurial outcomes as students learn to function across multiple disciplines while working toward a shared goal. While we've documented academic improvements in these courses elsewhere [1] the improvement in entrepreneurial or innovation outcomes has not been analyzed previously.

In addition to offering a better experience for the student, this topic is important to universities in general as it increases the net positive economic impact of a university education, increases the donor pool, and raises the profile of the university among investors and venture funders.

JMU, like most universities, has not tracked the number of startups arising organically from classes due to the difficulty in post-class pre-graduation tracking. Campus-wide entrepreneurial efforts are often difficult to track as students often found and abandon companies before faculty or staff know of their existence. Surveys of alumni are more helpful in ascertaining entrepreneurial activity, but come a number of years beyond the time when measuring the impact of a course is useful. According to the University Technology Transfer Office, it is assumed that the average is less than 1 viable startup per year. Without further study at this campus and among alumni this is currently unverifiable.

So, given that there is little comparable data we think that an an educational model that demonstrably creates new businesses is important for the university community to understand and track. This understanding can be applied toward developing a pathway to entrepreneurship through project-based coursework that will help foster innovation on campus and will develop more viable startups than standard classroom models.

LITERATURE REVIEW

Looking at rates of university entrepreneurship over nearly the past 40 years we see a marked increase starting in the late 1990s as seen in Fig. 1. With the rise of technology transfer offices , university incubators, and entrepreneurship programs, universities have begun to support both student and faculty innovation in more tangible ways.

While this support has increased, the rates of entrepreneurship still remain relatively low as a percentage of the total number of graduates. The Association of University Technology Managers (AUTM) reports that as of 2016, 1024 new businesses arose out of the 195 U.S. colleges reporting, or roughly 5.25 per university per year. This represents an almost nine-fold increase in per-university startup rate since

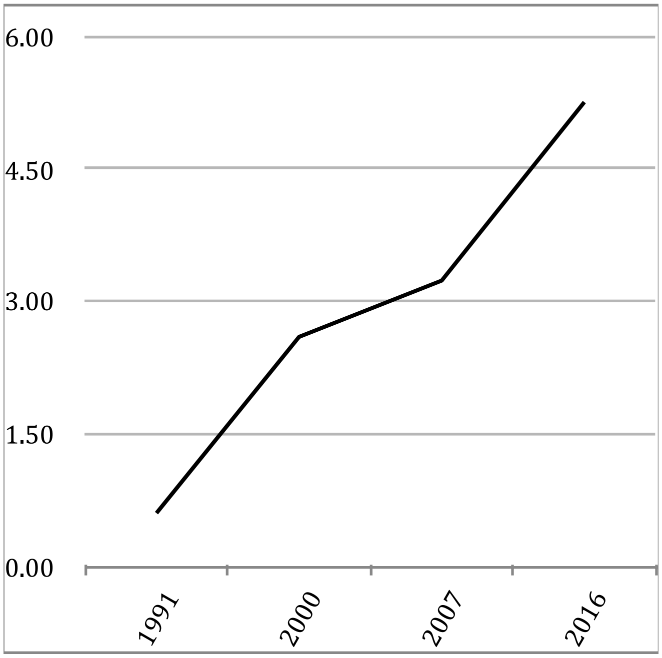

Figure 1. Startups by year per reporting University [2]

1980. [2]

The rate of startups per university has increased on average, but the top 20 or so schools make up a disproportionately large fraction of the total startups reported. For instance between 1995 and 2001, The Massachusetts Institute of Technology was averaging 22 startups produced per year, a number that has almost certainly grown in the ensuing 17 years. [3] So what is it about these schools that makes them more effective producers of startups?

O'Shea, Allen, Chevalier and Roche identify eight factors that contribute to the success of universities in promoting entrepreneurial endeavors.

1) a history of producing technology-based companies,
2) a hi-quality science and engineering program,
3) a large number of post-docs working in R&D,
4) a higher percentage of industry funding,
5) bigger science and engineering budgets,
6) higher percentage of federal funds going to life science, computer science, and engineering than other disciplines,
7) larger technology transfer departments, and
8) a university affiliated incubator. [3]

These factors apply very well to the top 20 schools, but what about schools that are not able to meet all of these criteria for missional or financial reasons? We still see innovation and entrepreneurship at smaller schools with more limited resources. How is this currently supported, and what factors contribute to smaller school successes?

Contrasting the eight factors set forth by O'Shea et al, a recent guideline set out by AUTM suggests the following as recommendations for universities that want to foster entrepreneurship: promoting and supporting inventors, developing institutional commitment, appointing or having the right people promoting new ventures, entrepreneurial office availability and outreach, cross-pollination between departments, universities, and industry, and developing a good incubation program.[4] These guidelines are more applicable to the development of an innovation culture at a mid-size non-R1 university.

Furthermore, Rasmussen and Borch note that universities that support entrepreneurship add "capabilities that open new paths of action, capabilities that balance academic and commercial interests, and capabilities that create new resources." [5] Or simply put, entrepreneurship increases at universities that support innovation and commercialization, and that provide new spaces, technologies, and staff who actively support new spinoffs.

In a more recent paper, Rasmussen, Mosey, and Wright explored the impact of departmental support of entrepreneurship arguing, in essence, for a move away from a university wide approach to one of a departmental approach.[6] This democratization of entrepreneurship to the departmental level represents a shift in how most universities currently function, breaking down the role of specialization and emphasizing a more generalist approach toward entrepreneurship. Furthermore it presents challenges in approach, competency, and resource management.

Moving out further from the department, and even the university, it is important to recognize the entrepreneurial actions of a university as a part of a larger community. The support of entrepreneurship from the community, local, and state government can be just as vital in the ongoing formation and success of entrepreneurial efforts as what is created on campus. In areas where community support is strongest, we see cultures of entrepreneurship develop, providing mentorship as well as financial and social networks to help support new companies. This "triple helix" model of supporting entrepreneurship is critical in places like Massachusetts and Silicon Valley, and helps to answer the question of why colleges in those areas are able to produce so many successful startups.[7]

For the purposes of this paper we did not delve deeply into technology transfer office impact on entrepreneurship as none of the startups used or created university-partnered intellectual property. Technology transfer can boost entrepreneurship in some instances, as outlined in [8] and others, but it can also become a hindrance as noted in the same article. Ideally technology transfer should be for profit, for equity, or entirely inventor owned for best results.[9] Regardless, it was a non-factor in our cases.

The role of interdisciplinary education in the promotion of entrepreneurship is less studied in general, but there are a few interesting things to be aware of. As mentioned previously the role of departments promoting entrepreneurship is more effective than a purely university-wide approach.[6] These programs should exist beyond just the business department, since entrepreneurship occurs across disciplines. [10] A program at St. Mary's University in San Antonio extends this further to an interdisciplinary entrepreneurship program. The program aims to address five key challenges entrepreneurship faces: isolation, time, limited expertise, cost, and rapid globalization. Their approach, particularly targeting non-business majors in entrepreneurial endeavors

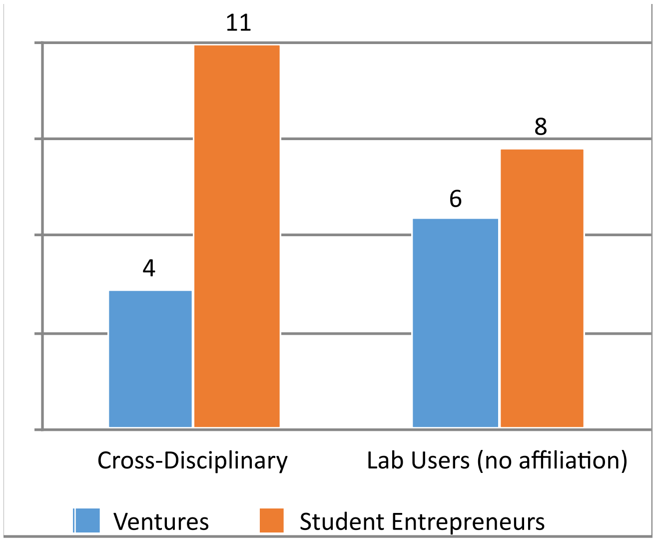

Figure 2. Ventures and student entrepreneurs by type

has had some success in promoting entrepreneurship. [11]

Studies have also indicated that interdisciplinary courses better prepare entrepreneurs and general business-focused students for the multifunctional team environment in most workplaces. This cross-pollination of ideas can help lower barriers to good communication and produce a better product.[12] There is some evidence to suggest that even slightly more than nominal interdisciplinary approaches are worthwhile and show improved outcomes.[13] Furthermore there is some evidence that interdisciplinary courses appeal to students more by providing more engagement and challenge.[14] Finally, and most importantly, interdisciplinary approaches produce a better end-product (more effective commercialization).[15]

So, interdisciplinary approaches, are necessary, lower barriers, increase productivity, and produce better results. So, what is the role of cross-disciplinary courses in the promotion of innovation and entrepreneurship?

Looking at how the Design Thinking and lean startup models promote entrepreneurship and "making" toward a purpose we see the following trends. Design Thinking approaches allow students to foster creativity and empathy in their approach to a problem, and results in more creative solutions. [16][17] A Design Thinking approach, in the absence of cross- or interdisciplinary teams, also has been demonstrated to create more (and better) entrepreneurial results.[18] It also has been shown to produce higher motivation in students and more satisfaction with results.[19]

The lean startup methodology can ideally be thought of as a subset of Design Thinking. And although there are criticisms of the creativity of this approach by N. Hussein and others, its application could be considered a condensation of the empathize, define, ideate, prototype, test approach of Design Thinking.[20]

CASE STUDIES

From these frameworks for the university and community, in this case study we looked at only the following criteria: the effectiveness of cross-pollination between departments, schools, and universities, the role of an on-campus incubator, and industry involvement in development. Additionally we recorded access to venture funding, and governmental funding sources.

To get a sense of location and scope, JMU is a mid-size school, of roughly 22,000 undergraduate and graduate students.[21] It is not an R1 research institution and has a relatively new (founded in 2008) engineering program. Our campus is located in Harrisonburg, Virginia, which is in the northern Shenandoah Valley. This region is largely an agricultural area, but has a number of universities, as well as manufacturing, technology, and defense contractors.

Regarding the Triple Helix model our area is not as well balanced in governmental (local and state) and industry support for entrepreneurship as other areas of the state where the R1 universities reside.[7] These factors tend toward a general atmosphere with less venture, industry, and public funds than would be typical for a school our size.

Looking at the types of ventures created through the JMU X-Labs model we can point to two generalized cases of organizational formation.

- The first case includes those companies founded at the lab that are not an outgrowth of a cross-disciplinary course. These are companies arising from a founder's vision and pulled together with JMU X-Labs support, but independent of class structure.
- The second includes companies founded as a direct result of a cross-disciplinary course. These companies have built on ideas developed over the course of a semester, or two, as part of a class. These classes, as previously mentioned, are project-based and use the lean startup methodology and Design Thinking approach. This approach and method require students to form cross-disciplinary teams, repeatedly interview various clients, develop, build, and test multiple prototypes, and build fully functional final products to present to their clients.

There are three other case types not covered in this paper: entrepreneurial ventures founded out of a traditional class at JMU X-Labs, ventures founded from a traditional class not occurring JMU X-Labs, and ventures arising generally from the student population not associated with a particular class. These cases are interesting to explore, but data acquisition outside JMU X-Labs is difficult to accurately obtain and/or not happening at this time. For the case of entrepreneurship deriving from traditional classes occurring at JMU X-Labs, we have seen no businesses formed in the greater than two years of data we have.

The two cases we have represent 10 businesses formed in two years. Of those 10 businesses, six were formed outside of direct cross-disciplinary courses as seen in Fig. 2. Within the two cases, we look at other factors in transitioning from innovation to entrepreneurship, specifically access to government funding, access to venture capital, direct industry funding, and whether they were part of a university incubator program.

Data Tracking

In addition to the specific entrepreneurship data, we also tracked course enrollment, type of class, general non-class lab use, and output data over the two complete academic

Table 1 . Startup types and factors

	Incubated	Venture Capital	Industry Funding	Government Funding	Cross University	Cross-Disciplinary
Hydra Systems Corp.	X	X	X	X		
Duo Musical Playground	X				X	
Fueled		X	X	X		
Youfory Flag Co.						
95 to Infinity	X					
Zeppy	X	X				
Canvex	X					X
Presence	X					X
Sentinel Defense Systems						X
Sentien Robotics				X		X

years (2017-18 was the third full academic year, data pending). Using this data we were able to analyze size, composition and entrepreneurial outcomes of the courses run within the lab.

For each case we looked at whether the startups had access to the following factors: whether or not they participated in a nincubator or accelerator program, whether they had access to venture capital, whether they had direct industry investment, whether they had access to governmental funding, and whether they were formed as cross-disciplinary corporations.

Case 1: General non-associated startups at JMU X-Labs

These companies can be characterized as single-founder corporations (five of six). For the company that is a partnership between the two founders (Duo Musical Playground), both partners are from the same field, although they are students at different universities. Half participated in a university accelerator or incubator. Half also received venture funding, and two of six received both industry and governmental funding. (Table 1)

Each of these corporations remains in business as of this writing, so no conclusions can be draw about viability based on business model, funding streams, or other factors.

Case 2: Startups associated with a cross-disciplinary course at JMU X-Labs

These companies can be characterized as strongly cross-disciplinary regarding the backgrounds of the founders. Half participated in the university accelerator/incubator and one of the four received a significant amount of government funding. Of the four companies, one has since gone out of business.

University support systems

The university system offers a variety of tools to these companies, which can be considered the baseline of available resources. For businesses that involve new inventions created with university staff we have a technology transfer office (TTO), but for the scope of this paper the TTO was not a factor for any of the 10 businesses covered in the cases. The JMU TTO did sponsor an Innovation Commercialization Assistance Program (ICAP) program with the Shenandoah Valley Small Business Development Center, which was beneficial to some of the cases. In addition to our TTO, we have a recently reorganized entrepreneurship program which offers classes, as well as an incubator/accelerator program with funding. Several of the businesses involved in the cases were participants in this program as noted in Table 1.

Analysis

Across the three types of courses offered at JMU X-Labs we see an improvement in the development of post-class entrepreneurship for students participating in cross-disciplinary courses compared to either cross-listed or traditional classes. When compared to entrepreneurial endeavors that are unrelated to specific classes, but launched from JMU X-Labs during the same time, we see an increase in involved students, but an overall decrease in the number of total ventures. If we normalize the data for non-cross-disciplinary ventures across all other classes, or even just capstone classes (59 majors), the spin-off production per class on cross-disciplinary courses is still greatly increased (1.57 entrepreneurs per class vs. 0.14 per class university wide or 0.57 ventures per class in the lab vs. 0.10 per non-JMU X-Labs course).

As a percentage of non class affiliated lab users per venture compared to the percentage of students in classes involved with new ventures the resulting relative difference in ventures generated is large. (Fig. 3.)

Our data show that at the current rate a student would be 15 times more likely to be involved in a startup venture after taking a cross-disciplinary class than they would be as a general lab user (6.40% vs. 0.42%) if the non-course entrepreneurs are representative of university startup activity as a whole rather than just as a portion of lab users, the percentage entrepreneurship drops from 0.42% to 0.04%. It is also roughly eight times more likely that a venture will come out of a cross-disciplinary course than out of general open lab work for a given group of students (2.33% vs. 0.31%). While

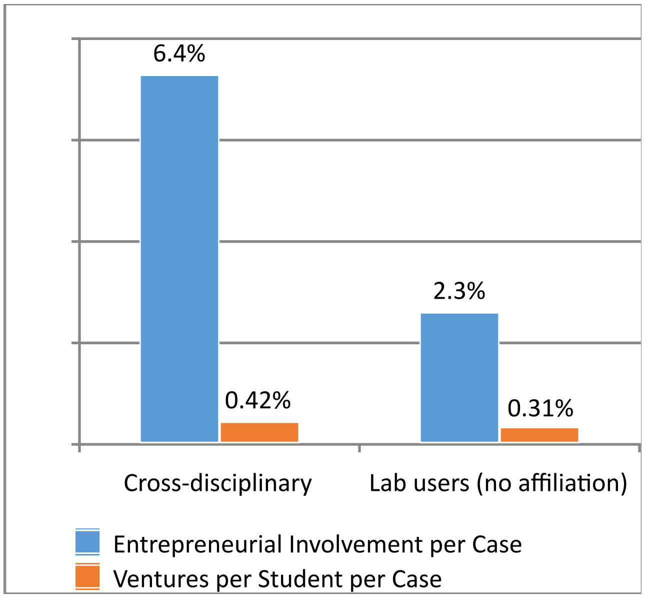

Figure 3. Entrepreneurial activity by case

these are not high percentages, there is a noticeable difference between the approaches.

Our working hypothesis for why we are seeing this improved pathway to entrepreneurship is that students who are exposed to cross-functional project solving are more likely to develop critical product design skills, as well as have a more complete set of business skills on their team at launch.

Because the work belongs to the project teams and not the university, complete inventor ownership of ideas may have a motivational role in the creation of new startups.[9]

What we do not know is whether teams that graduate after completing cross-disciplinary courses form companies outside of the university environment. This has not yet been captured on alumni surveys (too recent), but research shows that such companies are likely to exist, and are also likely to need better support from the university system.[22]

Future Analysis

Although any results here are preliminary, this trend appears to be continuing in early 2018, and we expect similar results by the end of the year. Early startup activities are in line with the data from prior years. In order to more accurately track these data we have implemented a number of user surveys as well as more formalized lab-user tracking.

Also, further analysis is necessary to determine the average number of new businesses per class university wide in order to better understand these numbers in context. The technology transfer office was contacted about this paper, as was the Center for Entrepreneurship, but neither has campus-wide information on startup activity.

Finally, cross-university research into this approach is necessary to understand what factors may be unique to the environment at JMU X-Labs, and which are reproducible. As each of the classes that have resulted in these startups was a cross-university course, we will be looking into partner institutions in the coming months to see if startup activity was present there as well. Beyond this system and the 4-VA umbrella, broader studies in similar programs would be beneficial to understanding this success.

Assuming this approach continues to produce good entrepreneurial results, a full matrix of factors outlined in the literature could be useful in determining gaps in university or departmental policy, pedagogical approach, local, state, and government funding availability, and access to industry help within an entrepreneurship curriculum. These factors could then be developed into key performance indicators for tracking entrepreneurial efforts. Full institutional review board approved research of the approach would also be warranted at this time.

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