LESSONS LEARNED FROM ADAPTING THE NSF I-CORPS CURRICULUM TO UNDERGRADUATE ENGINEERING STUDENT ENTREPRENEURSHIP TRAINING

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Abstract

At the NYC Regional Innovation Node, we have taught hundreds of National Science Foundation I-Corps™ researchers the Lean LaunchPad methodology of hypothesis-driven customer discovery. We observed that the leaders of the I-Corps teams, the Entrepreneurial Leads, who were often graduate or post-doctoral students, had little to no previous knowledge of business model development and testing, nor possessed an entrepreneurial mindset and corresponding skills. This study sought to adapt the NSF I-Corps model to an undergraduate engineering classroom setting in order to immerse young students in an entrepreneurial curriculum. It is hoped that this will enable them to think innovatively while gaining the confidence and abilities necessary to be successful in a graduate school, professional workplace, or startup. Data were collected from five iterations at NYCRIN Network institutions for tuition paying, matriculated students who own their intellectual property (IP). This study relied on a phenomenological research approach where observations and interviews were conducted along with quantitative survey analyses with the participating students (n=110), mentors (n=41), and co-instructors (n=6). Our results show an increase in the undergraduate engineers' customer empathy, grit, and critical, reflective, and creative thinking skills. Students gained an entrepreneurial mindset, real-world experience, and confidence in professional research proficiencies that has led to employment, competition entries, and career track changes. We conclude that the NSF I-Corps training program can be successfully adapted to improve entrepreneurial skill sets in undergraduate engineering students.

Introduction

Since its inception in 1950, the National Science Foundation (NSF) has envisioned a nation that capitalizes on new concepts in science and engineering and provides global leadership in advancing research and education. The NSF has recently shown a heightened interest in actively increasing the commercialization of technology into products and processes that benefit society by fostering academic entrepreneurship (NSF 2011). This objective aims to capitalize on their investments in fundamental research by training NSF-funded researchers to assess the market value of their technology. In 2011, the NSF adopted the Lean LaunchPad methodology of entrepreneurial immersion, hypothesis-driven customer discovery, and business model validation (Blank and Dorf 2012; Osterwalder and Pigneur 2012) via the creation of the NSF Innovation Corps (NSF I-Corps™) program (NSF n.d.).

The NSF I-Corps boot camp is seven weeks long and taught by seasoned commercialization experts, including serial entrepreneurs, investors, and directors of innovation. Each cohort consists of 21-24 teams of three: an NSF-funded Principal Investigator (PI), an Entrepreneurial Lead (EL) who is typically a graduate student or post-doc familiar with the technology, and an Industry Mentor (IM). These teams of three are required to develop business model hypotheses about their technology's Value Proposition and Customer Segments, which together create a product/market fit, along with the remainder of the Business Model Canvas. The team must test their hypotheses by "getting out of the building" and interviewing at least 100 potential customers during the seven-week course. Learning the customer pain points leads to insights that can either validate or invalidate the teams' hypotheses. The methodology favors experimentation over elaborate planning, customer feedback over intuition, and iterative design over traditional "big design up front" development (Blank 2013). The course is a modified flipped classroom in which the pedagogical learning is assigned through videos in the Udacity series "How to Build a Startup" (https://www.udacity.com/course/ep245) to be watched outside of class time. Class sessions are used for the teams to present their weekly insights with feedback from the Teaching Team, followed by a discussion of the video and corresponding assigned text, which covers one block of the Business Model Canvas each week. After sufficient data is gathered, the team can pivot as a result of a pattern of invalidations and must continue their customer discovery process to reach a Go or No Go conclusion by the end of the course. Simply put, the NSF I-Corps program enables academic researchers to quickly, and with a small grant supplement, determine the technology's readiness in the marketplace.

Since 2011, the I-Corps program has proven to be a success in feeding in to Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR), thereby supporting the NSF SBIR/STTR Innovation Model. Given these staggering successes, the NSF budget request for I-Corps in FY2014 increased by 208% from FY2013 to $25 million (NSF 2013). In order to accomplish such rapid success, the NSF relies on the National Innovation Network (NIN) (VentureWell n.d.). The NIN currently has seven I-Corps Nodes, which have trained over 400 I-Corps Teams, and 15 I-Corps Sites, all of which feed the I-Corps pipeline. The New York City Regional Innovation Node (NYCRIN), the third I-Corps Node created through support from the NSF, is led by the City University of New York, in partnership with Columbia University and New York University, and includes a network of over 25 regional institutions (Pellicane and Blaho 2014).

NYCRIN has a history of working with researchers funded by NSF who are interested in commercializing their technology through the I-Corps program. In the past two years, we've trained five cohorts of 88 NSF I-Corps Teams, representing 272 academic researchers, students, and mentors. By delivering I-Corps training to this level of national innovators, we've realized the potential to not only impact technology spinning out of university labs but also, perhaps most importantly, to alter the mindset of the junior researchers and would-be entrepreneurs: the Entrepreneurial Leads (ELs). The archetypical EL is a graduate student or post-doctoral fellow working in the PI's lab, is interested in working in industry or starting their own company, and is close enough to graduation that, if the team makes a Go decision, the EL can found the company and seek further investment. The EL is the leader of the I-Corps team. They must make the tough choice to pivot as needed, conduct most or all of the customer interviews, synthesize the insights from data collected, continue to drive the team forward through the "valley of despair," and present their weekly findings to the instructors and other teams. However, given the professional maturity I-Corps strives to cultivate in the EL, the majority have had little to no prior exposure to business model development, commercialization, growing and utilizing their network, succinctly describing their technology's value, or the concept of speaking to their customer *before* building a product.

Realizing this challenge, we sought to analyze courses for undergraduate engineering students (as well as some graduate students) centered on the NSF I-Corps program and Lean LaunchPad methodology at several institutions collaborating within the NYCRIN Network. The studies conducted were efforts to cultivate an entrepreneurial mindset (Täks et al. 2014) earlier in an engineer's academic career by enabling undergraduates with the skills and confidence to enhance their grit, customer empathy, creative thinking, critical thinking, and reflective thinking, as well as building an initial level of familiarity about business model testing and development. This paper will dive into and evaluate the lessons learned as we iterated and pivoted the curriculum five times over the span of twelve months. We present our results in the manner in which a course is presented so others may learn these best practices for adapting the NSF I-Corps Lean LaunchPad entrepreneurial training to empower their own undergraduate engineers with the skills necessary to become innovative, adaptive, creative, confident professionals in today's competitive market.

Iterations and Methods

Cooper Union Freshmen Undergraduate Engineering

The first implementation of our study to adapt the NSF I-Corps™ model of Lean LaunchPad to an undergraduate engineering course was at Cooper Union in the spring semester of 2014. The required 15-week core course, EID 103 Principles of Design, had one junior and 33 freshmen mechanical engineering students broken up into eight teams of three to four students each. Additionally, there were 13 mentors from a variety of backgrounds including (i) investment firms such as RRE Ventures, Innovate NY Fund, LP, Community Development Venture Capital Alliance, and New Venture Partners; (ii) schools such as Columbia University, City University of New York, and Baruch College; (iii) startup co-working space and incubators such as AlleyNYC and the Zahn Innovation Center; and (iv) serial entrepreneurs who operate companies such as Epion Health, 10Six Energy, Industrial & Technology Assistance Corporation, and Scheinman Law. This will continue to be a required second semester course for freshmen at Cooper Union.

Grove School of Engineering Student Entrepreneurship Competitions

As part of the Kaylie and Zahn entrepreneurship prize competitions at the Grove School of Engineering at the City College of CUNY, finalists enrolled in a specialized version of I-Corps training during the spring semester of 2014. The 15-week course enrolled 32 students who were part of eleven teams of two to five members. Over fourteen mentors who assisted the teams came from Columbia University and CUNY, as well as startups like Indiegogo, Keen Home, and local NYC law firms.

Summer Boot Camps

The next two iterations took place over the summer of 2014 at both the Zahn Innovation Center and the Penn Center for Innovation (PCI). The Zahn Center's first-ever Summer Social Entrepreneurship[1] course was offered to six startup teams for a total of thirteen entrepreneurs and focused on social and environmental impacts that had won the Zahn Social Innovation Prize, an annual social enterprise competition for City College of New York students, faculty, and staff. Secondly, the University of Pennsylvania's PCI held a summer Lean LaunchPad cohort with five teams with a total of twelve entrepreneurs and four mentors ranging from innovation in

1 http://www.zahncenternyc.com/zahn-social-innovation-prize/#!prettyPhoto

educational fields to NIH-funded research on brain wave patterns. This course was designed to serve as a beta test to train instructors in the hope of scaling the summer program so that it could be offered to Penn students and faculty that have disclosed their technology to PCI.

University of Pennsylvania Hybrid Course

Finally, the most recent implementation adapting I-Corps to matriculated students was in the University of Pennsylvania's EAS 590 Commercializing Software[2] course during the fall 2014 semester. As this was a third iteration of an adaption of the full NSF I-Corps Lean LaunchPad course, there were many accumulated best practices that were implemented and refined throughout the 15-week semester. The students were a mixture of graduates, undergraduates, and even staff (including Penn's Biobank) with various degree tracks and backgrounds. There were nineteen students from the Schools of Engineering, Arts & Sciences, Law, General Studies, and Wharton Business School, making up four teams of four to five students each. Each team had one or two mentors from a pool of six, including an entrepreneur-in-residence at the Wharton School of Business, an intrapreneur at Merck, a managing partner at the investment firm MissionOG, and founders from local startups PeopleLinx, Squareknot, and RJMetrics. The course will continue to be offered through the School of Engineering and Applied Sciences but will potentially begin to be offered twice annually with one semester focused specifically on life science startups.

Surveys and Instructor Assessments

Within the first two weeks and during the final presentations of all courses and boot camps, students were surveyed on the extent of their knowledge of various aspects of the Business Model Canvas and Customer Discovery process, as well as with certain entrepreneurial skill sets. Identical numbers of students who were enrolled in the 15-week courses at Cooper Union (n=17) and University of Pennsylvania (n=29) completed the pre- and post-course surveys. Students were asked to rank their knowledge prior and subsequent to the completion of the I-Corps training. Mean values (n=46) were plotted on histograms. In all courses and boot camps, instructors and mentors met weekly to discuss the general issues that arose during the course. These instructor debriefs serve as the basis of the best practices and lessons learned described in this report.

Results

Below, we describe the lessons learned through our experiments in adapting the I-Corps curriculum to various engineering courses and boot camps. Each key finding is a result of observations made through each endeavor, along with surveys and interviews conducted with the participating students, mentors, and co-instructors. The topics described below are presented in the manner in which they had to be addressed throughout the progress of each course.

Introducing the Course

Members of the NYCRIN leadership team actively support and assist with the stringent process of preparing and vetting teams for participation in the canonical NSF national I-Corps training program. Unfortunately, such formal application mechanisms are unlikely to be replicated and are generally not applicable to engineering student enrollment in a semester-long course. We recognize that an ideal situation would be for students to formally apply to the course as a team with a business concept already in place (Blank 2011). Unfortunately, this has not been the case with our studies so introducing the course on the first day is extremely important for several reasons. For instructors who will be revamping an existing course, especially one that has a prior reputation, it is essential to introduce the course requirements and emphasize

2 http://eas590.weebly.com/

its specific goals and expectations. This includes thoroughly explaining that most of the coursework will take place *outside* of the classroom. Class meetings are simply a session for sharing what new findings the teams have had in the past week.

We highly recommend that the syllabus include a bold, red-inked disclaimer forewarning students of the time-demanding, intense nature of the coursework and the real-world, direct feedback they will be getting from the instructors. In this course, students are not treated like undergraduates. They are entrepreneurs and, as such, will be expected to behave professionally and keep up with the unreasonable requirements. It is imperative that the instructors are upfront with students on the fact that they won't be building or learning technical skills in the class. While the development of a Minimal Viable Product (MVP) is a component of the course, it is not addressed until over halfway through the semester. Lastly, informed by the school's policy, a discussion should be had concerning the shared intellectual property (IP) the team will hold. In our studies, the students equally owned all IP rights and the school had no ownership of any resulting IP. In efforts to stress the aforementioned warnings, we have found that sharing previous students' feedback and suggestions has helped defray concerns, although there is no way to fully prepare students for their journey beforehand.

First-time instructors should consult or partner with an experienced instructor who can guide them in the style and format of instructor feedback during team presentations. Setting the expectation bar high in the beginning, in conjunction with kicking off the course energetically and with honesty, will instill reasonable caution in students, along with an understanding that this course will be different than anything they've experienced in school before.

Ideation

How you handle idea generation or "ideation" affects the rest of the course. Again, with NSF I-Corps cohorts, this phase is irrelevant since teams are investigating a previously funded technology – their challenge is to articulately define its value proposition. Thus, our experiments with ideation described here were born out of necessity. Many important lessons were learned in assisting with ideation in our undergraduate engineering courses. Always start by tackling a problem, not by creating a solution to test. This means that the students should not create a product concept (i.e., a *solution* to a problem) to test but rather should think about the problem a current underperforming or non-existent solution is aiming to resolve. Group brainstorming exercises help to begin defining problems with specificity. Before beginning the brainstorming exercise, creating a brainstorming warmup is not only a fun icebreaker but it also results in divergent thinking (Riederer, Baier, and Graef 2005). In our studies, we asked small groups of students to build the tallest structure they could with just woodcraft sticks within three minutes. The group with the tallest structure was the winner. The constant failure and rebuilding of the structure taught the students to fail fast and keep moving forward as a team.

After sharing their experiences, the groups were given three prompts and were allowed to work together on each prompt for fifteen minutes. The prompts were: "Think about a deficiency or problem resulting from (i) a place you went today, (ii) a person you interacted with, and (iii) something you did." The group's outcomes were shared amongst the class and, once all three prompts were completed, the group was asked to select one problem per student to concentrate on for the remainder of the week. When entering this critical thinking phase, assigning an "Idea Journal" as homework in week one can lead to a range of interesting topics and executable ideas (Rees 2010; Jablokow et al. 2014). As homework, students submitted a short written description of the top three problems and potential solution(s) they'd like to address. During the next class meeting, students presented their favorite idea from the top three and other students contributed feedback as part of the convergent thinking process. Once all ideas were presented, students voted on their favorite ideas, the top ten were selected, and team formation began around those top ideas.

Team Formation

In order to determine the group composition and ensure a range of skill sets, a personality quiz was assigned to identify the hustlers, hackers, and designers (Blank 2011) in the room. Self-selecting of individual personality types is a helpful introspection tool that can be exploited for team formation. However, challenges may begin when assumptions are made about the skill sets of each archetype (e.g., "Why can't our hacker make a good website?") so a lecture on cross-boundary teamwork would be prudent shortly after team formation. Through our studies, we found an ideal group size is between two to four students per team. As described above in the introduction, NSF I-Corps teams have three members: the PI, EL, and IM, with an occasional co-EL or co-IM, as needed. A smaller team size is ideal to avoid issues with managing too many individuals per team. However, due to the heavy workload of each undergraduate team in our course, in addition to their other course load, having four members on the team appears to help alleviate the burden through distribution. A team leader will likely arise organically from within each group. This person should serve as the point of contact and communicate with the teaching team to coordinate meetings such as office hours.

In our studies, we found that internal team issues may become a challenge if no standards are set and regular evaluations are not given to catch issues early on. As such, we began requiring office hours with struggling teams. We repeatedly emphasize that the rigor and intense nature of the program was to be expected and was normal: all teams struggle at some point. Finally, we recruited former students to serve as panelists who used their own personal experiences to confirm that our seriousness was a reality, not just a threat. When problems of accountability arise, instructor intervention may be necessary. Setting up a full team meeting with preferably all instructors and the team mentor is advised. During this meeting, teams should be allowed to express their grievances with the intention of finding a resolution. Allowing teams to "fire" a founder is a cliff no one wants to jump off of. This is taken seriously and puts the scale of the issue into perspective. If firing is necessary, the fired individual must come up with another project concept and keep up with the class assignments. If the team stays together, coaching on management and allocation of responsibilities related to skill sets is needed. If this does not suffice after implementation, the instructor will have to divide and assign tasks to hold individual members accountable. When team issues arise, always use it as a learning opportunity! Ask questions about (i) what each student learns as a result of working together in a team, (ii) how they manage their workload, and (iii) how to resolve conflict. Our findings with our engineering student teams are consistent with the accepted notion that people problems are the leading cause of failures in startups (Wasserman 2012) so using this as a positive learning experience can result in rapid student maturity.

Mentor Recruitment and Engagement

In the NSF I-Corps program, mentors are required to dedicate no less than fifteen hours per week during the seven-week training program; their effort could be potentially rewarded by joining a new company if one is formed. The expectations of NSF I-Corps teams are more akin to company formation whereas the undergraduate team outcomes are pedagogical and experiential learning of the commercialization process, along with professional development. Given the lack of intrinsic value in founding a new venture that the mentors often seek, mentor involvement in our engineering student courses often dwindled as the semester progressed unless we incentivized attendance and involvement in the course. One suggested way of overcoming this is to have mentors present a short "day in the life" topic each week in which they explain their company and how they got there. Prior to the course kicking off, we met with all the mentors to explain their role. Our expectations included critiquing all team presentations during class as well as meeting and coaching (*not* consulting) their specific team and commenting on their Customer Discovery narrative and interview insights.

We found that hosting a mentor panel after idea generation and team formation was beneficial to both mentors and teams. This allowed both parties to familiarize themselves with the other participants and directly led to mentors being assigned to a team they preferred to work with. Additionally, sending weekly email reminders with the content of upcoming material makes the mentors feel needed and important. Requesting their presence at all team presentation sessions and being sure to specifically call them out for their input during team presentations became a best practice. It is the instructors' responsibility to ask mentors their opinion outside of class on how their team is doing in regard to specific learning that week. After a range of approaches, we found that assigning mentors to one team, rather than having them float amongst all teams, encourages ownership and pride and, therefore, participation.

Assessment

At the very beginning and on the final day of the NSF I-Corps training program, teams are required to take a survey. The same is required in our adaptations to the engineering student classroom. Initial assessments captured skills and confidence levels related to grit (Duckworth and Gross 2014), empathy (Leonard and Rayport 1997), creative thinking (Torrance 1962), and critical and reflective thinking (Moon 1999; Shanteau and Pounds 1997), as well as an initial level of familiarity with the topics to be covered. Our surveys focused on two distinct metrics: (i) how familiar the students became with the Lean LaunchPad process and the Business Model Canvas and (ii) did their confidence in their own entrepreneurial skills change. Final assessments captured lessons learned, confidence level in skills including delivering presentations, communicating with professionals, growing and utilizing a network, gaining insight by analyzing data, and collaborating effectively in a team. Measuring levels of familiarity on the topics covered, teamwork, course difficulty level and suggestions for improvement (for use in later courses), career trajectory changes, internship or job seeking, project status and plans, and learning environment effectiveness should also be captured.

For example, students enrolled in the 15-week courses were surveyed pre- and post-course with respect to Value Propositions and Customer Segments, the two core components of the Business Model Canvas (Osterwalder and Pigneur 2010), as described in Methods. The combined (n=46) results indicate that the initial level of students reporting "a great deal" and "some" knowledge of Customer Segments was 33% and 60%, respectively, and knowledge of Value Propositions was 37% and 50%, respectively. When looking at the exit surveys, the percent increase of Cooper Union students who reported learning "a great deal" about

Customer Segments was 43% and the increase about Value Propositions was 46% (data not shown). Likewise, the percent of University of Pennsylvania students who responded that their level of knowledge improved "in a very substantial way" was 29% and 24% for Customer Segments and Value Propositions, respectively (data not shown).

While students becoming familiar with Lean LaunchPad and the Business Model Canvas is a desired course metric, their confidence levels about a range of skill sets were also collected at the beginning and end of the semester. Survey results (Figure 1) were collected as described above. The combined (n=46) average of both Cooper Union and University of Pennsylvania engineering students' stating "a large extent" of confidence in regard to collaborating effectively in a team, which increased by 20%. Similarly, gaining insight by analyzing data increased by 21%. Delivering presentations increased by 27%. Communicating with professionals increased by 30%. Finally, growing and utilizing their network increased by 16%. Improvements were also seen in responses to questions about team collaboration, customer empathy, design thinking, agreement in building a product considering customer input, and the value of peer evaluation (data not shown). While most educators hope that many of these traits are the natural outcomes of the courses they teach, it was rewarding to discover that, in our case, it was actually validated. Overall, our results show a marked increase in many entrepreneurial and professional skill sets we had hoped to cultivate in the engineering undergraduates in these studies.

Grading

Grading in a project-based course can be problematic, as there is a large degree of variance per course, team, and students. Additionally, a major portion of the learning took place over the duration of the course rather than as points in time. Grades in these studies were heavily team-based, with individual assignments counting for less. Objective team metrics include customer interview numbers, weekly presentations, and final presentations and videos. As there was a strong emphasis on each team reaching 100 customer interviews over the duration of the course, there was a tendency for quantity rather than quality becoming the team's focus. In the later iteration of the 15-week adaptation process, we attempted to shift the class focus away from the stress of their grade and toward embracing the process, which allowed for more honest learning.

Competitiveness was used to inspire the teams to push each other further each week. Each team was able to see other teams' progress in regard to both quantity of customer interviews on their class customer discovery blog and quality of insights gleaned each week during the team presentations and the post-presentation discussion of the assigned Udacity video. Objective individual metrics included quizzes, blog posts, and initial idea presentations. Assigning one team or a couple of students to post on a class blog encouraged reflective thinking and student discourse, since non-blogging teams were assigned to comment on that week's blog post. We used Lore.com for the student blog posts. A common problem was that some ELs did not regularly watch the assigned Udacity video lectures. We found that giving pop quizzes or weekly, assigned quizzes ensured that students watched the assigned videos. In an effort to keep the class lecture sessions interactive and engaging, we incorporated the quiz question and answers into the lecture slides. Subjective metrics were determined by the team's willingness to learn and grow, with the biggest growth demonstrator being accepting failure and recovering. The grading strategy is still being refined, but each iteration of the study resulted in better outcomes.

Discussion

Training our nation's undergraduate students, particularly engineers, has until recently been centered on developing theoretical and practical skills which will prepare undergraduates to enter graduate schools and subsequently the workplace with the ability to skillfully function on a team led by an experienced supervisor. However, it has been found that there is a consistent mismatch in what graduate schools and employers seek and the skills engineers possess. The skills deficits are described as "communication and the related ability to work across a variety of 'borders' – organizational, technological, disciplinary, as well as cultural and national" (Salzman and Lynn 2010). Creating successful alumni means providing a new generation of engineers who think not just about the technical objectives but about how the work they do affects the customer and impacts society as a whole. We have found that engaging students through entrepreneurial immersion is another crucial part of undergraduate education. This notion was succinctly summarized as follows: "Vanilla doesn't cut it anymore. It's all about what chocolate sauce, whipped cream and cherry you can put on top. So our schools have a doubly hard task now - not just improving reading, writing and arithmetic but entrepreneurship, innovation and creativity" (Pink 2006).

Conclusions

Based on our five studies in 2014 at schools around the NYCRIN Network, we conclude that the canonical NSF I-Corps training paradigm can be successfully adapted into a classroom setting for undergraduate engineers. Success metrics thus far have included students applying for local competitions, such as the Wharton Business Plan Competition and Cooper Union's Invention Factory, acquiring an internship or job as a result of the skills gained or connections made during their customer discovery in the course, improved data analysis and presentation delivery, academic track changes including switching majors and deciding to go to grad school, and finally a culture change within the university. Since our first iteration of engineering I-Corps in the spring semester of 2014, Cooper Union's board has approved the launch of the Computer Science, Design and Innovation program, which is heavily centered on Lean LaunchPad process, as a revenue-generating program. We fully anticipate similar future success stories as additional engineering schools embrace the I-Corps Lean LaunchPad entrepreneurship training process.

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Figures

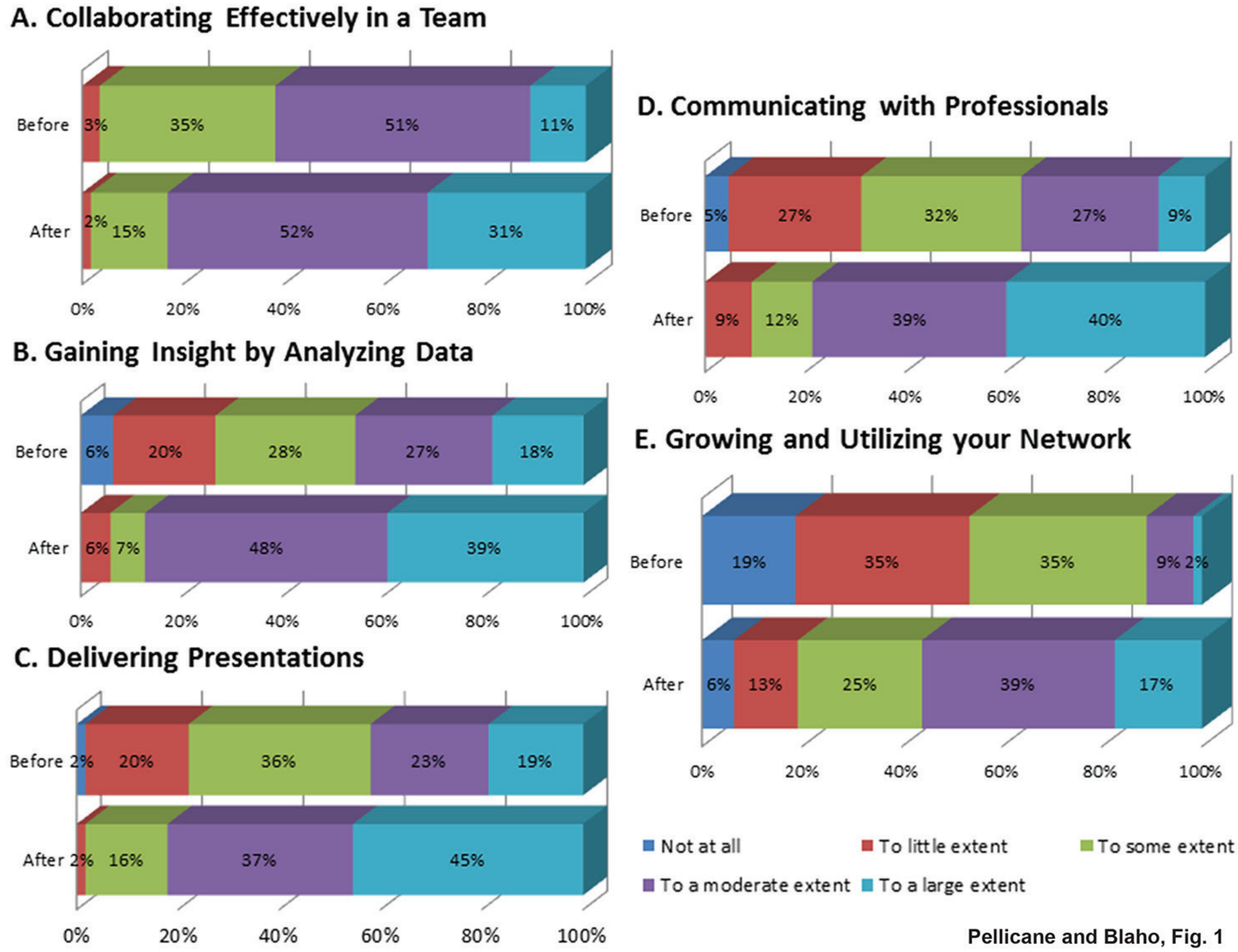

Figure 1. Comparisons of levels of individual skills assessments prior to (before) and post (after) I-Corps training.

Survey mean values from full, 15-week I-Corps training at Cooper Union (n=17) and University of Pennsylvania (n=29) were acquired as described above, combined, and plotted as histograms. Colors represent the extent (none, little, some, moderate, and large) to which individuals assessed their own ability to perform five unique skill sets and are expressed as percentages.