

# Training Faculty in Entrepreneurship and Innovation: An Evaluation of the National Science Foundation Innovation-Corps™ Program

Entrepreneurship Education and Pedagogy

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## Abstract

Evaluating the impact of entrepreneurship education is difficult given the heterogeneity of programming which presents challenges related to the generalizability of findings. The National Science Foundation's Innovation-Corps (I-Corps) program, which incentivizes academic researchers to explore the commercialization potential of their research, offers a unique opportunity to examine the outcomes of entrepreneurship and technology commercialization training from an educational perspective given its standardization across populations and settings. We used the four-level Kirkpatrick Model for evaluating the impact of training and education programs to examine faculty experiences with I-Corps in depth. Using a qualitative inquiry methodology, we conducted 26 interviews with faculty innovators across three large public research institutions. Findings revealed that faculty had positive impressions of the program overall and attributed specific knowledge gains to participation. They also described behavioral changes impacting both their research and teaching.

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However, participants also identified challenges with I-Corps pedagogy and identified opportunities to improve training. This program evaluation and description of specific learning outcomes (skills, knowledge, attitude, and behaviors) contributes to best practices associated with delivering technology commercialization and entrepreneurship training to academic researchers.

### **Keywords**

entrepreneurship, faculty attitudes, faculty development, technology commercialization

As the economic benefits of entrepreneurship become more evident in society, the call for entrepreneurship training continues to grow (Martin et al., 2013). Today, entrepreneurship education programs directed at students are well established in colleges and universities (Gilmartin et al., 2016; Huang-Saad & Celis, 2017; Morris et al., 2013). Increasingly, these are also being directed at academic researchers, in some cases in cooperation with the support of foundations and government organizations (Nnakwe et al., 2018). The largest is the National Science Foundation Innovation-Corps (NSF I-Corps<sup>TM</sup>) program, which was created in 2012 to incentivize and train engineers and scientists to explore the commercial potential of their technologies through commercialization and entrepreneurship training. The rapid growth and perceived success of I-Corps has resulted in calls to document outcomes through program evaluation to demonstrate impact to academic and government stakeholders (Nnakwe et al., 2018).

Given its standardization across populations and settings, NSF I-Corps offers a unique opportunity to examine educational outcomes, in addition to entrepreneurial outcomes, enabling educators to reflect and iterate on practice (Fayolle, 2013). From this perspective, I-Corps provides a unique opportunity to address a major hurdle in entrepreneurship education research, which is the heterogeneity of program models that limits the transferability or generalizability of findings regarding outcomes (Maritz, 2017; Maritz & Brown, 2013). While there is general consensus among educators and researchers that the impact of entrepreneurship education is positive, many questions remain related to the scope and effectiveness of particular curricular and pedagogical approaches, as well as means and measures to assess outcomes (Mwasalwiba, 2010). Some scholars blame this gap on the weak connection between entrepreneurship research and education research (Fayolle, 2013; Huang-Saad et al., 2018). This has led to calls for the application of more rigorous methods to entrepreneurship education and assessment (Duval-Couetil, 2013; Duval-Couetil et al., 2020; Fayolle, 2013; Pittaway & Cope, 2007).

I-Corp's highly structured training program is centered around the Lean Launch methodology (Huang-Saad et al., 2017; Nnakwe et al., 2018).

The methodology includes a common curriculum that is used across the I-Corps network, which is comprised of more than 100 Nodes and Sites that are geographically distributed at universities across the United States (Nnakwe et al., 2018). I-Corps participants can be considered a fairly homogenous population, given that most are engineering and science faculty working at research-intensive institutions. Further, prior to participating, they must have received research funding from NSF and developed intellectual property (IP). In just 7 years, the program expanded from two universities to more than 100. The curriculum continues to be adopted by universities, regions, other government agencies, and even other countries (Nnakwe et al., 2018).

In light of the rapid adoption of I-Corps, it is critical that the pedagogy and outcomes be understood and evaluated. Given that it is a technology commercialization program that is enabled through training, it merits being examined from educational perspective. To do so, we conducted 26 interviews with NSF I-Corps faculty innovators across three large, research-intensive institutions. We analyzed these using a qualitative inquiry methodology aligned with the well-established, four-level Kirkpatrick Model for evaluating the impact of training and education (Kirkpatrick & Kirkpatrick, 2006). To our knowledge, this is the first in-depth evaluation of participant experiences in a large-scale faculty entrepreneurship training program. Our study addresses the significant gap between entrepreneurship research and education research, while informing I-Corps best practices through robust evaluation practices.

## Background

### *NSF I-Corps*

Economic and societal trends are exerting significant pressure on academia and the professoriate to transform (Berman & Paradeise, 2016; Edgerton, 1993; Fairweather & Rhoads, 1995; Kezar & Maxey, 2015; Schuster & Finkelstein, 2006). The rising cost of higher education (Blumenstyk, 2014), increasing research demands (Fairweather & Rhoads, 1995), and preparing students for a global economy (National Academy of Engineering, 2004; National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2010) are requiring institutions, faculty, and students to become more innovative and market-driven. One element of this transformation is placing a greater emphasis on promoting academic entrepreneurship (Etzkowitz et al., 2000) through greater access to training (Duval-Couetil et al., 2020). The NSF I-Corps program is the first formalized entrepreneurship training program for faculty delivered nationally, at a very a large scale (Nnakwe et al., 2018).

Piloted in 2011 and formally launched in 2012, the NSF I-Corps program helps “develop scientific and engineering discoveries into useful, technologies, products and processes” (NSF, 2011, para. 1). Through I-Corps, NSF sought to

build a national innovation network able to offer immersive training, networking, and incentives to faculty to pursue technology commercialization activities, thereby complementing investments in basic research. I-Corps offers a unique approach to using government funding for the purpose of accelerating academic entrepreneurship.

The program is intentionally highly-structured and time-intensive. Competitively selected I-Corps teams are required to participate in 6 to 8 weeks of training, which is delivered both in person and through webinars. The curricular foundation for the training is Steve Blank's Lean Launch methodology developed at Stanford University. It focuses on developing business models (Osterwalder & Pigneur, 2010) and conducting primary market research through a process called *customer discovery* (Blank & Dorf, 2012). This requires that I-Corps teams talk to at least 100 potential customers to gather sufficient market data to validate assumptions about their potential business models. Teams are organized into cohorts that come together for 3 days at the start of the program, participate in weekly online instruction and instructor office hours, and then meet for a final 2 days at the conclusion of the training.

To incentivize participation, NSF provides \$50,000 to each team to support expenses related to interviewing potential customers. Unlike the typical NSF proposal process, I-Corps awards require the submission of an executive summary and an interview with the proposal team. Early in the program's development, teams were comprised of a faculty member, principal investigator (PI), an entrepreneurial lead (EL), and a business mentor (BM), where the EL was a graduate student associated with the research, and the BM helped network and familiarize the team with business practices and customer interviews. Today, requirements are less rigid. ELs can be entrepreneurial students, postdocs, research scientists, or faculty members. Also, BMs are now referred to as industry mentors.

Currently, there are 9 NSF I-Corps Nodes and 99 Sites that administer I-Corps programming and comprise the I-Corps Innovation Network (VentureWell, 2019). The Nodes administer training for national teams and build collaborations and efficiencies across universities and regions to leverage infrastructure, resources, industry knowledge, and start-up talent. It is likely that science and engineering faculty, as well as graduate student involvement in programs similar to I-Corps will grow. The success of the program has led to its adoption by other federal agencies, including the National Institutes of Health, Department of Energy, and Department of Defense (Nnakwe et al., 2018).

### *Kirkpatrick Model for Educational Evaluation*

The wide adoption of the NSF I-Corps program across universities offers the unique opportunity to critically reflect on a large-scale entrepreneurship training program and assess current practice from an educational perspective. To do so,

we used the Kirkpatrick Model for program evaluation (Kirkpatrick & Kirkpatrick, 2006). The Model, first developed in 1959, is one of the most widely used for program evaluation (Frye & Hemmer, 2012). Embraced for its simplicity (Tamkin et al., 2002) and clear distinction of learning outcomes that extend beyond learner satisfaction (Frye & Hemmer, 2012), the Kirkpatrick Model describes four levels of outcomes: (a) reaction, (b) learning, (c) behavior, and (d) results (Kirkpatrick & Kirkpatrick, 2006).

The first level of the model, *reaction*, captures the essence of learner satisfaction. While Kirkpatrick and Kirkpatrick (2006) acknowledged that a positive reaction to a program does not equate to learning, they recognized that a negative reaction is more likely to reduce the likelihood of learning. The second level, *learning*, refers to what is learned by participating in the program. For example, how do learner attitudes change, what knowledge is gained, and how are skills improved? According to the model, behavior cannot change without some type of learning, and learning is demonstrated by a change in attitude, an increase in knowledge, or an improvement in skill. The third level, *behavior*, is what captures the corresponding behavioral change. While some believe that learning has not occurred without a demonstrated behavioral change, Kirkpatrick and Kirkpatrick (2006) cautioned users to reconsider this assumption. According to the authors, behavioral change is conditional. Ultimately, the learner must (a) want to change, (b) understand what to change and how to change, (c) be working in a climate receptive to change, and (d) be rewarded for change. The final level, *results*, refers to long-term results that are related to program participation but apply to a broader context than specific learning outcomes. For example, Level 4 results for universities that train faculty in entrepreneurship could include more companies being launched from university technologies, increased funding to support commercialization activity, or more disclosures and patents. For the purposes of this study, only Levels 1 through 3 were explored, leaving Level 4 longer term outcomes for further study at a later date.

It should be noted that the Kirkpatrick Model does have its limits (Bates, 2004), such as the assumption of a causal link between positive reactions and learning and the implication that importance increases from Levels 1 through 4. Nonetheless, this model offers a preliminary approach to evaluating the NSF I-Corps program and unpacking resultant outcomes with respect to reactions, learnings, and behaviors.

## Methods

### *Methodological Foundation*

To evaluate I-Corps education from the perspective of participants, we used a qualitative interview approach for this study (Elliott & Timulak, 2005; Merriam, 2002; Vaismoradi et al., 2013). This method is well suited to small-scale

exploratory research, which relies on participants' accounts of particular experiences (Creswell, 1998; Drever, 1995; Patton, 2002) and an in-depth understanding of them (Merriam, 2002). Semistructured interviews were conducted, offering more control over the topics covered than unstructured interviews, while also providing a means of arriving at consensus or comparisons across participants.

An interview guide, aligned with the Kirkpatrick Model's first three levels, was developed to organize questions into key themes and specific questions to be asked (Ayres, 2008; Patton, 2002). This ensured consistency across the interviews (Patton, 2002), which were "highly focused, [with] the interview time used effectively" (Patton, 2002, p. 346), yet conversational in tone (Harrell & Bradley, 2009). The guide also facilitated the data analysis through the ability to group responses by question (Patton, 2002).

Interviews were conducted by the study authors. For the early interviews, two investigators were present, with one taking the lead in interviewing, and the other note-taking. Recordings of interviews were professionally transcribed.

## **Participants**

Our sample included 26 faculty members across the three large, Midwest, R1 institutions. The sample size of interviewees is consistent with the norms of qualitative content analysis and was sufficient to achieve saturation (Moser & Korstjens, 2018). Program administrators at each site provided contact information for I-Corps participants, who were asked via email to participate in the study. No incentives were offered for interviews. Faculty in the sample were predominantly male (92%) and represented a wide range of disciplinary backgrounds, academic departments, and career stages (Table 1). The population is characterized as a "double" self-selected population, given that they (a) chose to participate in I-Corps between 2012 and 2017 and (b) consented to be interviewed for the research.

## **Data Analysis**

In our qualitative research analysis, the following phases occurred recursively with frequent reviews between steps (Vaismoradi et al., 2013). In the preanalysis phase, all of the interview transcripts were read several times to develop a comprehensive understanding of participant perceptions of their I-Corps experiences (Elliott & Timulak, 2005). Next, each transcript was divided into chunks, or distinct meaning units (Rennie et al., 1988; Wertz, 1983), based on interview questions. Once the chunking was complete, each meaning unit (or each response to a specific interview question) was reread several times to gain an overview of the range of participants' perceptions. Next, coding categories were derived from the text data (Charmaz, 2006; Hsieh & Shannon, 2005) to establish "domains" or ranges of experiences aligned with central themes (such as "social

**Table 1.** Participant Demographics (N = 26).

	<i>n</i>	%
Gender		
Female	2	7.69
Male	24	92.31
Discipline they received their PhD in		
Applied Science (Engineering and Technology)	12	46.15
Formal Science (e.g., Math, Computer Science)	4	15.38
Health care	2	7.69
Natural Science (e.g., Physical Science, Life Science)	6	23.08
None of the above	2	7.69
Academic department employed in		
Applied Science	18	69.23
Formal Science	1	3.85
Health care	3	11.54
Natural Science	3	11.54
None of the above	1	3.85
Job title/rank		
Professor	12	46.15
Associate professor	9	34.62
Assistant professor	2	7.69
Research scientist/other	3	11.54

interactions”). Preliminary thoughts about the domains covered in the meaning units were noted, and specific text within each was highlighted to illustrate the phrasings reflecting these domains and to establish the properties of each code.

Within each domain, meaning units were coded further and categorized based on patterns in the data or similarities across responses (e.g., “insights gained from peers” or “talking to people outside your field”), keeping as close to the original language of participants as possible (Glaser & Strauss, 1967; Vaismoradi et al., 2013). Category labels were refined throughout to capture more precisely the distinct experiences as separate categories. This required the constant comparison of meaning units throughout the analysis (Glaser & Strauss, 1967).

Finally, the domains and categories assigned *within* each interview question were compared across questions to examine any larger patterns across the entire data set (Corbin & Strauss, 1998; Onwuegbuzie et al., 2009). This was done to achieve *essential sufficiency*, meaning that core themes were identified that depicted the phenomenon under examination in the simplest way possible (Charmaz, 2006; Elliott & Timulak, 2005). Transcripts were reread and coded according to the core themes, and these were tied back to the research questions (Braun & Clarke, 2006). In the presentation of results, quotations are used to

illustrate experiences and beliefs to deepen understanding and to give participants a voice (Corden & Sainsbury, 2006).

## Results

Overall, faculty participants reacted positively to their experiences in I-Corps (Level 1), identifying several aspects that made the program particularly beneficial. Specifically, they described specific gains in knowledge and skills and changes in attitude (Level 2) and identified behavioral changes in their research and teaching (Level 3; Table 2). Several participants spoke in detail about climate, one of the Kirkpatrick Model's four conditions for change. These are discussed in more detail in the following sections.

### *Level 1: Reaction*

In general, participants expressed positive experiences with I-Corps: “The experience was very good”; “I-Corps was extremely helpful”; “It really put a whole bunch of ideas into practice in ways that I would not have been able to do without this experience.” When further prompted for feedback on specific program elements, responses focused more on the logistical and social aspects of the program such as time, accountability, and the ability to learn from others rather than the curriculum.

*Dedicated Time Set Aside for Commercialization.* Several participants reported that one of the most valuable aspects of I-Corps was that it made them spend time on commercialization activities. For example, “If we hadn’t been in the program, we’d have been pulled different ways because we’re all university employees and all doing other things that would’ve called for our time.” They were also pushed to apply what they learned immediately. This emerged as an especially valuable logistical component because the majority of interviewees were full-time faculty

**Table 2.** Emergent Themes With Respect To the Kirkpatrick Model Levels.

Level	Emergent learning themes
1. Reaction	Dedicated time set aside for commercialization Legitimizing commercialization as an academic activity Accountability Networking and learning from others
2. Learning	Customer discovery skills ( <i>skills</i> ) Market-driven vs. technology-driven approaches ( <i>knowledge</i> ) Mindset ( <i>attitude</i> )
3. Behavior	Approach to research Approach to teaching

members who were juggling a number of academic responsibilities. For example, one explained that:

I think the biggest help from I-Corps, honestly, is that time that we had [that pushed] us to work on it. You always see in normal academic life, you're so busy to do that on a full scale. [I-Corps] gave us a venue, and was a pressure, to really spend that amount of time, the necessary amount of time on this technology.

**Legitimizing Commercialization as an Academic Activity.** While the amount of funding provided through I-Corps (\$50,000) was of varying importance to interviewees, a common theme was that it enhanced the perception of commercialization as a legitimate academic activity. For example, “the funds came with the explicit mandate to do precommercialization customer development in the university enterprise as part of my research enterprise. That’s the most valuable piece.” As such, faculty felt they had an externally valid reason to spend time working on commercializing their research, rather than feeling that they were neglecting their paid jobs. One said:

“That’s the most valuable piece” and “The existence of a grant in the university to do this gave me, as a faculty member, not only authority to, but it was part of my faculty responsibility to develop this in this direction. It also created a model for other vehicles in our ecosystem to grow in that direction.”

Other participants felt the funding also provided external legitimacy by serving as objective proof that their research had commercialization potential (even more so than those whose research had not been funded), and they could point to the funding as justification (to colleagues, department heads, etc.) for time spent on nonacademic work projects. “To the external world, it means something. Actual money means something.”

**Accountability.** While most participants said that online portion of the program (i.e., the WebEx lectures) was “not very conducive to learning” and “not particularly useful,” they acknowledged that checking in for weekly meetings kept them on track with their goals. It made them feel accountable (i.e., they “didn’t want to have to report that they hadn’t done the things they’d committed to do during the week”).

**Networking and Learning From Others.** Many participants perceived greater value in the social interactions I-Corps offered (e.g., national cohort meetings and interactions with program instructors, mentors, and other participants) than the more formal program elements. One interviewee said, “hearing from people who had done startups” and interacting with instructors from outside academia

was worthwhile—"one of the things that's really valuable is having [I-Corps] faculty that aren't [academic] faculty. They had very different perspectives on things . . . It's really different on paper than it is in real world."

Interactions with I-Corps participants from other teams at the national cohort meetings also provided a frame of reference and opportunities to learn from the mistakes and strategies. For example, one said, "It was interesting to see some of the other teams. That really made it easy, the way you could see everybody going through the same thing." another said:

I think it's also very helpful to see different teams. See how they look at things, because every team comes from academia. We saw the mistakes that other teams made, then we looked at ourselves and said, "Well, maybe we are making the same mistake." I don't think we have that kind of experience in most universities, because we basically spend time with our peers doing similar things.

The networking and sharing of advice and resources was also cited by some:

One of the things that I think is important is, you're not in a vacuum, it's not just you, but you're part of a cohort. And, the other people in your cohort could have expertise or relevant connections for you.

Another participant noted:

It [the networking aspect of I-Corps] was helpful. During I-Corps, we frequently had people connecting us with other people, so we tried to help each other. Saying, "Hey, maybe you ought to talk to this person. That person may be either potential users or potential competitors for you to learn from." So, different teams would help each other. I think that was important.

The resulting sense of camaraderie also led to confidence building: "The cohort meetings were good. The cohort meetings were very helpful, I think, for first time entrepreneurs. They provide a tremendous amount of confidence boosting" and "the camaraderie that developed among the teams—it's like basically you were cheering for everybody."

### ***Level 2: Learning***

In the Kirkpatrick Model, learning is defined as skills gained, improved knowledge, and change in attitude due to program participation. At the core of all interviews was the role the process of customer discovery played on their learning with respect to skills, knowledge, and attitude: "I-Corps was very much focused on the customer discovery interview process and I think there's great

benefit to that, because I think it's a very serious weakness a lot of engineering teams have when they're approaching product design."

**Skills.** Several participants indicated that they were able to develop customer discovery skills, how to ask questions, and listen for problems: "I-Corps helped me know what to look out for, and [the] personal experience helped me really understand" and "it's the root mechanics of the company. The real essence is learning how to listen for problems and figure out if you can solve them. That was very valuable." Participants also learned how to identify customers, as well as what they value, need, and want. One interviewee said: "You need to know how to talk to people. I had no idea that even existed. Before, I thought 'You give your message and that's it.'" Another had a similar insight and explained that:

It mostly helped us to understand how to communicate with them [potential customers], because we've never had this experience. We never knew what they were looking for. When we talked to them, [we learned] the language and the thinking process they have, so we can ask the right questions.

Others emphasized that through repeated practice, they learned how to better communicate ideas to people outside of their fields. One said that "I think this experience [of] talking to people of [from] different disciplines helped us understand from their viewpoint, so we can explain things better."

**Knowledge.** As a result of collecting primary market research data through the customer discovery process, interviewees gained an understanding of the difference between market-driven and technology-driven approaches. Several interviewees were surprised by the results of their market research, which showed that customers did not have the needs they expected. One learned that you have to "do your homework before you do anything else." Similarly, another learned that "[Customers] don't really need the technology. It's very nice to have, but they don't need it." Another reported that a significant insight came when they realized that "even if we had very groundbreaking technology, there is no way we could actually realize this technology in real [market] situations."

Interviewees reported they learned how to better approach innovation. Before I-Corps, they had a technology-driven understanding of commercialization. The experience of talking to customers taught them to take a market-driven approach instead: "I discovered that we have a great technology. Then we were looking for problems. We found there are problems and now we're working towards that." Others realized that "having something cool is neat, but it's not enough for a viable product" and "you cannot just say, 'Wow, my technology's great, so I can set up a company to make a profit from it, or even bring a product to the market.'"

Many stated that, ultimately, their participation in I-Corps was crucial to identifying the most commercializable form of their technology and their target market: “I-Corps, in our case, played a very critical role in actually finding out what actually would be the best strategy for developing this product in the end.” Another mentioned that they had developed:

the ability to accept that if you’re wrong, it’s not that your technology is wrong. It’s that you are not placing it where it should be, and there are more ways [to do this] than whatever you think it should be.

*Attitude.* Many interviewees reported that I-Corps influenced their mindset. One participant said:

[I-Corps] was completely mindset changing. This is something you have to think about from a different perspective, from a product point of view, from a customer point of view, to understand their needs. [From an academic perspective] you have to pursue the best, the most perfect. You have to make the sensitivity high, the sample consumption smallest, the speed fastest. [A market perspective] is different, more practical. If you want to commercialize, your products may not be very fancy, but at least highly reproducible.

Other interviewees noted that they had experienced broader shifts in perspective regarding their research:

“I think it affected my mindset about, I mean, the entrepreneurial aspects of running a research group as well, right? So even if it’s not customer discovery for commercial [applications], you know, I have to have customers for my research program in terms of sponsors and things like that. So I think it has been good training” and “Actually, this week in my lab group meeting we’re going to talk about what our core values are as a lab. Just because, again, it’s kind of related to customer discovery. Like why are we doing this? Who really cares? Make sure we all know what that is. I don’t know that I would have done that with or without I-Corps.”

Their attitudes toward technologies also shifted, for example, “research people have all got in their minds that what they’re working on is the most important thing ever, but that has no relevance to the business world.” Others said “when we started, we thought that we had this perfect technology for the field. It’s actually a quite different world” and “you always think that your thing is great, whether people need it or not.” One realized that their idea “may not actually be important at all. So I think that the fact that you can go out and prove something’s important because people tell you they need what you’re doing, that [was] an extremely valuable lesson.” Another shifted from thinking “it’s a

great technology” to looking at that technology with new eyes and asking “How can you really commercialize this technology? Where is the market niche? How can you make the profit from that?”

Finally, participants felt that I-Corps changed their attitudes toward the problems they were trying to solve:

Still, I think that the problems that we try to solve should not be just interesting. [They] should be... interesting and important. What I do eventually should benefit the whole society. The whole [I-Corps] experience, I would say, further strengthened my belief.

and,

I think it helps me think about how to design research projects [that are] more meaningful to the real world, more than writing research papers. [I] think about how [society] can benefit, and it has helped me direct my research more from “This can [become] a research paper” to “This will change the world.”

### **Level 3: Behavior**

When asked about professional outcomes, participants spoke very concretely about how I-Corps influenced their behaviors with respect to research and teaching. Responses are summarized in Table 3 and are described in more depth in the following sections.

**Changes to Research.** Most interviewees emphasized that I-Corps changed how they established their research *focus* or *objectives* (Table 3), while for others, it changed their research *process*. For example, one explained that they now focus on market potential and customer input from the start:

I pay a lot of attention to talking with customers early on, even in research projects, to try to determine whether what we’re working on actually has the market need as opposed to just being something interesting and novel. Interesting and novel is insufficient.

Others expanded on this sentiment, saying “there are some engineering scientists who do very fundamental and basic research.” However, some described a fundamental shift in their research focus post-I-Corps, for example:

Now I’m more focused on what the needs are in industry. You go to the potential consumer, [and] you basically value their input more than anything else. You want to sell your product, and you basically want to design your product to actually

**Table 3.** Faculty Perceptions of I-Corps Influence on Research and Teaching.

Research	<ul style="list-style-type: none"> <li>- Openness to changing research processes</li> <li>- Considering the “value proposition” at the start of a research project</li> <li>- Focus on market potential at the start of the work</li> <li>- Determining who specifically is interested in the work or scholarship</li> <li>- More focus on addressing the specific needs of industry</li> <li>- Considering how to broaden interest in the research</li> <li>- Considering how to impact society or change the world</li> <li>- Clearly delineating between academic and “business” work</li> <li>- Greater consciousness of reproducibility and affordability</li> <li>- Listening rather than predisposing</li> <li>- Prioritizing of projects and applications</li> <li>- Running a research group as an entrepreneurial team</li> </ul>
Teaching	<ul style="list-style-type: none"> <li>- Curricular elements and speakers to integrate into courses</li> <li>- Real-world experiences to share with students</li> <li>- Real-world context for knowledge and research</li> <li>- Improved focus and broader perspectives in research and project-based work</li> <li>- Changes in approaches to mentoring graduate students</li> <li>- Ability to advise students interested in entrepreneurship</li> <li>- Comfort with teaching different types of courses</li> <li>- Changes in ways they engage with students in class</li> <li>- Recruiting graduate students and postdocs with an interest or experience in commercialization and entrepreneurship</li> <li>- Demonstrating to students the potential value of their design projects</li> <li>- Motivating students with entrepreneurial opportunities</li> <li>- Encouraging students to participate in intellectual property protection</li> <li>- Encouraging students to participate in entrepreneurship competitions</li> </ul>
Other influences on academic work	<ul style="list-style-type: none"> <li>- Enhanced business literacy</li> <li>- Enhanced preparation for administrative roles within the university</li> <li>- Enhanced ability to work with and reach out to different constituents</li> <li>- Ability to communicate with a broader audience</li> <li>- Increased awareness of the needs of diverse stakeholders</li> </ul>

address that specific concern they have, [or] specific problem they have. So that is basically a totally different approach.

Others described how customer discovery skills shifted the focus of their research by forcing them to better listen to customer needs rather than creating a solution in the lab and then trying to convince the customer to use it:

Just asking questions and saying, “Hey, I’m a researcher, I’m trying to better understand what your problems actually are. Could you talk to me about what it is you do?” And listening to that, rather than predisposing, you know, saying

“Hey, I’ve got some kind of solution to a problem I think you have,” – changing that role, flipping that direction, I think really gives a much better perspective of the kinds of problems that we’re interested in solving in our lab, which are very pragmatic and practical, industry focused.

One interviewee said they now consider the “value proposition” before starting a research project:

I try to say, “What’s the value of your paper? What are you trying to do here? You may think that it’s really important from whatever you’re doing, but how is it changing the world? I think that it has significantly impacted my research.”

Another mentioned that they approach their work “with a business model canvas mentality now.” Prioritizing research was another benefit of I-Corps:

It really helped to figure out exactly which projects are the top priority. We’ve eliminated certain elements of what we’ve been looking at because we don’t think that we’re solving a true need. So really, verifying the needs was a big thing that changed our research direction.

Another participant mentioned:

Before I develop the entire technology or the program, the first question I ask [myself] me and my co-PI is, “Where exactly is the application?” Actually, I ask this question and, “Is this nice-to-have? Or is it must-have?” I don’t want to develop something if it’s nice-to-have – we need to do something must-have.

*Changes to Teaching.* Some interviewees mentioned that they had begun to incorporate elements of I-Corps into their teaching: “Yeah, it changed my teaching. I mean, I was already teaching creativity and innovation, and so this plugged in really nicely to that,” and “I’ve incorporated elements [of I-Corps] into other courses I’ve taught.” Others noted: “It gives me more breadth in terms of experience, which you can always share” and:

I’ve used some of the lean startup principles in class. And, just from I-Corps, I then had a whole set examples about, “Well, we know somebody who is doing a startup like this.” “Oh, how’d you know him?” “Well, they were at I-Corps.” Just a nice set of examples for students.

Many differentiated between teaching undergraduate and graduate students: “If you’re talking about undergrad level courses, [these are] mostly very, very

well-established courses. The impact could be on the grad level courses.” One explained the reason for this differentiation, saying:

Teaching, yes. Especially graduate level teaching, it helped me quite a bit. ‘[Because] I think there we’re talking about a project. Undergraduate, it’s not that big a change. Undergraduate, basically, is more like a curriculum that you follow and topics that you need to follow. At the graduate level teaching, all classes have a project, and the project needs to solve a specific problem. I tell them.... Basically, your project solves what? And is it valuable to anybody? Or is it just hypothetical?

The interviews revealed themes related to impacts on teaching in broader ways, including shifts in how they mentor graduate students, the advice they give students interested in entrepreneurship, as well as how they interact with, and engage students during classes. For example, an interviewee made a distinction between teaching contexts, stating: “My [classroom] teaching I would say is not affected, but my teaching in terms of research teaching or training, oh, yes. That is very, very different.” One explained that things had changed “not in terms of course work, but in terms of mentoring and advising my students, both graduate and undergraduate.” One interviewee even said that his I-Corps training had changed the types of individuals he mentors: “I have an even stronger drive to bring it [research] to commercialization” and:

I’m already testing that feature in the post docs that I’m hiring, whether they would be interested in that or not. It almost became part of the job specifications that I’m looking for when we are looking for post docs.

Some reported including more entrepreneurship and commercialization content and speakers in their classes, for example, “I actually tell them to open their eyes to these activities. I actually have started inviting people who work in this commercialization entrepreneurship areas, to give a seminar to our grad students.” Similarly, others noted: “I think I give students more examples in my class, and I also invite speakers from industry to share their experience, so that students can see things in different ways,” and “the way in which I would say I changed it, I inserted quite a large proportion, 30 percent, of guest speakers from industry, to provide the students with the industrial perspective of what I’m teaching.”

Some said the students found the real-world experiences interesting and engaging, noting:

After this experience, sometimes I try to integrate [it] with my teaching, just to share with the students my experience. Also, I encourage them to open their mind...the students like this. When I tell some of the stories about this [I-Corps], the students get excited about it.

Another said: “All of them were interested in what I do . . . I was so surprised. So I think it changes the way that you think about academic life” and:

If I teach any topic, we always think about, “What is the application?” I always mention to the students, if you can solve this problem you can be a millionaire. I think that actually motivates them to think about it as well.

One interviewee took this a step further, saying that he “incorporated elements [of I-Corps] into other courses I’ve taught” to shift how students perceive the projects they work on in class.

Students very often think that they’re incapable of doing anything that anyone else would care about and they, as a result, pick obvious projects, throw away projects, because they’re sure that nothing they could do, could matter. And I spend a bit of time trying to show them that that ain’t so. That in many of the courses that I teach, the project that they have to do to just finish and get a passing grade, is technically more sophisticated than many successful products. And so, if they could think a little bit, and maybe talk to some potential users before they get started, there’s a much higher probability that they make something that lives beyond the course. And [since I started doing that] probably two teams have their own IP and the other one actually set up company based on an idea that they generated [from] the project from the class. And, then they did the pitch and they got 50 thousand dollars.

Other interviewees noted that they had not yet had the opportunity for their I-Corps training to impact their teaching; however, they felt more capable of teaching classes that dealt directly with commercialization (“I do feel that I’m more suited, or I could now, a little bit more confidently, teach a course in our tech center” and “last semester I did actually an independent study . . . with a bunch of students who were trying to think through technology. I was unafraid to hammer them on ‘Exactly who are your customers?’ Go talk to people things, [and] ‘This is what I learned in I-Corps’”). Another anticipated integrating it into future courses: “I’m actually developing a course for our undergraduate program. I’m just making it almost exactly like I-Corps for undergrads. Now I have a better verbiage and terminology to use and experience with that.”

Finally, a few interviewees mentioned they noticed an impact on other faculty responsibilities, including administration:

“I moved to this administrative position, which removed my teaching [responsibilities]. I think it [I-Corps] maybe has affected my ability to do this job, which also requires a lot of stretching and reaching out to parties. So I think just in terms of how I go about scoping out the sentiment of peers or people about some proposed direction, some project we’re going to do, or direction, or how I can relate to

different constituencies,” and “Certainly it [I-Corps] helps you with communication with thinking about different stakeholders. Talking to different kinds of audiences. You know. All that stuff. So in that sense, I think it does help.”

**Climate.** While applications of the Kirkpatrick Model tend to be at four levels, the model also describes learning as conditional. One of these conditions is related to fostering a climate receptive to change. When interviewees were asked about challenges they encountered with the program, responses tended to focus on climate.

A feature of the I-Corps curriculum created by Steve Blank in 2011 at Stanford is its “boot-camp tenor” (Calao, 2012). The origin of this boot-camp style is described as being “straight from Blank’s own experience as an airplane mechanic in Thailand during the Vietnam War” that is “designed to break years of bad habits in one traumatic day” (Calao, 2012). A negative reaction to this style of instruction was mentioned in most of the interviews, with interviewees noting that I-Corps would be better off without “the drill sergeant/militaristic boot camp aspect.” Participants said:

The military rule was a little bit over the top. That was definitely off-putting. I mean, I could handle it, but I think anybody that was slightly more susceptible to that type of negativity would definitely be turned off by the whole thing

and,

I probably wouldn’t have this sort of drill sergeant, boot camp mentality. I just have a different style of instruction, but that was definitely a big part of what they did, and they made it clear from the start. They were like, “Get up there and do your best, or we’re going to chew you out.” Three seconds into the presentation, they’re hopping all over you. They’d be yelling at everybody.

Other participants expressed similar sentiments, including “the cutthroat intensity was off-putting,” and “there was an aggressive attitude, a very testosterone-driven, male-style organization and leading of everything,” and “it was a little patronizing sometimes. I didn’t even mind it being intense. It just seemed artificially intense.”

Some noted that this style of instruction was likely motivated by a “means to get somebody to do something – to be aggressive and push people, rather than to inspire them. It’s very difficult to do that in a short amount of time. It’s really hard to strike a correct balance.” Another interviewee said:

The thing is, these instructors...it’s the style issues. Some of them are shouting, saying that you have to make this count. And, I felt like the program is such that

the instructors also have this reverse [i.e., negative] incentive, in a way, to really push the teams to [meet their goals]. Because otherwise it counts as a failure for them too. And, I think those sort of reverse incentives don't really deliver the learning outcomes. So I think that balance needs to be very carefully weighed.

Others stated: "I think that that style helped some people, but I think there were some people that [who were] almost were crying, it was a put off and I don't think it helped them." Also,

Being literally screamed at, for a graduate student, is not a terribly productive way to proceed. And you didn't really expect that. Some of the grad students in the program literally were close to breaking down, and several of the teams split up during the activities and said they never wanted to do anything again.

Someone else said: "My industry mentor actually walked away because he felt insulted." One interview noted:

I think for some people that works well. For other people, it's terrible. [In our cohort], there were a couple of the instructors that behaved that way, and it was a real turn off, but there were a couple that were not that way. We connected very well with the ones that were not that way.

## Discussion

The purpose of this study was to provide an in-depth evaluation of the NSF I-Corps training programming through the lens of education. Despite I-Corps' widespread adoption at universities across the country, we have little evidence-based data supporting its ability to enable technology commercialization through education. Our goal was to offer insight into the impact of the I-Corps program on faculty, by examining their reactions, learning outcomes, changes in behaviors, and barriers, with the intent of informing best practices for technology entrepreneurship training directed at academic researchers.

From our interviews, it was clear that faculty who participated in I-Corps were enthusiastic about its impact on their understanding of opportunity identification and the entrepreneurial process, more generally. Most important, I-Corps made them aware of the value of integrating customer feedback early in the technology development process. Secondarily, they gained an appreciation for the needs of various stakeholders in the commercialization process (e.g., customers, technology transfer professionals, and investors) and valued learning from these interactions. The experience of working closely with these stakeholders for an extended period of time gave them greater ability to discern

differences in the mindsets and behaviors of business people versus academic researchers.

Beyond the direct impacts I-Corps had on advancing commercialization, interviewees also described specific ways the programming influenced their approaches to research, teaching, and careers. Faculty reported integrating aspects of I-Corps training into their research by considering feedback from customers and commercial partners as part of their discovery. Some became more interested in recruiting graduate students and postdocs who had experience with or an interest in commercialization and entrepreneurship. Others described impacts on teaching, including integrating I-Corps concepts into their classes and telling students stories about their entrepreneurial experiences. These outcomes align closely with a movement to foster more entrepreneurial cultures at universities by developing more entrepreneurial talent and skills in college graduates to meet economic and workforce needs.

Faculty indicated that a significant feature of I-Corps is that it is a formal program, accompanied by NSF funding, which is a source of research support that is recognized (and expected of faculty) within engineering and science disciplines. This allowed participants to “legitimately” dedicate time and effort to commercialization activities, which was important vis-à-vis administrators and peers. The program’s rigid milestones created a sense of urgency for many participants, which they felt accelerated their progress. However, while interviewees appeared to have been fully engage during the I-Corps period, most felt the allocated time and funding amount were insufficient to engage fully in entrepreneurial activity.

It was clear from the interviews that it was impossible for most faculty to sustain I-Corps and entrepreneurship-related activities with the same intensity beyond the program period, due to competing demands or a lack of desire to do so. Faculty noted the tension of balancing traditional responsibilities and commercialization activities. At R1 institutions, many tenure-track and even tenured faculty struggle to balance commitments to teaching, service, and grant writing, particularly when research funding is becoming more difficult to obtain (Howard & Laird, 2013). To some extent, I-Corps’ team structure was designed to relieve some pressure on faculty by requiring the involvement of ELs and BMs. However, from the interviews, it is clear that this model is far from perfect. The team structure creates a number of new challenges having to do with inexperienced graduate students leading I-Corps activities, finding mentors with the specific industry experience necessary, and incentivizing experts to work with early-stage ventures, over the long term, for little or no pay.

When asked for recommendations on how to improve I-Corps given efforts to scale the program and increase its value to academic researchers, most interviewees were very positive and enthusiastically offered formative program feedback. General comments had to do with better aligning the expectations of participants and instructors, and improving the format and content for both

the in person and online aspects of the program. Most felt the webinars and online activities were far less valuable than the in-person meetings and cohort interactions.

The strongest critique of the program had to do with the learning climate. Many faculty struggled with the boot-camp tenor of the program, which made these educators uneasy. One attributed this to the belief that “maybe that’s just how things are done in the business world.” While most understood the rationale for such an approach, they were uncomfortable with it and expressed that it was inappropriate, particularly if I-Corps is supposed to cater to a diverse audience. Interestingly, the approach seems at odds with NSF’s strong emphasis on broadening participation and efforts to minimize stereotypes to garner more participation in entrepreneurship (Kauffman Foundation, 2015; Robb et al., 2014). Our sampling showed that far less women are participating in I-Corps than are men. It is possible that I-Corps continues to propagate masculine stereotypes and biases that are associated with entrepreneurship, and which have been shown to impact who chooses to participate, judgments related to the merit of particular start-ups, and access to start-up funding (Malmström et al., 2017; Marlow & McAdam, 2012; Wheadon & Duval-Couetil, 2019).

Our results have implications for future research. While it is clear that I-Corps has a positive impact on research and teaching, our data begin to answer questions that should be considered as the program grows, for example: How can specific I-Corps programming components be improved? How should the effectiveness of I-Corps be measured at an individual and institutional level? Do the outcomes of I-Corps as described by participants match NSF’s objectives for the program? Are there misalignments between the value participants expect from I-Corps and what they actually obtained? And, what changes could increase the value of I-Corps to individual researchers, as well as institutions?

Given the sentiments relayed by participants, the time commitment required to participate in I-Corps is likely to be a significant barrier to growth. As it stands, faculty may be reluctant to participate given what they have heard from peers about the time commitment. Overcoming the time demands inherent to commercialization activity is not simple, leading to a number of questions, for example: Would lowering the time commitment make faculty members more likely to participate in I-Corps? Would faculty report the same benefits if the time commitment is reduced? And, in what ways could universities free up faculty time to work more proactively on commercialization activity?

Another challenge is how to support faculty commercialization activity after I-Corps. Several interviewees pointed to the lack of follow-up support to help faculty implement what they have learned. It is unclear whether once participation in I-Corps ends, if faculty are able to continue to implement the practices they have learned. For example, are they more or less likely to have time to devote to commercialization activity? What happens when I-Corps funding runs out? Are the long-term outcomes of I-Corps more closely tied to research and

teaching activity rather than commercialization? How do you engage and incentivize the very specialized business talent required in certain fields? And, finally, to what extent do institutions care about I-Corps sustainability given how few faculty and researchers actually participate?

There are several limitations to our research having to do with our sample, as well as the long-term timelines and complexities associated with technology commercialization activity. First, we have taken a snapshot of faculty experiences that occurred across very different industries and cohorts of I-Corps participants. As such, it is difficult to know how widespread these opinions are, particularly given that our interviewees elected both to participate in I-Corps and to be interviewed (a “double” self-selected population). It is very possible that the opinions of these interviewees are not representative of I-Corps participants or faculty researchers nationwide. However, we found considerable similarities across academic departments, universities, and industry sectors, suggesting that they are at the very least representative of individuals willing to discuss I-Corps. If we assume these interviewees are among the most enthusiastic supporters given their willingness to participate in the program as well as our study, their feedback should be considered as NSF further develops I-Corps, particularly if broader participation is a goal.

Measuring the impact of education and training on technology commercialization activity is complex given the many factors determining venture success or failure. These have to do with the robustness of the technology, competition, business models, licensing agreements, talent, opportunity cost, and so forth. Our results suggest that the value of I-Corps extends beyond catalyzing or accelerating technology commercialization activities, given its potential impacts on research, teaching, and careers. Future work around faculty motivation for participation in I-Corps can offer insight into the long-term sustainability of changes to higher education through entrepreneurship. It can also explore the extent to which universities and government agencies can support involvement in entrepreneurial activities given their inherent complexity and the competing demands on academia today.

## **Conclusion**

Given the movement to create more entrepreneurial universities, academic researchers are exploring opportunities to commercialize their discovery. I-Corps is only one initiative among many that universities offer to encourage greater faculty involvement in technology commercialization; however, it is a powerful one in that it is accompanied by federal funding that legitimizes it as an academic pursuit. These data suggest that participants see many benefits to participating in I-Corps that reach beyond advancing technology commercialization, leading to interesting questions related to its impact as a commercialization accelerator program, an experiential educational program, and an

initiative to transform university culture. Because commercialization outcomes are complex and measuring them is difficult, particularly over time, answering these questions will require more research. Meanwhile, it is clear that I-Corps is creating value for faculty and is helping move technology into society. Program administrators can enhance its value for future participants by addressing some of the shortcomings identified in this study.

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