Faculty and Trainee Perceptions of NSF I-Corps Technology Commercialization Training

—Alanna D. Epstein
Biomedical Engineering Department, University of Michigan, Ann Arbor, MI 48109 USA

—Aileen Huang-Saad
Biomedical Engineering Department, University of Michigan, Ann Arbor, MI 48109 USA

—Nathalie Duval-Couetil
Department of Technology Leadership and Innovation, Purdue University, West Lafayette, IN 47907 USA

(Corresponding author: Aileen Huang-Saad.)

IEEE DOI 10.1109/EMR.2020.3036280

***Abstract*—*At universities, interest is increasing in expanding entrepreneurship education opportunities for both engineering faculty and students, with the goals of improving the professional skills of students and accelerating research commercialization by faculty. However, questions remain about the effective design of entrepreneurship education initiatives for both of these two audiences. Comparing the experiences of trainees (including primarily graduate students and postdoctoral researchers) and faculty in entrepreneurship training will better allow for meeting the distinct needs of these two communities. In this analysis, structural equation modeling was used to examine differences between trainee and faculty perceptions of usefulness, instructional climate, and workload in the National Science Foundation Innovation Corps (I-Corps) entrepreneurship training program. Data were drawn from the publicly available VentureWell I-Corps dataset, including precourse, postcourse, and longitudinal follow-up survey responses from 722 faculty and 781 trainee participants. Results show that trainees perceived the training program as more useful to their careers than did faculty, although no differences in perceived usefulness to one's research program were found. Trainees also perceived instructional climate more negatively and experienced a greater workload.*

Key words: Entrepreneurship, faculty development, graduate education, motivation, structural equation modeling (SEM), survey, technology commercialization

I. Introduction

Efforts to commercialize university research, through activities now broadly referred to as "academic entrepreneurship" [1], [2] such as patenting, licensing, start-up formation, and university-industry collaborations, have been increasingly recognized as important drivers of regional and national economic growth [3], [4]. However, although the participation of university researchers in technology commercialization has expanded [5], the ability of universities to accelerate these activities through faculty involvement has not met expectations [6], [7]. Therefore, strategies to support academic entrepreneurship, such as technology commercialization training, have become active areas of research interest [8], [9]. In parallel with these calls to improve entrepreneurship education offerings for faculty, interest in expanding access to similar programs for engineering students has also grown. Entrepreneurship education has been described as a means to provide engineering students with more flexible employment prospects as well as key professional skills [10], [11].

The National Science Foundation (NSF) Innovation Corps (I-Corps) is a large-scale technology

commercialization training program that provides a unique opportunity to study, longitudinally, the effectiveness of entrepreneurship education for both faculty and students. Given the significant constraints on faculty time, some scholars have argued that students may be a more appropriate audience for entrepreneurship education designed to promote technology commercialization [12], [13]. This article examined this issue by testing whether trainee participants (graduate students and postdoctoral researchers) perceived the I-Corps program as more useful than did faculty participants. Another remaining concern in entrepreneurship education instructional design is the extent to which curricula should be tailored differently for faculty and student audiences. This article addressed this question by comparing faculty and trainee attitudes about several components of the training program, and then examining whether these attitudes impacted opinions about usefulness.

II. NSF Innovation-Corps

The NSF I-Corps program was designed to provide "immersive, experiential entrepreneurial education for scientists and engineers" [14, p. 7] that addresses several important barriers to research commercialization within academia. For example, at an individual level, faculty may view academic and entrepreneurial (career) identities as conflicting [15]. They also lack exposure to entrepreneurial skills [16], [17], and possess few relevant social contacts [18], [19]. Social networks that connect academics with individuals in business and industry are considered key to facilitating commercialization [20]; however, few founders of university spinoffs report significant early involvement by nonacademic partners in their ventures [21], [22]. At the business level, another significant challenge facing academic entrepreneurs is difficulty adapting technology to successfully meet market demand [19], [23]. Academic entrepreneurs, in particular, struggle to translate ideas from a noncommercial to a commercial context [24].

The I-Corps program, first piloted in May 2011 and primarily serving participants in the field of engineering [25], was created to address these specific challenges through entrepreneurship education targeted at university faculty, students, and postdoctoral researchers. The curriculum is based on entrepreneurship educator Steve Blank's Lean LaunchPad approach and a methodology called "customer discovery," which requires participants to speak with potential customers and stakeholders [25] to determine whether projects are commercially viable [14], [26]. As of May 2020, 1585 teams had been awarded grants to participate in the program, with 97% related to projects in engineering [27].

Faculty who received an NSF grant within a prior five year period are eligible for the program, with participants applying in project teams of three [26]. The Technical Lead (TL), usually a faculty member, represents the primary source of technical expertise. The I-Corps Mentor (IM) is a volunteer advisor from a relevant industry. Finally, the Entrepreneurial Lead (EL), referred to in this article as the "trainee" participant, is usually a graduate student or postdoctoral researcher and is the primary full-time leader of the project [14], [26]. The training involves in-person classes at the beginning and end of a seven-week period, with online instruction in between. Teams are required to complete 100 interviews, most of which are conducted by the EL. Participants report that the course requires full-time immersion, precluding other major commitments such as teaching or taking classes. Teams receive $50 000 grants, to be used for travel associated with conducting customer discovery and limited salary support for the EL [28].

III. Postgraduate and Trainee Entrepreneurship

In light of the significant challenges associated with increasing entrepreneurial activity by faculty, some scholars have suggested that the focus of technology commercialization efforts could shift from faculty to students and trainees [12], [13]. Students experience a lower opportunity cost when devoting time to entrepreneurial activities, as these efforts are less likely to detract from earnings at a paid job [29]. Students have greater access to university resources, such as business plan competitions [22], [30] and opportunities to network with business school contacts [29]. Students may also be more willing to consider shifting their career aspirations from research to pursuing a business full-time [31], [32]. Graduate students, in particular, are considered effective targets for programs promoting academic entrepreneurship [12], [29]. Compared to undergraduates, graduate students possess greater expertise in new technologies [33] and are better positioned to connect academic and business contacts through their close relationships with faculty [21], [22].

While limited research exists regarding the role of graduate students in successful technology transfer, primarily because the outcomes of faculty-led projects are easier to track [29], [30], several quantitative and qualitative studies indicate the importance of their involvement. For example, a study of eight MIT spinoffs founded by

graduate students demonstrated that all were based either on the students' thesis research or a research project initiated by the student [30]. Faculty engagement in these projects was limited, participating as a cofounder in one case, as a scientific advisory board member in two cases, and declining invitations to be involved in three cases. The students also reported that while their advisors' contacts and technical knowledge were important to the creation of the company, they were generally not interested in devoting significant time to projects unrelated to their faculty responsibilities.

Trainee participation in technology commercialization was also demonstrated in a qualitative study of 47 university spinoff companies [29], with doctoral students or postdoctoral fellows serving as founders or cofounders in 77% of cases. Interviewees stated that students and postdoctoral researchers possessed greater enthusiasm for the projects than did faculty, and that faculty commitment declined further over time. Similarly, a social network analysis of 79 university spinoff company founders indicated that graduate students represented the second most frequent category of business collaborators (14%) after faculty members (39%), and were described as essential to the formation of 29% of the companies [22].

The prevalence of student involvement in founding companies was further shown in a quantitative study that compared faculty and student entrepreneurial activity using the U.S. Scientists and Engineers Statistical Data System survey data from bachelor's and doctoral degree holders in science or engineering [12]. Recent graduates were twice as likely as faculty to found a company and were more likely to work for the company full-time. Further supporting the notion that early career academics are more willing to switch to nonacademic career paths, postdoctoral researchers and nontenure track faculty were more likely than tenure-track faculty to found companies.

In summary, university spinoffs that have been surveyed in prior studies include substantial participation by trainees, who in some cases are more extensively involved than faculty. Although this pattern may imply that graduate students and trainees are more receptive to entrepreneurship programming than faculty [13], more research is needed to support this claim. Graduate students also experience significant barriers to involvement in startup activities, such as maintaining focus on dissertation work and conflicts between academic research and research benefitting a new company [34]. In addition, existing university curricula often are not flexible enough to provide students with the time necessary to pursue entrepreneurship training and projects [35].

As a method to test whether graduate students and trainees respond more positively to entrepreneurship training than faculty, this article assesses whether these two groups differ in perceptions of whether participation had been "useful" to their careers and research. If trainee participants perceive the training as more useful than faculty, this could indicate either that they possessed greater initial interest in technology commercialization than faculty, or that the program improved their attitudes toward entrepreneurship to a greater extent. In both of these cases, the expansion of efforts to promote technology commercialization by targeting graduate students and trainees would be supported. Further, attitudes about entrepreneurship are strongly correlated with subsequent entrepreneurial behavior [35], [36] and previous research has shown that participation in entrepreneurship education can improve such attitudes [37], [38].

IV. Instructional Design for Faculty and Trainees

Regardless of whether or not graduate students report more positive attitudes toward I-Corps training than faculty, the structure and content of the program may present challenges to the expansion of trainee recruitment and participation. Compared to faculty members, trainee participants may need additional support in order for technology commercialization projects to ultimately succeed. For example, one study found that conflict between graduate students and faculty advisors was a significant problem [30]. In one case, a student's advisor established a rival company based on the same technology, requiring the student to change advisors to successfully complete their doctoral program. In another case, a graduate student withdrew from their academic program due to conflicts of interest with their faculty advisor, who was the company cofounder. In a third case, a graduate student reported that conflict arose with their advisor over ownership of the company. To test whether or not such interpersonal conflicts present a problem for trainee participants in I-Corps, survey responses assessing the perceived quality of team relationships were examined.

Second, some I-Corps participants have raised concerns about the "shark tank" [40, p. 259] instructional design, with the instructor training materials stating that "the class culture can feel brusque and impersonal" [29, p. 93]. In order to investigate whether these concerns about instructional style are expressed differently by faculty and trainees, survey questions related to

stress level associated with the course were included.

Finally, in their roles as team leaders, trainees have greater responsibility for managing projects than do other team members [41]. Therefore, differences in perceptions of instructional climate as well as stress level may be influenced by workload. To investigate this possibility, the relationships between perceptions of team relationship, stress level, and indicators of workload in the program were examined.

V. Research Questions

This article was driven by the following four research questions.

1) Do trainees and faculty have different perceptions of course usefulness?

It is hypothesized that trainee participants would find the course more useful than faculty participants.

2) Do trainees and faculty differ in perceptions of instructional climate?

It is hypothesized that trainees would perceive a more negative instructional climate than faculty members, defined as higher stress levels and more negative perceptions of project team relationships.

3) Does workload explain negative perceptions of instructional climate?

It is hypothesized that the additional workload experienced by trainee participants, indicated by the number of interviews completed as well as their number of hours of work per week, will statistically explain differences in perceived stress and team relationship between trainees and faculty.

4) Do negative perceptions of instructional climate negatively impact perceptions of usefulness?

It was hypothesized that participants who perceived greater stress levels and who reported more negative team relationships would perceive the course as less useful.

VI. Method

A. Sample The source of data for the present analysis was the publicly available "Impact of NSF's I-Corps National Program on Individual Participants" dataset, compiled by the nonprofit organization VentureWell in collaboration with the NSF [26]. It represents surveys administered to 39 cohorts of teams participating in national I-Corps training between spring 2012 and fall 2016. Participants completed three online surveys distributed through email, one prior to the course ("precourse survey"), one immediately following the seven-week course ("postcourse survey"), and one 9–16 months afterward ("longitudinal follow-up survey"). The longitudinal surveys were administered in September of each year to all team members who participated in the previous year, with an average length of time since taking the course of 13 months. Response rates were 95% for the precourse survey, 74% for the postcourse survey, and 60% for the longitudinal follow-up [26]. In the public-use dataset, data were available from 2589 individuals, including 843 TLs, 912 ELs, and 834 IMs. The specific professional roles for participants were not available in this dataset. However, NSF has reported that for participants between 2011 and 2018, 52% of ELs were graduate students, 16% were postdoctoral researchers, 3% were undergraduate students, and 29% were "others" [14, p. 26].

Since this study focuses on TLs and ELs, the analysis is limited to the 1,755 total participants that comprise these two groups. In addition, since the study addresses variables that appear only in the postcourse survey and the longitudinal follow-up survey, the sample was limited to participants who completed one or both of these. The final sample consists of 722 TLs and 781 ELs. Among ELs, 349 (45%) completed one survey wave and 432 (55%) completed both survey waves. Among TLs, 276 (38%) completed one survey and 446 (62%) completed both. To maintain confidentiality, gender and racial/ethnic identification data are not included in the public-use dataset. NSF has reported that of all the participants between 2011 and 2018, 19% were women, and one or more female members were included in 41% of teams [14].

B. Data Analysis Plan The survey data were analyzed using structural equation modeling (SEM), a family of procedures combining the features of both factor analysis and multiple regression. In this article, the use of SEM allowed the simultaneous assessment of hypotheses regarding group differences at multiple time points (1 and 2) as well as hypotheses about the mediation of these group differences by intervening variables (3 and 4). Whereas a multiple regression analysis could include only one set of predictors and one set of dependent variables, SEM is able to incorporate the three time points included in the current dataset in the same model [42].

Analyses were conducted using the lavaan package in R, using maximum likelihood estimation in fitting the SEM models as well as accounting for missing data using full information maximum likelihood estimation [43]. Two models were assessed. The first model examined the relationship between instructional climate perceptions (stress level and team relationship) and usefulness perceptions, and the second model also incorporated the engagement variables of hours worked and number of interviews. In all models, stress level was included as a latent

variable with three survey questions as indicators, and team relationship was included as a latent variable with six survey questions as indicators.

C. Measures The analyses included a total of eight survey variables. Two variables represented the topic of participant workload. The first participant workload variable, number of hours worked, consisted of a single open-ended survey question: "About how many hours per week (on average) did you personally spend on your I-Corps project?" The second participant workload variable, the number of interviews conducted, also consisted of a single open-ended survey question: "How many people (customers, users, etc.) did you personally interview during the I-Corps course?" For the number of interviews, three extreme outliers were truncated to values of 130 [44].

Next, two variables represented the topic of instructional climate. The first instructional climate variable, "stress level," consisted of three survey questions combined into single latent SEM variable: "Overall, how would you describe the learning environment created during the course: Stressful; Harsh; Exhausting" (Responses: 1 "Not at all," 2 "A little," 3 "Somewhat," 4 "Very," 5 "Extremely"). The second instructional climate variable, "team relationship," consisted of six survey questions combined into a single latent SEM variable: "Describe the extent to which your team did the following: Collaborated effectively; Had a clear leadership structure; Distributed the workload equitably; Shared decision making; Made good decisions" (Responses: 1 "Never," 2 "Seldom," 3 "Sometimes," 4 "Most of the time," 5 "Always").

Finally, the topic of perceived course usefulness was represented by four variables, each of which was composed of a single survey question. Two of these questions were included in the postcourse survey: "I will use the information and ideas from the I-Corps course in: my career; my research program" (Responses: 1 "Totally disagree," 2 "Disagree," 3 "Unsure," 4 "Agree," 5 "Totally agree"). Two similar questions were then included in the longitudinal follow-up survey: "Participation in I-Corps influences my approach to: my career; research" (Responses: 1 "Very negatively," 2 "Negatively," 3 "Neither positive nor negatively," 4 "Positively," 5 "Very positively"). To correct extreme skew [44], values of one and two were truncated to values of three for postcourse (Career, $n = 19$; Research, $n = 35$) and longitudinal (Career, $n = 4$; Research, $n = 4$) usefulness perceptions.

VII. Results

A. Usefulness Perceptions On both the postcourse survey and the longitudinal follow-up survey, all participants expressed high levels of agreement that the course was useful to their research and career. On the postcourse survey, the strongest level of agreement ("Totally agree") was selected by 75% of ELs for career, 64% of TLs for career, 63% of ELs for research, and 60% of TLs for research. On the longitudinal follow-up survey, the highest level of agreement ("Very positively") was selected by 57% of ELs for career, 44% of TLs for career, 54% of ELs for research, and 47% of TLs for research.

B. Model 1 The first model, which included usefulness perceptions and instructional climate, demonstrated good fit ($\chi^2(53, N = 1503) = 157.52$, $p < 0.001$, CFI $= 0.975$, RMSEA $= 0.036$, SRMR $= 0.044$). As hypothesized, ELs perceived greater usefulness of the course than TLs to their careers, both on the postcourse survey ($b = 0.14$, $p < 0.001$) and the longitudinal follow-up survey ($b = 0.13$, $p = 0.009$). However, contrary to expectations, there was no significant difference between ELs and TLs in perceived usefulness to research at either time point (postcourse survey, $b = 0.07$, $p = 0.06$; longitudinal follow-up, $b = 0.02$, $p = 0.75$). The potential moderating variables included in the first model consisted of stress level and quality of team relationship. As hypothesized, ELs perceived poorer team relationships ($b = –0.29$, $p < 0.001$) and greater stress levels ($b = 0.60$, $p < 0.001$) than TLs. As hypothesized, team relationship positively predicted both postcourse career usefulness ($b = 0.09$, $p = 0.003$) and postcourse research usefulness ($b = 0.11$, $p = 0.004$). However, contrary to expectations, stress level showed no relationship with postcourse usefulness in either domain (Career, ($b = 0.01$, $p = 0.81$; Research, $b = 0.01$, $p = 0.56$). Therefore, ELs perceived the course as more useful to their career than TLs, despite perceiving greater stress levels and poorer team relationships.

C. Model 2 In the second model, hours worked and number of individual interviews were added as potential moderators of usefulness perceptions ($\chi^2(73, N = 1503) = 190.64$, $p < 0.001$, CFI $= 0.978$, RMSEA $= 0.033$, SRMR $= 0.044$). Consistent with the results of the first model, ELs perceived greater usefulness of the course than TLs to their careers, both on the postcourse survey ($b = 0.14$, $p < 0.001$) and the longitudinal follow-up survey ($b = 0.13$, $p = 0.009$). However, contrary to expectations, there was no difference between ELs and TLs in perceived usefulness to research at either time point (postcourse survey, $b = 0.08$, $p = 0.07$; longitudinal follow-up, $b = 0.02$, $p = 0.75$). Consistent with the program design, ELs completed more hours of work ($b = 17.05$, $p < 0.001$) and interviews ($b = 37.51$, $p < 0.001$) compared to TLs. Contrary to the hypothesis, neither number of hours ($b < 0.01$, $p = 1.00$) nor interviews ($b < 0.01$, $p = 0.36$) related to perceptions of team

relationship. Also contrary to expectations, number of interviews completed was in fact related to lower stress levels ($b = –0.003$, $p = 0.03$). However, consistent with expectations, hours worked ($b = 0.02$, $p < 0.001$) was related to higher stress levels. After including these mediators, the effect of role on stress level remained significant ($b = 0.41$, $p < 0.001$), with no relationship between stress level and postcourse usefulness (Career, $b = 0.01$, $p = 0.65$; Research, $b = 0.02$, $p = 0.45$).

VIII. Discussion

This article addressed two main questions related to entrepreneurship education that targets academics. The first is whether trainees (graduate students and postdoctoral researchers) represent a more effective target audience for entrepreneurship training than faculty members; the second is whether trainees perceive the entrepreneurship education curriculum more negatively than faculty members. The analysis took advantage of a large-scale survey dataset from the NSF I-Corps program. This entrepreneurship education initiative, which primarily enrolls engineering researchers [27], includes both faculty and trainees and therefore allows for the direct comparison of their attitudes and experiences.

To address whether the program had a more positive impact on the attitudes of trainees or faculty members, the perceived usefulness of participating in the program was compared between these two groups. As hypothesized, trainees perceived greater usefulness to their careers, a difference that was not only found immediately after the course, but was also maintained in a follow-up survey approximately a year after course completion. However, contrary to expectations, no difference was found between groups in perceived usefulness to their research programs. This result is consistent with the view that trainees are more receptive than faculty to shifting their career aspirations toward entrepreneurship as a result of training, supporting the argument that entrepreneurship education for students may be more effective in promoting technology commercialization than efforts targeting faculty members.

Next, to address the question of whether the I-Corps curriculum could be improved by additional instructional support for trainee participants, attitudes toward team relationships and stress level related to participation were examined. As hypothesized, trainee participants reported poorer team relationships and higher stress levels (e.g., stating the program was “stressful,” “harsh,” and “exhausting”) than faculty, a pattern consistent with prior research demonstrating that trainees can encounter conflicts with faculty members when collaborating on startup projects [34]. Furthermore, this result is not explained simply by the fact that the trainee participants completed more project-related work than faculty. These findings indicate that the success of commercialization projects in I-Corps and similar programs could be enhanced by providing additional instructional support to student and trainee members for managing stress and negative team interactions. However, more research would be needed to understand the sources of trainee stress, which could arise from issues related to the completion of academic program requirements, conflicts over ownership, or specific interpersonal problems.

Finally, the present analysis tested whether the poorer team relationships and greater stress levels experienced by student and trainee participants negatively impacted their perceptions of the usefulness of participating. As expected, perceived quality of team relationship was significantly correlated with perceptions of course usefulness to career and research. However, contrary to expectations, stress level did not relate significantly to either type of perceived usefulness. This result further indicates that the effectiveness of the I-Corps curriculum design might be enhanced for trainee participants through guidance in team interactions.

In summary, key findings of these analyses are that trainee participants in the I-Corps program perceived the program as more useful to their careers than did faculty members, despite their perceptions of greater stress and poorer team relationships during the training. These findings support the I-Corps instructional design that gives trainee participants leadership roles in the project teams [25], as well as the claim that efforts to promote technology commercialization could benefit from targeting graduate students rather than faculty. Beyond prior research indicating that students go on to engage in actual entrepreneurial behavior more often than faculty [30], the long-term perceptions of usefulness found in this article represent an additional metric of program success, as they reflect the perceived career benefits of entrepreneurship and customer discovery skills more broadly. Therefore, these results support calls for the expansion of entrepreneurship education opportunities for students, as well as the academic program flexibility required to pursue them [10], [11]. In addition, this article indicates that poor team relationships may present a key challenge for trainees who are working on commercialization projects with faculty members. Additional research is necessary in order to evaluate strategies that might mitigate this issue, such as training in positive team interactions or the provision of

conflict resolution resources. Overall, the conclusions of this analysis support call for additional study of the role and instructional needs of graduate students and trainees in technology commercialization [1], [12], [13], [30].

IX. Limitations

The conclusions drawn from these analyses must be interpreted in light of several limitations. First, several variables were not available in the public dataset in order to maintain participant confidentiality. These include gender identification, race/ethnicity, and which participants were on the same team. In addition, the NSF I-Corps program incorporates several unique features that limit the ability to generalize the results of this analysis to other entrepreneurship training programs. For example, it is based on a standardized three-member team structure and targets recipients of NSF research funding. Further, the fact that the teaching approach is intentionally "tough" [45, p. 5] may alter the relationship between stress level and other variables examined in this article. For example, potential academic entrepreneurs may choose not to participate if they believe this approach does not meet their needs. In other words, the extent of possible self-selection bias is not known.

Acknowledgment

This article was made possible with the data collected and published by VentureWell. This material is based upon work supported by the National Science Foundation under Grant 1643280.

References

[1] R. Grimaldi, M. Kenney, D. S. Siegel, and M. Wright, "30 years after Bayh-Dole: Reassessing academic entrepreneurship," *Res. Policy*, vol. 40, no. 8, pp. 1045–1057, Oct. 2011.

[2] M. S. Wood, "A process model of academic entrepreneurship," *Bus. Horiz.*, vol. 54, no. 2, pp. 153–161, Mar. 2011.

[3] M. Guerrero, J. A. Cunningham, and D. Urbano, "Economic impact of entrepreneurial universities' activities: An exploratory study of the U.K.," *Res. Policy*, vol. 44, no. 3, pp. 748–764, Apr. 2015.

[4] N. Salimi and J. Rezaei, "University relationship management," *IEEE Eng. Manage. Rev.*, vol. 46, no. 2, pp. 121–132, Apr. 2018.

[5] J. G. Thursby and M. C. Thursby, "University licensing," *Oxford Rev. Econ. Policy*, vol. 23, no. 4, pp. 620–639, Dec. 2007.

[6] R. T. Harrison and C. Leitch, "Voodoo institution or entrepreneurial university? Spin-off companies, the entrepreneurial system and regional development in the U.K.," *Regional Stud.*, vol. 44, no. 9, pp. 1241–1262, Nov. 2010.

[7] D. S. Siegel and M. Wright, "Academic entrepreneurship: Time for a rethink?," *Brit. J. Manage.*, vol. 26, no. 4, pp. 582–595, Oct. 2015.

[8] A. Schmitz, D. Urbano, G. A. Dandolini, J. A. de Souza, and M. Guerrero, "Innovation and entrepreneurship in the academic setting: A systematic literature review," *Int. Entrepreneurship Manage. J.*, vol. 13, no. 2, pp. 369–395, Jun. 2017.

[9] A. Huang-Saad, J. Fay, and L. Sheridan, "Closing the divide: Accelerating technology commercialization by catalyzing the university entrepreneurial ecosystem with I-Corps™," *J. Technol. Transf.*, vol. 42, no. 6, pp. 1466–1486, 2017.

[10] A. Nelson and T. Byers, "Challenges in university technology transfer and the promising role of entrepreneurship education," in *The Chicago Handbook of University Technology Transfer and Academic Entrepreneurship*, A. N. Link, D. S. Siegel, and M. Wright, Eds. Chicago, IL, USA: Univ. Chicago Press, 2015, pp. 138–167.

[11] N. Duval-Couetil, T. Reed-Rhoads, and S. Haghighi, "Engineering students and entrepreneurship education: Involvement, attitudes and outcomes," *Int. J. Eng. Educ.*, vol. 28, no. 2, pp. 425–435, 2012.

[12] T. Åstebro, N. Bazzazian, and S. Braguinsky, "Startups by recent university graduates and their faculty: Implications for university entrepreneurship policy," *Res. Policy*, vol. 41, no. 4, pp. 663–677, May 2012.
[13] B. Beyhan and D. Findik, "Student and graduate entrepreneurship: Ambidextrous universities create more nascent entrepreneurs," *J. Technol. Transf.*, vol. 43, no. 5, pp. 1346–1374, Oct. 2018.
[14] National Science Foundation, "2019 NSF Innovation Corps (I-Corps™) biennial report," 2019. [Online]. Available: https://www.nsf.gov/news/special_reports/i-corps/pdf/I-CorpsReport–6_4_19FINAL_508.pdf
[15] S. Jain, G. George, and M. Maltarich, "Academics or entrepreneurs? Investigating role identity modification of university scientists involved in commercialization activity," *Res. Policy*, vol. 38, no. 6, pp. 922–935, Jul. 2009.
[16] S. Mosey and M. Wright, "From human capital to social capital: A longitudinal study of technology-based academic entrepreneurs," *Entrepreneurship Theory Pract.*, vol. 31, no. 6, pp. 909–935, Nov. 2007.
[17] M. Wright, K. M. Hmieleski, D. S. Siegel, and M. D. Ensley, "The role of human capital in technological entrepreneurship," *Entrepreneurship Theory Pract.*, vol. 31, no. 6, pp. 791–806, Nov. 2007.
[18] F. Murray, "The role of academic inventors in entrepreneurial firms: Sharing the laboratory life," *Res. Policy*, vol. 33, no. 4, pp. 643–659, May 2004.
[19] E. Rasmussen and M. Wright, "How can universities facilitate academic spin-offs? An entrepreneurial competency perspective," *J. Technol. Transf.*, vol. 40, no. 5, pp. 782–799, Oct. 2015.
[20] C. S. Hayter, "Conceptualizing knowledge-based entrepreneurship networks: Perspectives from the literature," *Small Bus. Econ.*, vol. 41, no. 4, pp. 899–911, Dec. 2013.
[21] C. S. Hayter, "Constraining entrepreneurial development: A knowledge-based view of social networks among academic entrepreneurs," *Res. Policy*, vol. 45, no. 2, pp. 475–490, Mar. 2016.
[22] C. S. Hayter, "A trajectory of early-stage spinoff success: The role of knowledge intermediaries within an entrepreneurial university ecosystem," *Small Bus. Econ.*, vol. 47, no. 3, pp. 633–656, Oct. 2016.
[23] T. Duening, M. Metzger, and G. N. Stock, "Entrepreneurial persistence: Entrepreneurial virtues as dynamic constraints over the entire lifepath," *IEEE Eng. Manage. Rev.*, vol. 47, no. 3, pp. 42–56, Sep. 2019.
[24] A. Vohora, M. Wright, and A. Lockett, "Critical junctures in the development of university high-tech spinout companies," *Res. Policy*, vol. 33, no. 1, pp. 147–175, Jan. 2004.
[25] C. C. Nnakwe, N. Cooch, and A. Huang-Saad, "Investing in academic technology innovation and entrepreneurship: Moving beyond research funding through the NSF I-CORPS™ program," *Technol. Innov.*, vol. 19, no. 4, pp. 773–786, Jul. 2018.
[26] VentureWell, "Impact of NSF's I-Corps™ national program on individual participants, data file and codebook: Release 2.1," Aug. 28, 2019. [Online]. Available: https://go.venturewell.org/PublicUseData2
[27] National Science Foundation, "National Science Foundation award search." 2020. Accessed on: Apr. 23, 2020. [Online]. Available: https://www.nsf.gov/awardsearch/
[28] National Science Foundation, "Frequently asked questions (FAQs) for I-Corps™ team solicitation, NSF 18-057," 2019. [Online]. Available: https://www.nsf.gov/pubs/2018/nsf18057/nsf18057.jsp
[29] W. F. Boh, U. De-Haan, and R. Strom, "University technology transfer through entrepreneurship: Faculty and students in spinoffs," *J. Technol. Transf.*, vol. 41, no. 4, pp. 661–669, Aug. 2016.

[30] C. S. Hayter, R. Lubynsky, and S. Maroulis, "Who is the academic entrepreneur? The role of graduate students in the development of university spinoffs," *J. Technol. Transf.*, vol. 42, no. 6, pp. 1237–1254, Dec. 2017.
[31] J. Bercovitz and M. Feldman, "Academic entrepreneurs: Organizational change at the individual level," *Org. Sci.*, vol. 19, no. 1, pp. 69–89, Jan. 2008.
[32] P. T. Gianiodis and W. R. Meek, "Entrepreneurial education for the entrepreneurial university: A stakeholder perspective," *J. Technol. Transf.*, vol. 45, pp. 1167–1195, 2020.
[33] R. Jensen and M. Thursby, "Proofs and prototypes for sale: The licensing of university inventions," *Amer. Econ. Rev.*, vol. 91, no. 1, pp. 240–259, 2001.
[34] N. Duval-Couetil, M. Ladisch, and S. Yi, "Addressing academic researcher priorities through science and technology entrepreneurship education," *J. Technol. Transf.*, pp. 1–31, Apr. 7, 2020.
[35] P. Shekhar, A. Huang-Saad, and J. Libarkin, "Understanding student participation in entrepreneurship education programs: A critical review," *Int. J. Eng. Educ.*, vol. 34, no. 3, pp. 1060–1072, 2018.
[36] M. Guerrero, D. Urbano, and A. Fayolle, "Entrepreneurial activity and regional competitiveness: Evidence from European entrepreneurial universities," *J. Technol. Transf.*, vol. 41, no. 1, pp. 105–131, Feb. 2016.
[37] V. Souitaris, S. Zerbinati, and A. Al-Laham, "Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources," *J. Bus. Venturing*, vol. 22, no. 4, pp. 566–591, 2007.
[38] D. Turker and S. S. Selcuk, "Which factors affect entrepreneurial intention of university students?," *J. Eur. Ind. Train.*, vol. 33, no. 2, pp. 142–159, Feb. 2009.
[39] K. Semcow and J. K. Morrison, "Lean startup for social impact: Refining the national science foundation's innovation corps model to spur social science innovation," *Social Enterprise J.*, vol. 14, no. 3, pp. 248–267, Aug. 2018.
[40] S. Blank and J. Engel, The National Science Foundation I-Corps™ Teaching Handbook, 2016. [Online]. Available: https://venturewell.org/wp-content/uploads/I-Corps-Teaching-Handbook-Jan16.pdf
[41] National Science Foundation, "Innovation corps—National Innovation Network Teams Program solicitation, NSF 18-515," 2019. [Online]. Available: https://www.nsf.gov/pubs/2018/nsf18515/nsf18515.htm
[42] R. B. Kline, *Principles and Practice of Structural Equation Modeling*, 4th ed. New York, NY, USA: Guilford, 2015.
[43] P. Allison, *Missing Data*. Los Angeles, CA, USA: SAGE, 2002.
[44] J. Osborne, *Best Practices in Data Cleaning: A Complete Guide to Everything You Need to Do Before and After Collecting Your Data*. Los Angeles, CA, USA: SAGE, 2014.
[45] VentureWell, "I-Corps™ course syllabus Midwest node," 2019. [Online]. Available: https://venturewell.org/wp-content/uploads/Summer-2019-Cohort-Midwest-Node-Chicago-IL-1.pdf