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Developing Intrapreneurship in the Next Generation of Engineering Innovators and Leaders

Dr. Tim Dallas P.E., Texas Tech University

Tim Dallas is a Professor of Electrical and Computer Engineering at Texas Tech University. Dr. Dallas' research includes developing educational technologies for deployment to under-served regions of the world. His research group has developed MEMS-based educational technologies that have been commercialized, expanding dissemination. He has served as an Associate Editor of IEEE Transactions on Education. Dr. Dallas received the B.A. degree in Physics from the University of Chicago and an MS and PhD from Texas Tech University in Physics. He worked as a Technology and Applications Engineer for ISI Lithography and was a post-doctoral research fellow in Chemical Engineering at the University of Texas, prior to his faculty appointment at TTU.

Dr. Heather Greenhalgh-Spencer, Texas Tech University
Dr. Kelli M. Frias, American University

Kellilynn M. Frias received her Ph.D. from the University of Arizona. She is currently an Assistant Professor of Marketing at the Kogod School of Business at American University. Her research interests include marketing strategy, business-to-business relationships, and commercialization of technology. Her teaching interests include technology commercialization, marketing strategy, marketing, and public policy. She has published research in Organization Science, International Journal of Engineering Education, Educational Philosophy and Theory, and Journal of Business & Management. She employs project-based learning and multi-method research in many of her courses.

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abstract

This National Science Foundation Scholarships in STEM (S-STEM) project responds to a growing disparity among technology firms and the number of under-represented people in managerial and executive positions. Of particular interest is developing mentorship relationships and intrapreneurial competencies (*i.e.*, entrepreneurship within established firms) because mentorship relationships and increased skills have been shown to improve workforce retention and promotability of engineering undergraduates (upon entering the workforce). Specifically, the project was designed to produce electrical and computer engineering graduates with intrapreneurial knowledge and skills, which are characteristic of managers and innovators. Using the Intrapreneurial Competencies literature, the authors develop and test a multi-phased project among a diverse group of engineering undergraduates. The literature suggests enhancing the intrapreneurial skills of students in engineering can be achieved through a combination of curricular and real-world experiences. Thus, this project incorporates faculty and industry mentorship, workforce development seminars, an industrial internship, and entrepreneurship programs.

introduction

The Tech Intrapreneurs Program (TIP) at Texas Tech University responds to a needs analysis and industry requests to hire a more diverse workforce [1] with individuals from traditionally underrepresented groups (women and ethnic minorities) advancing to managerial positions. The program is designed to produce ***intrapreneurs*** with a particular focus on bolstering the representation of underrepresented minorities**.** *Intrapreneurship* is the practice of developing a new venture, product, or service within an existing organization. *Intrapreneurs* are particularly critical for engineering because this academic domain often provides the foundation the technical expertise needed to commercialize innovation. Many important innovations will come from existing organizations; as such, most new graduates will begin their careers with established firms, and intrapreneurial skills have been identified as drivers in retention and career advancement in engineering-focused firms [2]. The literature suggests enhancing intrapreneurial skills of students in engineering can be achieved through a combination of curricular and real-world experiences [3]. Since traditional engineering curricula often neglect entrepreneurial topics, as well as intrapreneurial experiences, the project aims to rectify this gap through a combination of curriculum and mentorship experiences, emphasizing cultivating entrepreneurial/intrapreneurial characteristics. This is particularly important since the marketplace is in drastic need of diversity in managerial roles in engineering firms (Managers: 7.4% female [4], under-represented men 5.2%, under-represented women 4% [5]).

Entrepreneurs have been rightly celebrated for producing new markets and product categories that define modern society. Founders of high-tech companies, such as Google, Facebook, and Tesla are now celebrities worth billions of dollars. Their contributions as entrepreneurs are profound, but their ranks are tiny. In other words, there will be many more people who have experience in engineering than have experience as engineering entrepreneurs. As Menzel *et al.* [2] noted, *"most engineers will remain employed in organizations and never become independent entrepreneurs, but their managerial responsibility will increase and requires them to act*

entrepreneurial within the company." Intrapreneurial skills facilitate career progression and have been shown to improve managerial skills. Furthermore, Hayton and Kelley [6] found that intrapreneurs produce competitive advantages for their company, which stimulates growth. Ma *et al*. [7] reported that intrapreneurs create value for their company by identifying, developing, and exploiting new opportunities. One vivid example of this is Dr. Larry Hornbeck of Texas Instruments (TI), who had a radical idea for a new micro-mirror technology to render digital video. The project eventually spawned a new TI division (Digital Light Processing – DLP) and led to billions of dollars in product sales.

Intrapreneurial skills, as well as a focus on entrepreneurship + engineering skills, has been the focus of the TIP program. The following sections highlight the program activities, and then layout the research methods for analyzing efficacy as well as evaluating the student experience in the program.

project activities

TIP combines faculty and industry mentorship, workforce development seminars, an international experience, an industrial internship, entrepreneurship programs, and scholarships. The program was designed to improve curricular and co-curricular activities for scholars who are economically disadvantaged, many from underrepresented groups in engineering, and who are at risk of changing majors, delayed graduation, or not graduating. The expectation is improved graduation rates as well as engineers who are poised to excel in graduate school and industry.

The project leverages National Science Foundation (NSF) investment in I-Corps programs administered and hosted by the host university's innovation hub that provides innovators and entrepreneurs the training and resources needed for commercializing ideas. Through rigorous academics, intrapreneur training, innovation and entrepreneur programs, career training activities, and support programs, students are well-prepared for graduate school, a high-tech career in an established company, or doing a start-up. Program components provide students the resources and guidance needed to compete for industrial internship opportunities and full-time employment. Substantial scholarships (up to $10,000/year) help students overcome financial barriers that can impede progress, limit opportunities, and delay graduation. This project will study this education model to determine how the various components contribute to student outcomes.

There are a number of local and national needs that have influenced the program objectives.

National:

1. Companies, especially those that are engineering-focused, need innovative employees.[8]
2. Engineering companies want to have a diverse workforce.[9]
3. Engineering firms want to increase the diversity of their management.[10]
4. There are lower rates of entrepreneurship by underrepresented groups and women.[11]
5. There is a need for increased networking, mentoring, and access to capital for these groups.

Local:

1. The percentage of ECE students that are female is below national averages, but the retention rate is high.
2. Underrepresented engineering students graduate at a lower rate than university and national averages.

3. Most high-tech internship and employment is outside the university's geographical area.
4. Underrepresented groups need increased industrial mentorship and networking opportunities.
5. Financially needy students find it challenging to participate in mandatory international experience [*International experience is required of all engineering students].*

The main components of the TIP experience include:

- Intrapreneurial orientation courses
- Mentorship by faculty
- Mentorship by industry experts
- Internship (including the opportunity for international internships)
- Extra-curricular activities and projects focused on gaining experience with customer discovery, product development, and business plan development

The project has resulted in curriculum and pedagogical models that are aimed at fostering intrapreneurial thinking, dispositions, and competencies. The models advocate for the networking and connection points between extra-curricular activities, curriculum devoted to intrapreneurial experiences, and mentorship.

research methodology

In order to better understand the efficacy of the program as well as to evaluate and iterate on the student experience, the researchers used the following tools to collect data

TIP Experience	**Research Tool**
Mentoring	Interviews of Mentors
Curriculum Efficacy	Pre and Post Tests using ICMS (explained below)
Curriculum Efficacy	Pre and Post Tests using IMSS (explained below)
Student Overall Experience with Mentoring	Student Interviews / Survey
Student Overall Experience with Extra Curricular Activities and Intrapreneurship Courses	Student Learning Journals and other Document Collection on Student Experiences

Intrapreneurship Measurement Tools

Intrapreneurial Competencies Measurement Scale (ICMS)

The ICMS is composed of seven areas.
1. Exploiter of opportunities
Knowledge to detect opportunities, acting to take advantage of opportunities, and adopting behaviors to take advantage of opportunities for the company

2. Pro-innovator

Knowledge to create new things, acting to put new things into practice and adopt behaviors, and willingness to create new things for the company

3. Idea stimulator

Knowledge to create new ideas, acting to put new ideas to the test, and adopting behaviors to promote and support new ideas for the company

4. Planner

Knowledge to plan initiatives, acting to implement a new initiative plan, and adopting behaviors for the new company initiative plan

5. Resource manager

Knowledge to detect and estimate resources, acting to mobilize resources, and adopting behaviors to commit resources to new initiatives for the company

6. Support network builder

Knowledge to build networks, acting to join forces with others, and adopting behaviors to attract others and negotiate with others to support new initiatives for the company

7. Builder of interactions with others

Knowledge to involve others, acting to put the knowledge and experiences of others into practice, and the ability to know how to encourage others to support new initiatives for the company

Students are asked multiple questions corresponding to each of the seven areas above. Their answers to these questions show the level of intrapreneurial competencies.

Intrapreneurial Motivation Scale Survey (IMSS)

The IMSS includes questions designed to get at intrapreneurial motivation. This is a 12-question set designed to get at various levels of motivation.

Cohort 1

It is important to note that the data reflected for Cohort 1 in this paper shows data collection for the first components of TIP. Not all data tools were used (for example, interviews) because, at this time, not all of the components of TIP have been experienced by the students.

Students are given multiple experiences, in each course, to develop intrapreneurial dispositions and competencies, and the theory of action is that the combination of coursework experiences, internship experiences, mentorship, and other job-related experiences provided by the TIP, that we would see an increase in intrapreneurial competencies and dispositions as measured by ICMS and the Intrapreneurial Motivation Scale. Furthermore, we collected data from the students about their perceptions of TIP to lead to new skills and mindsets, and we added this to our array of data to help us understand the efficacy of TIP to increase intrapreneurship within our graduates.

Cohort 1 is comprised of a diverse group of 16 students (8 men, 8 women, 8 ethnic minorities) in a Department of Electrical and Computer Engineering (ECE). Students attended lectures by prominent engineering entrepreneurs, participated in a 3-day start-up weekend hosted by the university's Innovation Hub, attended engineering job fairs and two semesters of project-focused seminars, and read entrepreneurial and/or leadership-related books. This included reading books and providing oral reports of prominent entrepreneurs across various domains (to supplement discussions held during synchronous seminars). The students also met with mentors on a regular basis. Furthermore, they engaged in intrapreneurial-focused curriculum activities that were designed to increase understanding of and engagement with intrapreneurship.

Program component details:

- *Faculty mentorship*: Students chose an Electrical and Computer Engineering faculty mentor. The student was responsible for setting up monthly meetings that were typically conducted through phone or video calls due to COVID-19. Meeting durations ranged from 0.5 – 1 hour.
- *Industry mentorship*: Students chose an industry mentor; met in person or virtually, on a monthly basis for 0.5 – 1 hour. A mentor list was made available to the scholars through a departmental alumni LinkedIn group. Some students found mentors from outside this group. The student was responsible for setting up monthly meetings that were typically conducted through phone or video calls due to COVID-19 and living in different geographical areas.
- *Workforce development seminars:* Students heard presentations from entrepreneurs discussing their experiences starting their own companies and others working in established companies.
- *Reading Resources Program*: Students have access to a collection of leadership and entrepreneurship-related books for supplemental reading and use in oral reports, class discussions, and as talking points with mentors.
- *International experience:* Students are required to complete an international experience that meets the criteria established by the College of Engineering. Due to COVID related restrictions, a service-learning activity could be used instead to fulfill the requirement.
- *Industrial internship*: Many students participate in an internship at a technology-related company and work in an engineering role.
- *Entrepreneurship programs:* Students participate in entrepreneurial programs hosted by the Texas Tech Innovation Hub. Most students participated in a 3-day start-up event with students from across various academic domains and class standings. These programs are supported by a variety of local and national organizations.
- *Scholarships:* Students receive a scholarship for up to $10,000/year. The average award is over $8500/year.

Data streams were collected in multiple ways to address each research question. This is reflected in Table I.

TABLE I. Program research question and associated data streams

Research Question	**Data Stream**
Does TIP lead to an increase in intrapreneurial competencies and dispositions?	ICMS student responses collected every semester
Does TIP lead to an increase in intrapreneurial competencies and dispositions?	Intrapreneurial Motivation Self-Assessment Survey
How do students self-evaluate their gains in intrapreneurial skills and the efficacy of the program?	Mentor reflections
How do students self-evaluate their gains in intrapreneurial skills and the efficacy of the program?	Student Self-Reflections on the program

Data were collected in the form of student reflections about being a mentee in the mentor relationships and interview data from mentors (*i.e.*, engineering professionals and faculty). Students documented their mentoring sessions, which were reviewed by the project team. A primary theme that emerged from mentor reports was the effects of COVID-19, mostly how students thought about their coursework and how their industry mentors thought about their jobs. Although there was deep concern about the impacts of COVID-19, the students expressed a sense of growth and learning in spite of the virus. Students self-reported that the S-STEM experience was still highly beneficial, even as much of the coursework and mentoring for the latter half of the Spring semester had to be moved online. The students responded well academically, with the average semester GPA rising from 3.483 in the Fall 2019 semester to 3.774 in the Spring 2020 semester.

Data were collected by survey pre- and post-semester to measure improvements in Intrapreneurial Competencies. The "Intrapreneurial Competencies Measurement Scale" (ICMS) by Vargas-Halabi *et al*. [12] was used to measure and evaluate the development of intrapreneurial competencies, which include: (1) Opportunity promoter, (2) Proactivity, (3) Flexibility, (4) Drive, and (5) Risk-taking. Each of the categories of the ICMS is divided into 3-9 sub-categories to assess skill and mindset in the five general categories. In answering the questions on the ICMS test, students evaluated their proficiency in each of the areas. Growth was evident for almost all the categories and sub-categories across each of the three data-gathering points.

results and findings

Students' responses to these questions showed growth in each of these key areas, as shown in the graphs below tracking responses to ICMS as well as IMSS. The graphs track the number of students who showed growth from at least one proficiency quintile to the next proficiency quintile across each sub-category question. The data is from the beginning of the Fall 2019

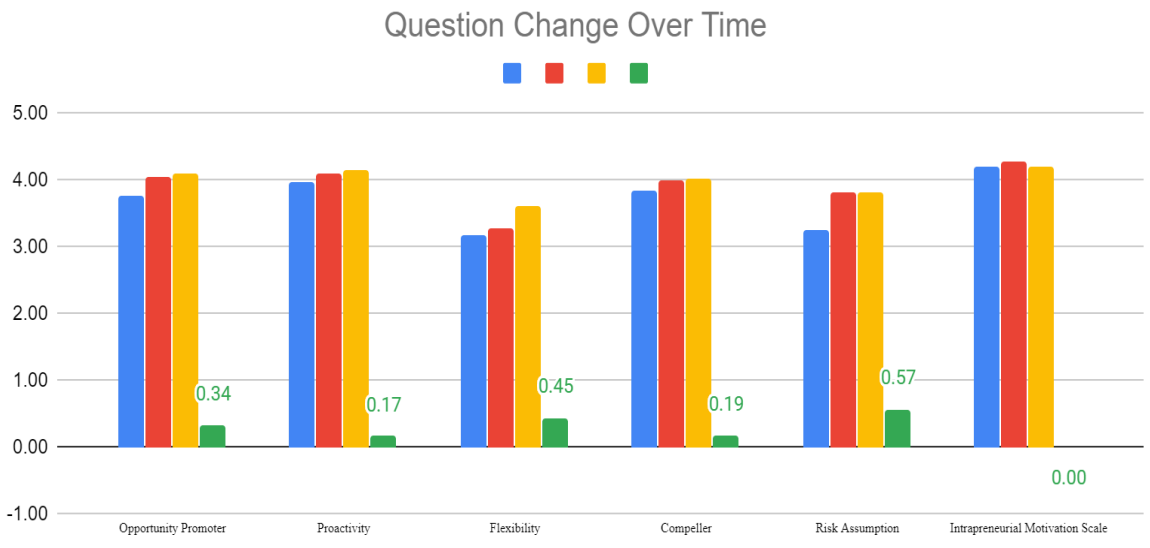

Figure 1. Average student responses over time

semester (August, 2019) to the end of Fall 2019 semester (December, 2019), and then again at the end of the Spring 2020 semester (May, 2020).

The graph in Figure 1 shows the average responses from all survey respondents for each question category in August 2019 (blue), December 2019 (red), and May 2020 (orange). The green bars indicate the average change from the beginning of the year to the end of the year for each question category for the class as a whole.

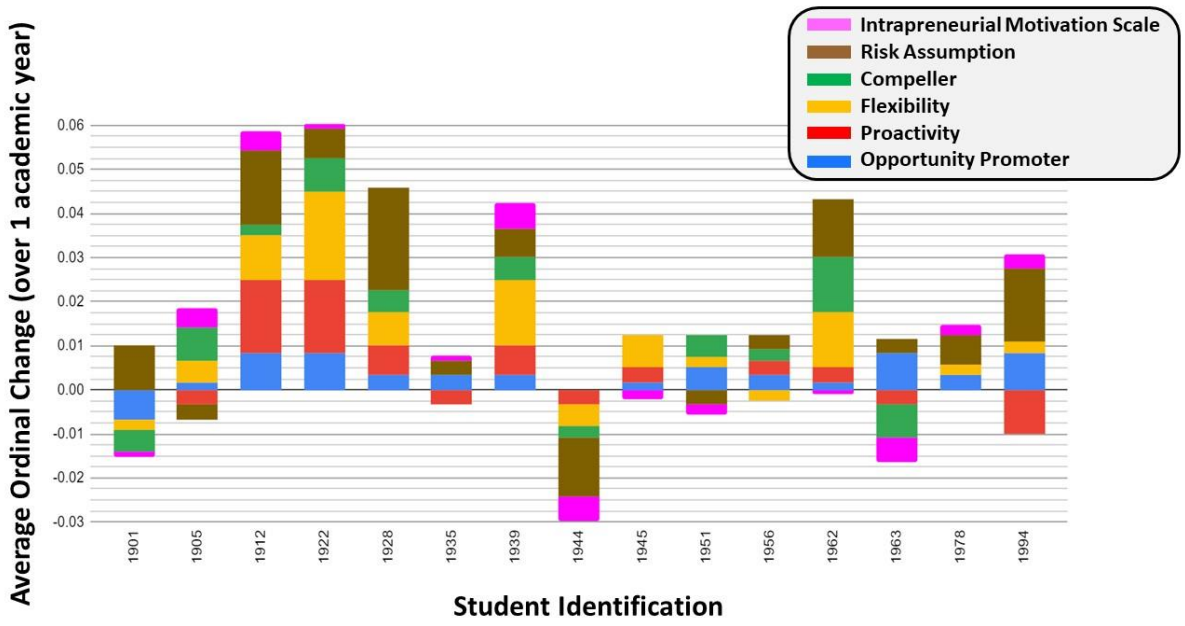

Figure 2. Student attitude change over time

The chart in Figure 2 shows the average change in responses for each question category by survey respondent. The Y-axis of the graph represents the ordinal change from the beginning of the academic year to the end of the academic year for each respondent and for each question category. The X-axis is the respondent's anonymous identification number.

Figure 3 shows student growth on the Intrapreneurial Motivation scale. One of the main themes that emerged from the mentor reports was the effects of COVID-19. This theme emerged in relation to both how students felt about their coursework, as well as how their mentors (engineering professionals) felt about their jobs. In general, students felt concerned about the effects of COVID-19. However, they also expressed a sense of growth and learning in-spite of the virus. In general, students self-reported that the TIP experience was still highly beneficial, even as much of the coursework and mentoring for the latter half of Spring semester had to be moved online.

mentoring objectives, activities, and outcomes

One of the integral components of TIP is the experience of being mentored by faculty and industry experts. This next section discusses the mentoring objectives, experiences, and preliminary outcomes.

There were several mentoring objectives during the first year of the program. Data was collected from student learning journals and other student-produced documents on their experiences. The documents speak directly to the experiences of students with mentoring.

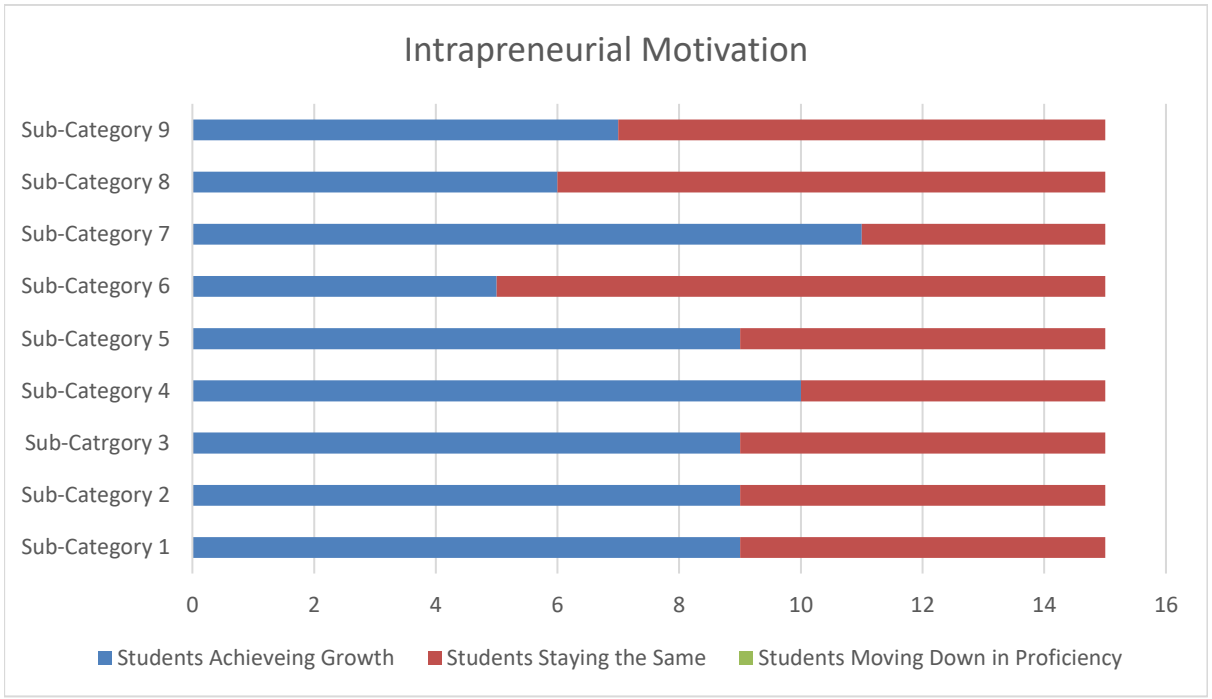

Figure 3. Intrapreneurial Motivation results.

Mentoring Objectives

The primary objectives of the mentorship component of the TIP program were to provide access to industry and faculty mentors (in engineering-related fields), to identify underrepresented mentors (whenever possible) and create matches with under-represented TIP students, and to provide career-related advice and guidance (*e.g.*, resume assistance, curriculum assistance). The project objectives were constructed broadly to identify initial topics of conversation, areas of requested improvement (from both students and mentors), and an opportunity for initial inductive inquiry about the types of interaction and dialogue within these relationships.

Mentoring Activities

Students were required to meet with their mentors approximately three times during the semester. Meetings could have been conducted across multiple faculty and industry mentors or with one mentor. In the circumstances where students only met with one mentor, it was typically because the other mentor was unavailable when the student was available. A change of circumstances with the mentor made it particularly difficult to garner their assistance (although this was rare). Of the 16 TIP students in Cohort 1, 12 students had formal agreements to be mentored by one faculty and one industry mentor. Students met on average of 3 times per semester, either by phone or in person.

Mentoring Outcomes:
As researchers reviewed student documents and student learning journals, the following themes emerged around the experiences of mentoring.

Students are very appreciative of being given the opportunity to participate in the mentoring sessions. As determined from collected documents, topics of discussion with faculty mentors included:

- Finding time management strategies that were more effective for students.
- Achieving some career-life balance in their futures.
- Communication strategies with faculty (and advisors on campus).

Many of the students expressed interest in understanding how their faculty managed their schedules and what type of communication strategies were most useful for students when they were struggling in a particular class. Concerning industry mentors and time management, many discussions revolved around how to handle difficult bosses and career advice that may be inconsistent with the students' own goals. Further discussions were about particularly technologies being created at their respective companies and how these projects are organized and executed internally.

Students used a variety of different formats to report their discussions. Some appeared to have a format with pre-selected questions, while others preferred to have open-ended questions for their mentors. Similarly, some students said taking the lead on setting up the appointments with mentors, while others noted that the mentor scheduled regular calls with them.

When female students connected with female mentors, the topic of low numbers of females in the program/workforce comes up, in some cases repetitively. In male/mixed teams, gender does not come up as a topic. Industry mentors also often talked about their current roles within their company as well as former roles. Often this provided an opportunity for students to learn about how the mentor progressed and was promoted within their firm. It also provided a chance for some mentees to ask more about the skills needed upon entry into management. This was consistent with our objective of creating dialogue about their careers as well as progression to management (retention in STEM).

key insights and calls to action

There are several main takeaways from the project thus far, and this results in our calls to action.

- It is troublesome to realize how little students know about the faculty in the department, starting with correct names, positions, areas of interest/research. We claim to have an open-door policy, but it seems like students would not take the initiative to stop by for advice without a mentoring program. I think it would be worthwhile discussing mentoring/career advising in one of the next department meetings, given the reports.
- Some of the industry mentors agreed too fast to take on their mentor job and then did not follow up. A meeting regarding onboarding mentors is necessary prior to the next cohort. Potentially a short seminar series of videos regarding a template for mentoring sessions, diversity and inclusion in mentor/mentee relationships, a formal mentor/mentee contract to be used between the mentors (both faculty and industry), and students to generate a list of shared norms.

- The TIP seminar series gives students a great opportunity to reiterate and reinforce their learning about innovation and entrepreneurship. The seminar may also include time to discuss what individual mentees have learned from their mentors during the process (rather than only providing mentor reports to the PIs/faculty teaching their seminars).

emerging themes from students

Several themes emerged from the analysis of student reflections, mentor reports, and triangulation with the data from the scales.

Thus far, three themes have emerged from this stream of data: the need for specific expertise, flexibility in career paths, and gender in engineering or other STEM-related professions. This semester, the bulk of the writing prompts were done in conjunction with visits by entrepreneur experts and assigning/meeting with mentors. We believe this shaped the themes that emerged.

Need for Specific Expertise
Many students were struck by the ways that the experts / invited speakers with whom they had a chance to interact were experts in their fields. Most of the invited speakers had advanced degrees. Additionally, all of them had taken on many different types of projects to gain expertise that went beyond what they had learned as part of their formal education. One student reflected on how struck s/he was by an expert who is now working on ways to cure or ameliorate glaucoma. The student reflected that this expert had to gain very specific expertise and that a lot of the expertise came through experience and not just time in the classroom.

Flexibility in Career Paths
Several students commented on the twists and turns of the career paths of both the invited speakers and their assigned mentors. Many students noted that people were involved in projects that they did not, at first, foresee for themselves. Several students noted that they wanted to make sure they had flexibility in their own mindsets so that they could take advantage of opportunities that developed in their careers.

Gender in Engineering
Gender came up several times in the prompts. Because we collected this data in a way that does not link to PII, we are unable to determine and link the gender of the respondent to the specific response. Thus, we do not know whether there is a correlation between the responses that dealt with gender and the male or female gender of the respondent. What we can say is that several times the gender of the expert was mentioned. Students noted when they felt intrigued by the story of a woman in engineering and her abilities to thrive in a company. Many students reflected on the personal lives of female experts / invited speakers / mentors (whether or not the person was married, getting married, had children) and these topics did not seem to come up with the male experts / invited speakers / mentors. In many ways, this aligns with the scholarly literature showing that women are often asked about—or noted for—their personal lives in ways that men are not. In general, the students seemed to have a very positive perspective around women in STEM fields.

limitations of the data

While all studies have limitations, this is initial data collection effort is limited by sample size and the semester length. First, with this data spanning the first 16 students in the TIP, it is difficult to make strong claims about correlation and patterns between their experiences and the efficacy of the program. Furthermore, this data represents the data collected from just one year in the program. It will be interesting to see what—if anything—changes over the course of the next few semesters. Having said that, the data thus far gives high hope that students are having a positive experience that is leading to the students' feeling like they are more capable and have greater skills and competencies in intrapreneurship.

conclusion

The first year of the Tech Intrapreneurship Program shows many positive and promising steps toward achieving its goal of bolstering the skills, competencies, and dispositions associated with intrapreneurship in Electrical and Computer Engineering students at Texas Tech University. Survey results indicate that there have been measurable gains in intrapreneurial tendencies by the vast majority of the students. This bodes well for increasing the number of graduates—particularly underrepresented graduates—within the industry who have the wherewithal to contribute to a company in innovative ways.

acknowledgment

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appendix

Opportunity Promotor. *Please circle the answer that best matches your experience.*	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I act diligently to seize opportunities to make changes or generate new initiatives.	1	2	3	4	5
I ask questions that challenge how things are done.	1	2	3	4	5
I have the ability to convince others of the utility of carrying out new initiatives.	1	2	3	4	5
I have the ability to turn opportunities into manageable initiatives.	1	2	3	4	5
I am confident that the new initiatives I suggest will take place.	1	2	3	4	5
I promote enthusiasm in others during the execution of new initiatives.	1	2	3	4	5
Proactivity. *Please circle the answer that best matches your experience.*	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I have the disposition to work with others to evaluate any new opportunity that presents itself.	1	2	3	4	5
I carry out actions aimed at joining efforts between entities to implement new initiatives.	1	2	3	4	5
I support new ideas regardless of who proposes them.	1	2	3	4	5
Flexibility. *Please circle the answer that best matches your experience.*	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I have a well-defined scheme or way of thinking in order to recognize opportunities and generate new initiatives.	1	2	3	4	5
I am able to *identify* resources in order to finance a new initiative.	1	2	3	4	5
I recognize how to *obtain* the resources to finance a new initiative.	1	2	3	4	5
I have methods to evaluate the cost-benefit of a new initiative.	1	2	3	4	5
Compeller. *Please circle the answer that best matches your experience.*	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am excited by the idea of monitoring the progress of a new initiative	1	2	3	4	5
I am able to identify what kinds of resources will be needed to start and sustain a new initiative.	1	2	3	4	5
I am able to clarify to my superiors what a new initiative means.	1	2	3	4	5
I am able to support a new initiative even when others say it can't be done	1	2	3	4	5
Risk Assumption.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Please circle the answer that best matches your experience.					
I lean more towards new high-risk initiatives.	1	2	3	4	5
I enjoy taking risks on new initiatives.	1	2	3	4	5
I am willing to take a chance on new initiatives with uncertain results	1	2	3	4	5

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