

# Startup company self-employment and entrepreneurial confidence through Capstone Design

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Entrepreneurially focused capstone design courses do not often result in students being self-employed full-time in a startup company formed around their project post-graduation. To address this, we have developed, implemented, and measured the impact of a new course at the Georgia Institute of Technology: CREATE-X Capstone Design. In an entrepreneurial cohort of teams, we provide extensive resources, require real, quantitative customer discovery and validation of a business thesis, provide the substantial and specific rewards and follow-on opportunities, and trust the students. Six of the 19 teams (32%) that participated in the course in AY'18-19 started working full-time for their startup companies during the summer of 2019. Further, teams in this course were 4.5 times more likely to win awards at the end-of-semester institute-wide Capstone Exposition. Students gain entrepreneurial confidence due to the process we teach them; surveys have shown that more than 85% appreciate the course model and would recommend it to a friend. This program represents one of the most exciting educational innovations on campus and has the broader potential to fundamentally impact engineering education in the United States and beyond.

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## Introduction

Across the United States, accredited undergraduate engineering programs commonly culminate in a capstone design course: an integrative course in which student teams synthesize solutions to open-ended, real-world problems.<sup>1</sup> Typically, in one or two semesters, the teams define a problem, plan their approach, propose creative solutions, analyze the solutions, produce or implement the solutions, and communicate them internally and externally. Projects are often sourced from industry partners<sup>2,3</sup> and have succeeded at large scale.<sup>4-6</sup>

In the past decade, a more recent trend is to include entrepreneurship as an end goal in capstone design. For example, since 2007, 45 colleges and universities with ABET-accredited engineering programs have been funded by the Kern Family Foundation to participate in the Kern Entrepreneurship Education Network.<sup>7</sup> Recent publications describe the implementation of these courses, which can include principles of lean startup-methodology for problem finding and customer discovery through lectures or homework topics, team participation in business plan competitions, and resulting in an impact across disciplines, including business students.<sup>8-12</sup>

What is less clear is the extent to which these courses foster startup company formation leading to self-employment post-graduation, or commercial viability of products pursued in the course for any significant

proportion of the teams. The most comprehensive study of this, with over 100 capstone program respondents, indicates that while 60% indicated that their institution has infrastructure in place to support students who develop their projects beyond the Capstone course, these projects are only continued “often” by 12%, or “sometimes” by 55%, after course completion.<sup>13</sup> The proportion of those that continue which are entrepreneurial in nature was not measured, nor was “continuation” defined.

To our knowledge, there is scant evidence of entrepreneurially focused capstone design courses which result—to any significant extent—in student teams being self-employed full-time in a startup company formed around their capstone design project post-graduation. Our work describes an implementation and preliminary results and impact of such a course: CREATE-X Capstone Design.

The CREATE-X Capstone Design course is one part of the Georgia Institute of Technology’s initiative to enhance undergraduate entrepreneurial confidence, called CREATE-X. CREATE-X is a visionary enterprise aimed at systematically nurturing *entrepreneurial confidence* as one of the signature attributes of Georgia Tech graduates. The broader goal of this initiative is to provide the knowledge, skills, abilities, and experiences that will give Georgia Tech graduates the confidence to actively create their own future. During the past several years, campus competitions, classes, and programs (e.g.,

InVenture Prize, Invention Studio, VIP Program) have significantly changed the undergraduate culture at Georgia Tech as it pertains to entrepreneurial activities.<sup>14-16</sup> However, the entrepreneurial confidence initiative is an opportunity to provide a *mentored pathway* to nurture this beginning and fully leverage and scale what we have learned to transform the undergraduate experience. The CREATE-X initiative is unique because of the following core philosophies: (1) students explore entrepreneurship through the ultimate experiential learning mode – launching their own startups with seed funding, legal assistance, and intensive coaching; (2) all key elements of CREATE-X are curricular—students receive credit that counts toward graduation, and (3) the emphasis in CREATE-X programs is on “Deep Startups”, which are startups that are likely to have long-term impact as opposed to short-term gain.

### Methods

In the CREATE-X Capstone Design course, student teams design and build prototypes of their invention ideas and explore whether there is a market demand and value proposition for them. This is done in a nurturing environment, with mentorship and financial support for these entrepreneurial teams, including relevant lectures catering to the needs of a startup. This one-semester course comprises students from four majors (ME, ECE, BME, and CS). Basic structure includes weekly mentor meetings, course lectures, reports and presentations, and an end-of-semester campus-wide exposition competition.

During the first week of the course, the students attend lectures where they are introduced to problem finding techniques, form teams of ~5 students, and are assigned a faculty mentor. Frequently, students attend the first day of lecture with one or two ideas, and subsequently, do a poor job honestly evaluating their ideas’ true market potential, even with direct feedback from a faculty mentor. Therefore, during the first week we introduce techniques for finding and vetting real-world, unsolved problems. Using homework assignments, each student defines 100 problems, requiring the students to think creatively and broadly. Later exercises help the teams combine their ~500 ideas and whittle the list down to the top 5 by assessing impact, analogues, and pain points.

Starting at the second week of the semester, a series of evidence-based entrepreneurship lessons are introduced in lecture, with associated assignments, covering topics such as business thesis, value proposition, market landscaping, customer discovery, minimum viable product, and go-to-market strategy. Each week the students attend one 50-minute lecture, and eight days later present a corresponding deliverable at a 30-minute meeting between their team and mentor. Most successful

teams in this course spend 10-20 hours per week per person outside of class time working on assignments and building prototypes. Their top 3-5 ideas are evaluated and evolve through these lessons, assignments, and mentor meetings.

Mentors are chosen for the course based both upon technical knowledge and entrepreneurial experience, as well as having the student’s best interests at heart. Good mentors frequently act like investors in that they have the students try to convince them that their idea solves a real and useful problem. Weekly deliverables help facilitate productive conversations, asking specific questions such as:

- *In one sentence (<10 words), what is the problem being solved?*
- *Why do you think that this problem has not been solved?*
- *Who should/could you talk to test the feasibility of the problem?*
- *Create your startup’s business thesis following the form “X will buy Y because of Z.”*

After the first third of the course is complete, the students write a report and give a presentation where they give a business overview and include a ‘deep dive’ into the team’s target market. In this deep dive they answer questions such as:

- *How big is the target market?*
- *Who are the major companies in the space today?*
- *What do customers use today to solve these problems?*
- *What would be the distribution channels for your startup’s product?*

The second third of the course introduces additional relevant startup topics, such as intellectual property, financing a startup, and agile/scrum project management while transitioning to design and manufacturing processes. During this period, the students work with their mentors to develop design requirements and constraints. Here, they develop concepts, CAD models, and mock-up hardware. In this portion of the course, the students are also encouraged to pursue bench-level experiments to prove that their design concepts can technically function. At the end of the second third of the course, the students submit a second report and give their second presentation where they cover all the progress they have made to date.

The final third of the course is dedicated to prototyping. Each team is reimbursed up to \$1,000 (increased upon reasonable justification) to spend on materials, supplies, and other relevant business expenses. Students often use campus makerspace facilities (e.g., Invention Studio, the Hive, etc.) to construct their prototypes. At the end of the semester, the students give a final, cumulative report to the class and present their work at a university-wide senior design Capstone

Exposition (for all capstone projects), and compete for cash prizes and recognition. The best team from the course is awarded admission to the CREATE-X Startup Launch program (campus-wide, typically only 10% of direct applications are accepted).

The critical course elements that we hypothesize contribute to achieving our goal of startup company self-employment are as follows: (1) cohort effect, with entrepreneurial teams isolated from non-entrepreneurial teams; (2) providing vast resources (money, office and fabrication space, mentoring, time) so that the only limitation is the students' ideas and energy; (3) requiring legitimate, honest customer discovery and validation of the business thesis and value proposition; (4) making clear the substantial and specific rewards and follow-on opportunities for incubation, funding, mentorship, competition to continue under university auspices and beyond; and (5) trusting the students, empowering them (e.g., to spend the money as they see fit), and explicitly encouraging them to take a chance on their ideas to make an impact on the world.

Attributes which are not unique to this course but rather serve as requisite infrastructure include: student ownership of intellectual property rights, multi-disciplinary team opportunities, evidence-based entrepreneurship lecture content, accessible makerspaces and machine shops, and end-of-semester university-wide expositions.

## Results and Conclusions

Since launching the CREATE-X Capstone Design course in Fall 2018, the course has experienced monotonic growth in student participation (See Fig. 1). The initial enrollment in Fall 2018 was 36 students. This formed 7 interdisciplinary teams that spanned the majors of ME, CS, and BME. In the following semesters, ECE was added and BME voluntarily paused (to rejoin in Fall 2020 following curriculum changes). The total enrollment for the current Spring 2020 semester is 108 students comprising 20 interdisciplinary teams.

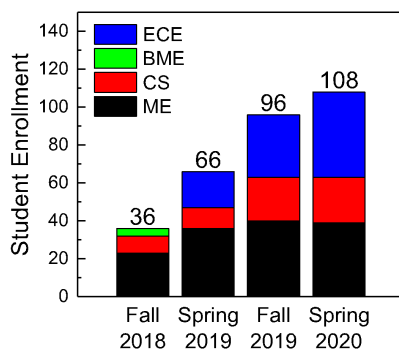


Fig. 1. Student participation in the CREATE-X capstone design course over four semesters, shown by major.

At the end of the semester, CREATE-X Capstone design teams present their work at the university-wide exposition. CREATE-X teams were 4.5 times more likely to win awards at the exposition as compared to the population of all teams. CREATE-X teams have won awards including: *Best Interdisciplinary* (Fig. 2) and *Best Mechanical* in both Spring 2019 and Fall 2019. This shows an external validation of the success of this approach to the capstone course as teams are judged alongside all other Georgia Tech capstone projects by external visitors including corporate executives.



Fig. 2. CREATE-X Capstone Design team winning *Best Interdisciplinary* award at the Capstone Exposition, Fall 2019.

The outcome of the class is reinforced by comments from students at end of semester surveys. For example, SmartEvals comments from anonymous students in Fall 2018 CREATE-X capstone design include the following quotations for various different anonymous students:

*"This course has potential to really transform education. I often hear people saying how pointless university is becoming and how you never really use what you learn in school. This made going to university worth it because it was the only class to actually transform how I see problems in the world and how I can actually use the knowledge gained in school to make a difference."*

*"I had an awesome time in this course and I'm really excited to see how it transpires in the future for other students and what comes out of it. I feel more motivated to become an entrepreneur and I see the world through a different lens. I'm really thankful for the effort put into this class by the creat e-x group and I hope to work with them again in the future years to come!"*

*"The freedom and control each team had on their project was a nice change and also humbling. Not being micromanaged is eyeopening to how you actually operate. I was so use to planning according to a rubric and knowing exactly what I had to do but this class shook that up a bit and made me actually think critically."*

Students consistently report two outcomes: (1) they now have the ability to converse with people outside of their social circles, which is useful as they advance their career searches and build professional networks. This is

because they are required to discuss their business idea with many potential customers; (2) they gain entrepreneurial confidence due to the process we teach them. Surveys have shown that more than 85% of our students appreciate the course model and would recommend this course to a friend.

Six of the 19 teams (32%) that participated in CREATE-X Capstone in Fall 2018 and Spring 2019 started working full-time for their startup companies in the summer of 2019 in the CREATE-X Startup Launch program post-graduation. The Startup Launch program provides \$4,000/team (with the option for \$20,000 in exchange for 7% equity), office space, mentorship, demonstration opportunities, investor interviews and entrepreneurial mentors. In contrast, only 1% of the non-CREATE-X Capstone teams participated in Startup Launch (2/143 non-CREATE-X teams). The Startup Launch program has collectively fostered the founding of 159 companies by undergraduate students in the past four years, valued at collectively more than \$310M.

These six companies, self-employing their founders as of summer 2019, are as follows:

1. *Backbar Solutions: automated cocktail dispensing for high volume bars*
2. *Next Century Farms: automation for farmers to remotely monitor conditions inside of poultry houses*
3. *Aerodyne Technologies: aerodynamic attachment for tractor trailers*
4. *Nix: vape technology to quit vaping*
5. *Edicratic: crowdsourced essay editing platform*
6. *Handld: bicycle-car collision detection*

These teams inspire successive generations of Capstone teams through guest lectures and publicity—they are “rock stars” on campus.

### Growing pains

As with any new and growing program, we must overcome barriers including bureaucracy, funding, leadership, and institutionalization. To maintain the culture of the course while growing enrollment at one of the largest engineering schools in the country, we must recruit new departments to participate, and they have to contribute mentors who are seasoned entrepreneurs. Departments must provide financial support, departmental leadership, and teaching credit for mentors. In addition, at \$1,000 per team, finding entrepreneurial alumni and foundations who donate because they want to see more students succeed like themselves is a development challenge.

We are optimistic that the “purpose-driven” focus of this course enables academic department to surmount barriers to offering interdisciplinary and flexible course options. We are enthusiastic that the CREATE-X program, recognized campus-wide in 2019 through the

Georgia Tech *Curriculum Innovation Award*, represents the most exciting educational innovation on campus, and has the broader potential to fundamentally impact engineering education in the United States and beyond.

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