Decades of Alumni: What Can We Learn from Designing a Survey to Examine the Impact of Project-based Courses Across Generations?

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ABSTRACT

For over half a century, the "Project-Based Engineering Design Innovation & Development" (ME310) course has engaged Stanford University graduate students in industry-sponsored projects focusing on various phases of integrated design thinking through engineering fabrication. In recent decades, in synchrony with the growing demands of today's design engineering professionals, these projects have advanced an innovation focus both in process and outcome. Yet, evidence of how the course experience has contributed to entrepreneurial interests lies primarily in anecdotal examples and stories about the career trajectories of former students and how they have gone on to leverage their prototypes into commercial products. As a result, this research paper examines the impact of intensive course-based design experiences such as ME310 on the entrepreneurial outcomes and innovation behaviors of alumni through the design and implementation of an alumni survey aimed at gathering feedback and input into specific curricular efforts.

Administered to over 800 alumni covering a 25 year span from 1992-2018, the ME310 Alumni Survey included demographic questions and items organized around three areas: 1) educational background and career decisions such as first job after completing the course and current or most recent job; 2) attitudes towards memorable and meaningful experiences in the course including key projects, assignments, and skills and abilities acquired; and 3) entrepreneurial outcomes and self-efficacy measures focusing on innovation and design thinking. This focus on the course experience as the unit of analysis resulted in new insights and a deeper understanding of intended and unintended learning outcomes as informed by the responses of former students based on their career choice pathways in a variety of industry sectors and the 'lessons learned' and takeaways from the course and reported over time. This longitudinal approach to course alumni surveys can be adapted for and implemented in other courses and environments for purposes of curriculum refinement and quality improvement in order to accommodate the needs of key stakeholders including the faculty and teaching team, alumni, and current and future students.

1. BACKGROUND/LITERATURE REVIEW

It is well recognized that the engineering degree prepares graduates to work and thrive in a diverse array of fields within and beyond engineering [1-3]. These decisions about what job options to pursue often occur again and again throughout one's professional trajectory, from the first job after graduation to the choices that are made on the basis of changing career interests and unexpected opportunities.

Prior research on career pathways in engineering have often tracked where students in engineering majors go, identifying the factors that influence persistence and retention [3]. Another category of research focuses on the pathways of alumni of engineering programs such as alumni of bachelors or masters degree programs at the national level [1] or the graduates of specific majors who are contacted through surveys conducted by departments for purposes of ABET accreditation, evaluation, and program improvement. The career decisions of particular demographic and interest groups also warrant attention [4]. The methods typically used in these studies include, for example, structured interviews and surveys that prompt current majors, graduating seniors, or alumni some number of years after receiving their undergraduate or graduate degrees to reflect on the impact of their educational experiences on current career decisions and plans [5-6]. Both cross-sectional and longitudinal approaches are common in studies employing mixed methods designs [7].

While surveys of alumni are often conducted by university associations for purposes of staying connected, the current study takes a unique look at focusing on alumni from a single course, “Project-Based Engineering Design Innovation & Development” (ME310). This graduate level class has been taught in the department of mechanical engineering at Stanford University for over half a century and has engaged students in an immersive yearlong (nine months) course sequence with industry-sponsored projects focusing on various phases of integrated design thinking through engineering fabrication. Through transitions in the teaching team, project sponsors, and paralleling the evolution in modern and innovative engineering practices and changing societal needs, ME310 maintains a pedagogical emphasis on helping student teams meet defined process milestones in order to produce a refined functional prototype that is presented to the broader design community at the end of the year [8]. In ME310, many alumni, as practicing professionals in industry, come back to the course to serve as project advisors, sometimes project sponsors, guest lecturers and reviewers, and serve to strengthen the social networking that can often lead to job leads and employment opportunities.

One component that has expanded over the last decade particularly in the ME310 course projects is an emphasis on innovation both in process and outcome. Correspondingly, the importance of entrepreneurship education in engineering has been well established [9-11]. This growing body of literature has focused on the development of innovation skills in engineering students [12-14] and early career engineers [15].

This study was guided by the research question: ***What is the impact of intensive course-based design experiences on the entrepreneurial outcomes and innovation behaviors of alumni?*** The course “Project-Based Engineering Design Innovation & Development" (ME310) was used as a testbed to inform the development of a typology that may help explain career pathways involving or avoiding design and research and development (R&D). This typology will be used to identify differences in job settings, functions, and activities of the course alumni as well as perceptions of self-efficacy related to engineering tasks, design thinking, innovation and entrepreneurship.

2. METHODS

2.1 Description of the Study Subjects

Working with the Alumni Relations and Student Engagement office in the school of engineering and the university's institutional research office, a list of around 800 ME310 alumni who completed the yearlong ME310 A/B/C sequence in its entirety was generated. In total, 301 student alumni participated in the online survey, yielding an overall response rate of 41 percent. Only completed survey submissions are included in our analysis resulting in an effective sample size of 273. These survey respondents are evenly distributed across year groups and clusters. The gender distribution showed that 78 percent of the survey participants who reported their sex are male and 22 percent are female. The survey was deployed in the latter half of July 2020.

Table 1: Description of the ME310 course alumni survey respondents by gender and race/ethnicity

Variables	N=273	Percent
Gender		
Females	58	21.2%
Males	208	76.2%
Missing	7	2.6%
Race/Ethnicity (Mark all that apply)		
American Indian or Alaska Native	2	0.7%
Asian or Asian American	110	40.3%
Black or African American	10	3.7%
Hispanic or Latino/a	22	8.1%
Native Hawaiian or Pacific Islander	1	0.4%
White	135	49.4%
Other	4	1.5%
I prefer not to answer	5	1.8%
Missing	7	2.6%

2.2 Survey Design and Key Variables

The research team worked closely with the course teaching team to align the pedagogical goals, milestones, strategies, and assignments to the survey measures and questions. The survey instrument addressed three general topics related to: 1) education and career pathways; 2) innovation, entrepreneurship, and design self-efficacy measures; 3) the learning experience of the course. This paper primarily addresses the first two areas.

Education and Career Pathways (31 survey items)
One major challenge faced by our research team was how to efficiently ask about the career paths and plans that students have pursued since graduating from Stanford, especially given the 25 year time span of our alumni. Survey participants were asked about their first job after completing ME310, and their current or most recent employment status. Their responses to the "first job" question provided insights into the changes in various industries and what opportunities graduates at that time may or may not have had at that time. In contrast, the "current job" question provides some insights into how their career paths as mechanical engineering graduates may have evolved over time, even though we only asked about two time points and not every job they have had since the start of their post-Stanford career.

Self-Efficacy Measures (47 survey items)
Self-efficacy has been defined as one's own beliefs in their ability to perform a specific task or action [16]. The framework of Social Cognitive Career Theory [17-18] has informed prior studies examining the factors that contribute to students' confidence in their career decisions especially in relation to engineering, innovation [5, 13-14], entrepreneurship [19], and design thinking [20]. For entrepreneurial self-efficacy, two sub-dimensions of the original six dimension scale developed by [19] were included focusing on: 1) identifying opportunities; and 2) dealing with ambiguity and unexpected challenges. These sub-dimensions were selected because they were most relevant to the ME310 student population and also because the reported mean scores showed the greatest statistical difference between entrepreneurship and non-entrepreneurship students in the original study using this scale [19]. Table 2 describes the self-efficacy measures included in this survey instrument.

Table 2. Descriptions of key self-efficacy and innovative behavior variables

Self-Efficacy Measure	Description	Measurement Scale
Innovation (ISE.5) [5 items]	Confidence in one's ability to innovate, i.e. to engage in specific behaviors that characterize innovative people.	Five-point Likert scale: from "Not confident" (0) to "Extremely confident" (4).
Engineering Task (ETSE) [4 items]	Confidence in one's ability to perform integral technical engineering "tasks" such as "analyzing the operation or functional performance of a complete	Five-point Likert scale: from "Not confident" (0) to "Extremely confident" (4).

	system."	
Entrepreneurial (ESE) [10 items]*	Confidence in one's ability to pursue a new venture opportunity, representing two dimensions related to developing "new product and market opportunities" and "coping with unexpected challenges."	Five-point Likert scale: from "Not confident" (0) to "Extremely confident" (4).
Design Thinking (DTSE) [6 items]	Confidence in one's abilities around empathy, reframing, ideation, prototyping, and testing.	Continuous scale: from "Cannot do at all" (0), "Moderately can do" (50), to "Highly certain can do" (100).
Innovative Behavior (IB) [6 items]	Individual behaviors that contribute to a collective innovation process focusing on idea generation, coalition building, idea realization and transfer/diffusion.	Five-point Likert scale: from "Never" (0) to "Very often" (4).

3. RESULTS

The results are organized around two areas: first, we examine the characteristics of the current jobs held by the alumni respondents. We then consider how innovation, entrepreneurial, engineering and design thinking self-efficacy measures vary across the sample, outlining three approaches to viewing the sample.

3.1 Overall Respondents Regarding Current Job

Some 200 of the 273 respondents reported their current job location. More than half (58%) of the 200 identified being located in California, of which 83% specified being in the San Francisco Bay Area (see Figure 1). This high concentration of alumni in the Bay Area is not surprising given Stanford's close proximity to Silicon Valley with ready high tech corporate and start-up job opportunities for alumni.

Just over 15% of those who reported their job location are working outside of the United States. Given that the survey was administered in July 2020 during the middle of the global pandemic, it is possible that the location of the current job may not necessarily reflect the alum's actual residence, both within the United States and internationally.

Fig. 1. Job locations of alumni survey respondents who report California as their current or most recent job location (N=96)

Figure 2 represents the current industry sector that best aligns with the current or most recent job. Some 17 percent of the survey respondents are working in the industry sector of Professional and Scientific Service (this becomes 23% when we remove the respondents who did not reply to this survey question (about one quarter of the respondents). The second top category "Other" includes write-ins such as academia, real estate to consumer products.

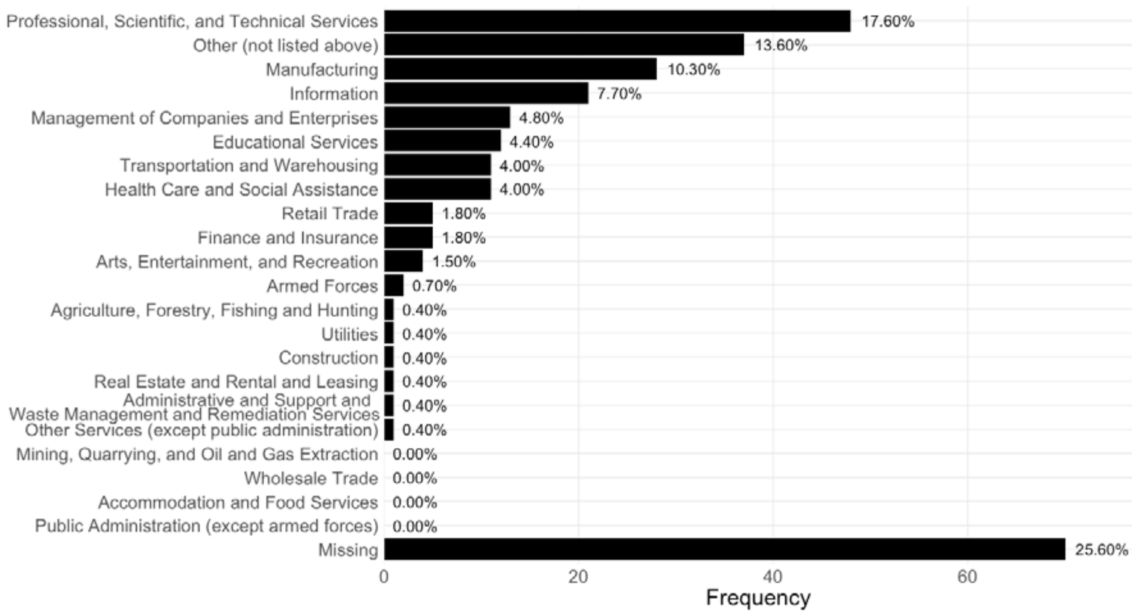

Fig. 2. Current industry sectors for current or most recent job (N=273)

Table 3 shows that at the time of the survey, some 35.9 percent of course alumni were working in medium-to-large firms (49% when missing responses are excluded), and 14.7 percent were working in small firms (20% without missing responses). Another 13.2 percent are founders of a for-profit organization. In comparison, the recent college graduates from the Engineering Majors Survey (EMS 3.0) study, a longitudinal cohort representing undergraduate engineering students enrolled at 27 universities across the United States, [5, 12, 15] paints a slightly different picture of where those individuals were working in the one to two years post- graduation -- nearly 70 percent of the EMS graduates were in medium-to-large firms and virtually none of them were founders. Another difference we see in these two groups is that some 5.5 percent of the course alumni are working in a university setting, most likely reflecting graduate work and the pursuit of an academic faculty or staff pathway.

Table 3. Organizational role best aligned with current or most recent job

Organizational Role (current or most recent job)	ME310 Course Alumni	
	Respondents	Percent
Employee for a medium- or large-size business	98	35.89%
Employee for a small business or start-up company	40	14.65%
Founder/co-founder of your own for-profit organization	36	13.18%
Faculty member or educational professional in a college or university	15	5.49%
Employee for a non-profit organization (excluding a school or college/university)	4	1.47%
Employee for the government, military, or public agency (excluding a school or college/university)	4	1.47%
Founder/co-founder of your own non-profit organization	1	0.37%
Teacher or educational professional in a K-12 school	1	0.37%
Missing	74	27.11%
Total	273	100.00%

Lastly, the alumni survey asked respondents how they would classify their current or most recent job and their first job after ME310. Respondents were asked to "mark all that apply" among a list of 16 functions or business units. As noted in Figure 3, 42 percent of the respondents reported working in Research and Development (R&D) and Design. Their current involvement in these functions is down from their first jobs, when nearly two thirds of the respondents reported involvement in these two functions.

Nearly one third (30.8%) of the alumni reported involvement in project management and nearly 19 percent in technical project management. The 30 percent number is nearly unchanged from their first jobs but the technical management involvement increased by a factor of nearly 6 between first and current or most recent jobs. This group of ME310 alumni reported first jobs that involved significantly more R&D and Design than our comparison group of EMS3.0 graduates [12, 15], which is perhaps not surprising given that the ME310 alumni completed a mechanical engineering masters degree that included an intensive 9-month course sequence devoted to design and product innovation. This is in contrast to the EMS 3.0 cohort which was primarily comprised of bachelor's degree graduates from a variety of engineering majors.

The three job functions that saw notable increases in respondent involvement between the first post-ME310 job and current jobs are Marketing/Public Relations, Sales and Technical Management (suggesting migration into these functions). The three job functions that saw notable decreases in respondent involvement were Design, R&D and Production/Manufacturing (suggesting migration out of these functions).

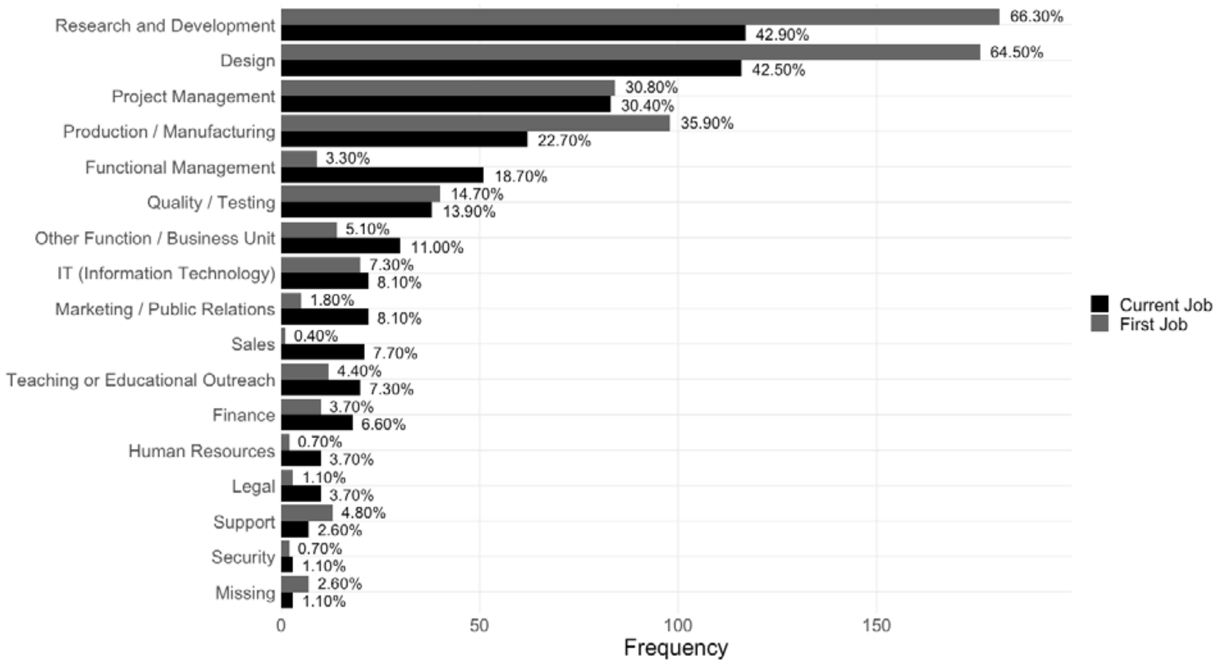

Fig. 3. Respondents reporting various job functions of their current job and first post-ME310 job (N=273)

3.2 A More Detailed Look at the Course Graduates

In our prior work, we have examined how measures of innovation vary across different demographic groups, and the influencing factors that contribute to its development. The longstanding pedagogical emphasis on innovation in the course looking at graduates' innovation self-efficacy as related to job function may be another piece of the puzzle of understanding career pathways. Also, given that we are studying individuals who completed graduate degrees in mechanical engineering, the other self-efficacy measures, particularly engineering task self-efficacy, may also be relevant. Table 4 describes these self-efficacy scores from the course alumni.

Table 4. ME310 course alumni survey self-efficacy and innovative behavior measures

Self-Efficacy Measure	ME310 Course Alumni					
	Overall Survey Total N=273		Leadership Comparison N=218		Organization Comparison N=174	
	M	(SD)	M	(SD)	M	(SD)
Innovation (ISE)	2.98	(0.58)	3.01	(0.58)	3.01	(0.59)
Engineering Task (ETSE)	2.93	(0.71)	2.98	(0.72)	2.92	(0.76)
Entrepreneurial (ESE)	2.68	(0.64)	2.74	(0.61)	2.77	(0.62)
Design Thinking (DTSE)	78.41	(12.28)	78.76	(11.72)	77.95	(11.74)
Innovative Behavior (IB)	2.82	(0.70)	2.87	(0.69)	2.93	(0.68)

A more detailed analysis of these self-efficacy measures led to the development of three approaches or lenses to better understand how an intensive project-based course experience such as ME310 could inform and guide alumni to different career paths and perhaps even different work environments.

3.2.1 LENS #1: Examining Levels of Leadership in Current Job

Varying levels of leadership responsibility can result in differences in Innovative Behaviors [12]. One third of the early engineering graduates (EMS3.0) in [12] reported leadership responsibilities, in contrast to 93 percent of the course alumni survey. This is perhaps unsurprising given the maturity of the ME310 course alumni sample. By grouping the course alumni into two groups representing high and low levels of leadership, these groups were significantly different at the $p<.05$ level on Entrepreneurial Self-Efficacy (see Table 5).

Table 5. Comparisons of levels of leadership among course alumni

Self-Efficacy Measure	ME310 Course Alumni				
	Low Leadership Level N=15		High Leadership Level N=203		p-value
	M	(SD)	M	(SD)	
Innovation (ISE)	2.84	(0.64)	3.02	(0.58)	0.251
Engineering Task (ETSE)	2.87	(0.65)	2.99	(0.72)	0.539
Entrepreneurial (ESE)	2.41	(0.64)	2.76	(0.61)	0.031*
Design Thinking (DTSE)	77.19	(11.27)	78.88	(11.77)	0.591
Innovative Behavior (IB)	2.00	(0.75)	2.93	(0.64)	<0.001***

Significance levels: p<0.05*, p<0.01**, p<0.001***

3.2.2 LENS #2: Differentiating by Organizational Roles and Types

Different types of organizations may also have an impact on Innovative Behavior. Following [12], we made this comparison with our course alumni population while also adding another comparison group---those who were founders of for-profit organizations (N=36). The self-efficacy measures were compared for each of these three groups and described in Table 6.

Table 6: Comparisons of organizational roles and types among course alumni

Self-Efficacy Measure	ME310 Course Alumni			
	Small Organization N=40 M (SD)	Medium+Large Organization N=98 M (SD)	For-Profit Founder N=36 M (SD)	F Statistic
Innovation (ISE)	3.07 (0.63)	2.95 (0.55)	3.11 (0.62)	F(2, 271) = 1.319
Engineering Task (ETSE)	3.01 (0.79)	2.87 (0.74)	2.98 (0.76)	F(2, 271) = 0.640
Entrepreneurial (ESE)	2.81 (0.64)	2.67 (0.62) [a]	2.98 (0.52) [a]	F(2, 271) = 3.680*
Design Thinking (DTSE)	77.5 (12.7)	77.8 (11.8)	78.7 (10.8)	F(2, 271) = 0.153
Innovative Behavior (IB)	2.88 (0.77) [c]	2.85 (0.65) [bc]	3.26 (0.55) [bc]	F(2, 271) = 5.954**

Significance levels: p<0.05*, p<0.01**, p<0.001***

[a] Group: Founder > Group: Medium + Large Organization *; [b] Group: Founder > Group: Medium + Large Organization **; [c] Group: Founder > Group: Small Organization *

Perhaps unsurprising is the finding that the for-profit founders reported significantly greater Innovative Behaviors than either those working in Small ($p<.05$) or Medium + Large ($p<.01$) organizations. There were no significant differences in Innovative Behaviors for those working in small and medium + large organizations. For the self-efficacy measures, the only significant difference was seen in Entrepreneurial Self-Efficacy, where the 36 founders reported significantly higher levels of self-efficacy than those working in Medium + Large organizations ($p<.05$).

3.2.3 LENS #3: Using Job Function to Describe Career Pathways

This third approach examines the emphasis on Research and Development (R&D) and Design and their presence or absence in the functions of the first job the alumni took after taking ME310e and their current or most recent job. Both of these areas are important components of the course which is why they are explored in Table 7, highlighting the relationship between current and prior job functions to describe a typology of five groups.

Table 7. ME310 Survey respondents grouped by involvement in R&D and/or Design (N=273)

Group ID	Group Description	N *(total=273)*	Percent
1	Current work heavily invested in R&D and Design, prior work invested in one or both	92	33.7%
2	Current and Prior work heavily invested in R&D, weaker connection to design	24	8.8%
3	Current work heavily invested in Design, past work may have been connected to design and/or R&D	25	9.1%
4	Current work not invested in R&D or Design, prior work in R&D, and/or maybe design	99	36.3%
5	Current work not invested in R&D or Design, prior work not in R&D or Design	33	12.1%

The five groups described in Table 7 led us to explore the relative differences in self-efficacy scores among the five groups listed in Table 8.

With respect to Innovative Behavior, Group 4 is an outlier with a relatively low mean as compared to the other groups whose means are fairly comparable. Group 4 exhibits less innovative behavior. All five groups have comparable means for Innovation Self Efficacy and Entrepreneurial Self Efficacy. With respect to Design Thinking Self Efficacy, the mean exhibited by Group 1 is higher than for Group 4 (with the difference approaching significance. For Engineering Task Self Efficacy, the mean for Group 1 is significantly higher than for Group 4 ($p<.05$), Group 5 ($p<.001$), and approaching significance for Group 3.

Table 8. Differences in self-efficacy scores of career pathway groups

Self-Efficacy Measure	**Group 1** N=92 **M (SD)**	**Group 2** N=24 **M (SD)**	**Group 3** N=25 **M (SD)**	**Group 4** N=99 **M (SD)**	**Group 5** N=33 **M (SD)**	**F-statistic**
Innovation (ISE)	3.08 (0.59)	3.02 (0.75)	2.94 (0.51)	2.92 (0.53)	2.89 (0.58)	F(4, 269) = 1.224
Engineering Task (ETSE)	3.20 (0.57)[ab]	2.83 (0.71)	2.79 (0.75)	2.88 (0.66)[a]	2.56 (0.94)[b]	F(4, 269) = 6.344***
Entrepreneurial (ESE)	2.78 (0.61)	2.70 (0.67)	2.68 (0.76)	2.59 (0.61)	2.69 (0.66)	F(4, 269) = 1.011
Design Thinking (DTSE)	80.15 (11.49)	80.19 (11.94)	75.89 (13.12)	78.18 (12.31)	74.86 (13.50)	F(4, 269) = 1.563
Innovative Behavior (IB)	2.98 (0.67)[a]	2.92 (0.64)	2.79 (0.57)	2.61 (0.70)[a]	2.95 (0.78)	F(4, 269) = 4.021**

Significance levels: p<0.05*, p<0.01**, p<0.001***
[a] Group 1 > Group 4 **
[b] Group 1 > Group 5 ***

Overall, we begin to see a few trends emerge. For Group 1, where the work of R&D and Design are combined, greater confidence in engineering tasks (ETSE) is exhibited, relative to all the other groups, except Group 2 where the focus is just on R&D). Based on [12], we had expected that Group 2's focus on R&D would result in greater Innovative Behavior than those focused on design (Group 3). However, this was not the case with the course alumni. Only Group 4, whose work does not currently involve R&D or Design despite having prior experience, was represented as an outlier and reporting less innovative behavior.

Lastly, there are interesting findings to follow up on for both Groups 4 and 5. These groups include those who have made a significant investment in graduate coursework involving design and innovation, however, the current trajectory of their career paths has had little involvement in these functions.

4. DISCUSSION AND IMPLICATIONS

These results from a unique survey spanning 25 years of alumni from a graduate course sequence demonstrate how the graduates of ME310 have built careers in a variety of directions and are scattered around the globe. There is no single pathway or even dominant industry sector into which these graduates migrate. Some stay highly technical throughout their post-graduate work, whereas others turn to less technical work immediately after graduation.

When we look across the 273 alumni using the three lenses presented above – high leadership vs. low leadership responsibility, type of organization, and presence of R&D and/or Design in their job function – we see some similarities and differences among these graduates.

Among the similarities are comparable levels of Innovation Self-Efficacy and Design Thinking Self-Efficacy no matter what subgroups are created. It seems that in whatever professional pursuits these graduates have undertaken, their confidence in skills related to being innovative (e.g., generating new ideas by observing the world, connecting concepts and ideas that appear, at first glance, to be unconnected) and in design thinking (e.g., sensing how another person feels and what they might be thinking, building a prototype solution that satisfies user needs) are comparable across the cohorts. Developing these types of skills (and associated confidence levels) represent exactly what the ME310 course is designed to do; this suggests that ME310 may play a role in providing students with a solid foundation of thinking creatively and innovatively that can be built upon in a variety of fields and be strengthened and augmented over one's career.

We do see differences in levels of Engineering Task Self-Efficacy (ETSE). Those with the "double-whammy" of first and current work involving both Research & Development (R&D) and Design (Group 1 in Table 8) exhibits the greatest level of Engineering Task Self-Efficacy, especially when compared with those whose current work involves no R&D or design and little design in their first jobs (Groups 4 & 5). This suggests that for this "double-whammy" group their past and current work has remained technical in nature, requiring continued attention to technical learning and challenges over time. Interestingly, while this "double-whammy" group stands out for its high level of ETSE, the Innovative Behavior mean for Group 1 is comparable to Group 5 and significantly higher than Group 4. One might expect that the R&D component of Group 1's work would involve "enhanced" innovative behavior in developing new technologies and processes but this is not borne out with our results.

These results suggest that those whose job function involves more of a leadership role (Table 5), are working in smaller organizations and/or are a founder (Table 6) are exhibiting more Innovative Behavior (such as searching out new technologies as part of idea generation, or promoting and championing ideas to others, as part of coalition building). Higher levels of leadership may offer more freedom and autonomy to engage in innovative behaviors. This interpretation may also apply to working in smaller organizations, as well as individuals needing to wear several and a variety of different hats. All of this suggests a challenge for larger organizations that are keen on inspiring more of their workers to engage in innovative behaviors.

These results also suggest that those whose work involves leadership and/or are founders exhibit higher levels of not only Innovative Behavior (compared to those in lesser-leadership roles, and those in medium and large organizations), but also greater Entrepreneurial Self-Efficacy (ESE). This means that they are more confident in, for example, getting concepts to market in a timely manner, determining what the business will look like, and working productively under continuous stress, pressure and conflict. This points to the distinction between being innovative and being entrepreneurial; recall that Innovation Self-Efficacy did not vary across the sample, but here we see variations in ESE. There may be other skills and abilities that engineering education is more-or-less successful in helping students learn when taking ideas to market.

Our message to educators is largely a reminder to help your students, especially those in a single discipline (in our case, mechanical engineering), realize that their engineering skills and abilities can lead them to a wide variety of industries, with jobs that are highly technical (drawing directly from their school-learned technical knowledge) or not-too-technical. Furthermore, the types of job our students get right out of school are not likely to be the jobs they retrain for during the course of their careers—people change industries, company size, and even the functions that make up their work.

In the classroom, this reminder can come in the form and types of examples students are given, the design prompts they are challenged with, and the guests that are brought into the classroom to talk about "engineering grads and work in the real world." It can also come through partnerships with campus career centers that offer professional development workshops and the types of internships students are encouraged to take (and reflect on).

5. LIMITATIONS AND FUTURE DIRECTIONS

Our survey asked respondents about their first position after completing ME310 and their current position (this choice in survey design was made to limit the length of the survey). As a result, details in career choices are missing in our dataset between those two time points (which for some respondents was only a few years apart and for others, many years). We are in part addressing this limitation with interviews in order to better understand the roles of influencers in career decisions. Some 39 interviews, based on individuals who exhibited high levels of ESE, ISE and/or were founders and intrapreneurs have been conducted by [21]. They are scattered across the five groups described in Tables 7 and 8 as follows: Group 1 (N=16), Group 2 (N=5), Group 3 (N=4), Group 4 (N=11), and Group 5 (N=3).

The first analysis of this qualitative dataset looked at the specific professional and academic learning experiences of the interviewed ME310 alumni engineers that contributed to their innovative and entrepreneurial confidence and behavior. The analyses resulted in identifying four categories consisting of 15 sub-factors that promoted ESE and ISE, which can be nurtured in educational settings. Based on these findings, several implications for engineering educators were derived in order to foster entrepreneurial and innovative behavior and action in engineering curricula by paying particular attention to the cognition and belief systems of the student engineers. [21] Future analyses of these interviews will look intentionally at how career development varied across these five groups.

While our survey responses were well distributed across graduation dates, our analytical approaches to identify subgroups (based on industry, leadership, etc.) have not explicitly considered how those course alumni who graduated in 1992 might be different from those who graduated in 2018 in terms of industry trends and available opportunities, the state of the economy, etc. The engineering world of 1992 is pretty different from the engineering world of 2018. In subsequent regression modeling (as described below), year of engagement in ME310 (taken as a proxy for when an individual began their engineering career) will be incorporated.

Among our future research projects related to our ME310 survey are:

- Regression modeling using Innovative Behavior (IB) as the dependent variable (patterned after the work of [12, 15]) to further study what work environment and education background factors may prompt IB.
- Comparative work, looking at actual work activities and tasks (a part of the survey not described in this paper) among the various ME310 subgroups defined in this paper, and between ME310 graduates and early career engineers (as studied in EMS3.0) to look at how work might change over a career.
- More detailed job function (e.g., R&D, Design, etc.) mapping, from first to current job. Our current groupings (1-5) begin to do this to some extent, but this approach does not fully capture the expansion, reduction, and transfer of functions reported by each individual between first and current jobs. This more detailed analysis of job functions, in combination with job activities and tasks, will allow us to paint a more comprehensive picture of professional work and career pathways of those educated as engineers.
- Statistical analyses of the other parts of the survey related to the ME310 course experience, particularly as related to impact on career directions and self-efficacy measures.

Among our future research projects related to engineering pathways, inspired by our study of the ME310 alumni cohort, are questions related to:

- *How do these findings about graduates from a 3-quarter long graduate course sequence apply to other course-intensive graduate engineering courses? How might the survey instrument be improved?*

- *How much did ME310 and the graduate school experience influence career paths, vs. "being set" even upon entry into graduate school? What other "beyond school" factors are in play at the graduate level?*
- *What are strategies that large engineering-based companies can use to inspire innovative thinking and behaviors among their engineers? Are entrepreneurial behaviors also desirable?*

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