Getting ”There”: Understanding How Innovation and Entrepreneurship Become Part of Engineering Education

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Abstract

The investments made to change engineering education in the US are immense, as anyone who has perused NSF's annual reports quickly realizes. As Giersch notes (2014), significant change requires attention to at least two dimensions: equipping individual faculty with effective tools and approaches, and working on an institutional level to scale and sustain improvement. How to operationalize this conceptual understanding is still elusive, however – both individuals and organizations tend to resist change, and the prospect of doing both simultaneously is daunting.

This paper presents the results of new research on a national network of universities engaged in an effort to embed innovation and entrepreneurship in undergraduate engineering education, in an attempt to "look under the hood" at the process of change. While innovation and entrepreneurship serves as the primary lens for this research, the lessons learned may be of value to engineering education transformation more generally, and perhaps also to transformation in other disciplines.

Previous articles examining the work of this network have summarized the types of activities that have been initiated at the institutions; this paper will update that information and move beyond to examine the work of change itself, with particular focus on these dimensions:

- Change as a team effort: How do team size and composition impact the effectiveness of transformation initiatives? How can teams organize their work to maximize their chances of success?
- Leading change: How do leaders of teams working in these initiatives approach their work? Are there particular leadership attributes or attitudes that can accelerate change?
- The context of change: What impact do institutional context factors, such as college or university leadership transitions, have on engineering education transformation efforts?

In addition to presenting the results of research currently underway, the paper will suggest areas in which additional research is needed.

The research presented here is not focused on the ways in which innovation or entrepreneurship are or should be taught – only with the question of how I&E offerings become embedded in the engineering education experience.

Introduction

As the Greek philosopher Heraclitus proclaimed, "change is the only constant." In an increasingly complex global market, organizations are driven to change for survival and success (Isaksen & Lauer, 2002). Higher education institutions experience the same pressures to continually evolve in response to internal and external demands. The number of enrollments in

higher education is on the rise, and students and faculty are travelling further in search of new experiences and opportunities for impact (Ashwin, 2015). A recent report also shows that students themselves are changing: The "non-traditional" student (e.g., working full-time, delayed entry to college, financially independent) is now the majority category of student enrolled in a university (American Council on Education, 2015). Yet another important factor is that the growing number of universities and the impact that technology has had on the way education is constructed and delivered, has made for a competitive environment in higher education (Staley & Trinkle, 2011).

Given all this, universities must look towards innovations that will enable their own survival and success while meeting the needs of students and faculty. These innovations may be at a grand scale, such as instituting a new strategic mission, or they may be smaller initiatives, such as cultivating a new culture within a department. One such development is the proliferation of offerings in innovation & entrepreneurship (I&E) in schools of engineering as well as university-wide. These range from single workshops or courses to extensive degree programs and start-up incubators. While the growth trend is clear (the growth of the engineering entrepreneurship division of ASEE itself is one indicator), not yet understood are the factors that enable or hinder successful efforts – in I&E, and even more generally in higher education.

Existing research

In examining efforts at universities seeking to embed I&E in their programming, we explore three critical considerations for the management of change in the university setting.

First, we consider *change as a team effort*. As the primary vehicle through which organizations accomplish most of their goals, universities also look towards teams to generate innovative ideas that promote growth and change for the university. One basic consideration in the context of teams is how the composition of the team impacts the management of change.

Second, we consider *the leadership of change*. Team members rely on their leaders for influence, guidance, and support (Amabile, Schatzel, Moneta, & Kramer, 2004; Zaccaro, Rittman, & Marks, 2001). Leaders must have the capacity to champion change for their teams and ensure effectiveness in the midst of change (Gill, 2002; Graetz, 2000). However, leadership need not be singular or even a formal role in teams; sharing in leadership responsibilities throughout change may be critical in ensuring effectiveness (Carson, Tesluk, & Marrone, 2007; Pearce & Conger, 2003).

Third, we consider *the context of change*. Although universities have multiple defined leadership structures, they are best understood as complex networks, in which change must be mediated through multiple relationships at multiple levels in the institution. In the same way that organizational culture (Schneider, Ehrhart, Mayer, Saltz, & Niles-Jolly, 2005) and structure (Silverman, 2012) can impact lower level activities, within the university as a whole, there are

factors that pervade (e.g., university or college leadership), which have the potential to impact change efforts attempted within smaller facets of the university.

Change as a Team Effort

Many – if not most - changes in organizational settings are not executed and developed by individuals, but by teams (Coghlan, 1994). Individuals that work together to problem solve have the potential to generate new and better ideas (Wuchty, Jones, & Uzzi, 2007) through the enhanced pool of knowledge that comes from different people on team (Horwitz & Horwitz, 2007). However, beyond simply putting together a team, one factor that contributes to the breadth of available knowledge is the team's diversity. When team members come from different areas of expertise or backgrounds, members have access not only to those individuals' reservoirs of knowledge and experience, but also to those individuals' external networks of knowledge and experience (Perry-Smith & Shalley, 2014; Reagans, Zuckerman, & McEvily, 2004). Therefore, teams stand to benefit when they can diversify their membership.

Within a university there are at least two key sources of diversity for teams that are attempting to institute change. The first is gender diversity. There is a skewed distribution of women in higher education (STEM fields in particular; (Beede et al., 2011; Shih, 2006). Within engineering specifically, only 22% of faculty are women (Gibbons, 2011), and women are thus less likely to be part of any change efforts. However, research suggests that women can greatly contribute to innovation (Bear & Woolley, 2011), and enable more effective teams (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010). Therefore, when endeavoring to develop innovative ways of instituting change, women may be key players. Therefore, we predict the following:

> *H1: Teams that include women will be more effective than teams without women.*

The second source of diversity comes from the knowledge held by the members. There are important differences between the faculty and staff at a university in terms of experience, education, and functional expertise. These differences allow for individuals to take different perspectives on issues that enable the team be more creative (Horwitz & Horwitz, 2007). Given the interdependence between faculty and staff, creating change that involves both groups will lead to change efforts that are more inclusive, and more accepted. Therefore, we predict:

> *H2: Teams that include both faculty and staff will be more effective than teams without this source of diversity.*

The Leadership of Change

Understanding how leaders manage the change process in their team is foundational for instituting effective change. Because leaders are viewed as having the most significant influence among members, it is often seen as incumbent upon the leadership to champion change (Kotter, 1995). This begs the question: which leadership styles are more effective for the acceleration of change? In a teamwork context, we turn to understanding how a leader's manner of interacting

with others may influence effective change. Social styles refer to individuals' observable patterns of behavior when interacting with others (Merrill & Reid, 1981). An individual's social style has two dimensions. Assertiveness refers to an individual's influence over others, whereas responsiveness refers to a person's display of emotions towards others. Individuals can thus be classified into four categories, as shown in Figure 1: expressives (high assertiveness and responsiveness), drivers (high assertiveness, low responsiveness), amiables (low assertiveness, high responsiveness), and analyticals (low assertiveness, low responsiveness).

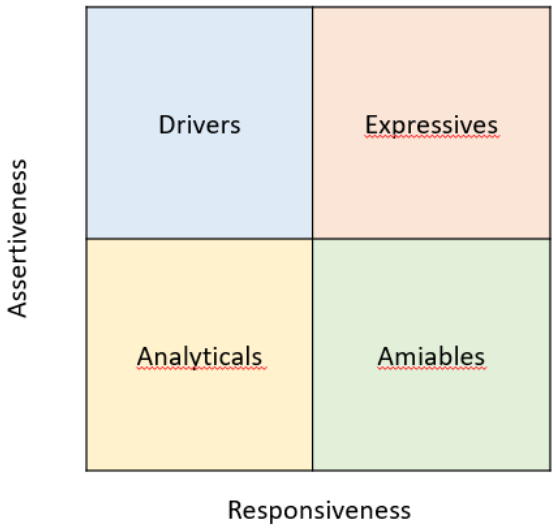

Figure 1: Social Styles

The type of style a leader employs may impact how change efforts are developed within a team, and there may not be one style that "fits all", but rather, the interaction between a leader's social style and the context may be critical (Hackman & Wageman, 2007). By considering leadership in context, we may better understand whether some styles of leadership are more effective than others. Therefore, in exploring leader social styles, we pose the following research question:

> *Are some leadership styles better than others when initiating and promoting change initiatives?*

In academic settings, an important individual characteristic of team leaders is tenure status. Among the faculty in a university, those that have tenure track positions, but have yet to gain tenure, are under great pressure to be productive compared to their tenured peers (Miller, Taylor, & Bedeian, 2011). Thus, they must pay special attention to their productivity in research, teaching, and service activities. As newer faculty, non-tenured faculty are often active and very

attuned to "being as good as they can be" in their role (Massy & Wilger, 1995). These faculty members may be a good source of fresh ideas and be highly motivated to participate in change efforts, but may be stifled by their lack of status as well as a lack of time for change efforts, when compared to activities seen as more critical for gaining tenure. Tenured faculty, on the other hand, do not experience the same pressures (Miller et al., 2011). These faculty members have reached a major milestone in their career, and while still expected to be productive, have more freedom to engage in non-traditional activities or pursue other endeavors at the expense of one of the pillars of research, teaching, or service. Therefore, we pose this additional research question:

> *Is there a particular tenure status of a team leader that is associated with higher team achievement?*

Leaders and how they choose to lead are important for instituting change (Kotter, 1995). However, whereas leadership is often viewed as a specialized role on the team, leadership need not apply to a single person. Shared leadership is characterized by shared influence and responsibility (Pearce & Conger, 2003). Sharing in leadership can create tighter bonds in the team and empower multiple members on the team to make contributions (Pearce & Sims, 2002). By creating trust and fostering motivation and knowledge sharing, shared leadership is a system of influence that opens up opportunities for creativity and innovation (Hoch, 2013). Therefore, we expect the following:

> *H3: Teams that have a shared leadership structure will be more effective than teams with unitary structures.*

Beyond these considerations, the question of how the leader should organize the work in order to effect change remains. Change within hierarchical academic institutions requires the development of a shared vision among community members (Borrego & Henderson, 2014; Henderson & Dancy, 2011; Henderson, Finkelstein, & Beach, 2010). In this context, the emergence of new networks, personal relationships and trust arise as critical factors within the dynamics of change (Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014; Finelli, Daly, & Richardson, 2014; Merton, Froyd, Clark, & Richardson, 2009). This is particularly important in the case of cross-functional teams, in which there is a high potential for misunderstandings among members which can lead to conflict (Lovelace, Shapiro, & Weingart, 2001).

Viewing change in engineering education from the perspective of complex adaptive systems alters traditional conceptions of leadership. Small groups do not operate as mechanistic systems. Rather, they act as complex dynamic systems in which participants freely interact with each other following simple rules of behavior (McGrath, Arrow, & Berdahl, 2000). Traditional leadership theories focus on the individual leader exercising "command and control" authority over followers in hierarchical organizations (Avolio, Walumbwa, & Weber, 2009; Marion & Uhl-Bien, 2001). By contrast, viewing leadership through the lens of complex dynamic systems reveals a different set of insights. A complex system has no central control; leadership is

distributed among participants through the system. Rather than focusing on control, effective leaders enable interactions among participants (Uhl-Bien, Marion, & McKelvey, 2007).

Using an "agile" strategy approach (Sullivan et.al, 2016, Morrison, 2012, 2013) represents a process of change that promotes this development of new networks, personal relationships and trust among members of a community, rather than control. The agile approach used by teams in this initiative, Strategic Doing (SD) represents a specific application of complexity leadership theory (Uhl-Bien et al., 2007). Change emerges from an appreciative process with open participation among community members. The SD process focuses on carefully designed conversations that guide participants toward actions with clear and measurable outcomes. The process further encourages participants to make adjustments through a continuous process of experimentation, also a central aspect of innovation in complex systems (Thomke, 2003).

The protocol of the SD process represents simple rules of interaction embedded in questions that participants explore and answer with the assistance of a guide (Lichtenstein & Plowman, 2009; Sullivan & Pines, 2016). It is a shared discipline of collective action. As participants follow these simple rules, new interactions take place and new outcomes emerge. Using simple, but not easy questions, participants develop both a shared outcome and a project to move toward their outcome. The project represents a short-term experiment. Participants learn whether they can move toward their shared outcome through the collective action they design. The process is iterative: as they learn, they move forward to complete some projects, adjust others and keep going, and take on new projects to reach their identified strategic outcome(s). Given the alignment between this approach and the complex nature of the university environment, we expect that:

> *H4: Teams that consistently use agile strategy processes will be more effective than teams that do not.*

The Context of Change

Universities, like most large institutions, are highly dynamic. This dynamic nature results in a bombardment of events that occur at every level. Researchers have examined this phenomenon by classifying types of events and the significant impact these events can have at every level of an organization (Morgeson & DeRue, 2006; Morgeson, Mitchell, & Liu, 2015). This work provides insights into how the contexts of institutional changes may impact teams like the ones in this study. They consider three characteristics of events: event novelty, event disruptiveness, and event criticality. Event novelty is defined as the newness or unexpectedness of the event. Disruptiveness refers to the amount of discontinuity the event causes in the organizational environment, causing a change in usual activities. Criticality is the degree to which an event is important, essential, or a priority (Morgeson & DeRue, 2006).

For a university, one such event that likely has all three of these characteristics is a turnover in leadership, especially at the top executive level (i.e., president, chancellor, provost etc.) and at

the dean level. The frequency of such an event, may differ from institution to institution. The average tenure according to a 2008 (King & Gomez, 2008) report the average president of a U.S. college or university remains in that position for 8.5 years. The level of expectedness may differ as well - a long-expected retirement is certainly different from an abrupt departure. In terms of how often these transitions occur, the latest data on the average tenure of deans comes from a 2002 article in the Chronicle of Higher Education (Jacobson, 2002) noting that deans generally stay on the job between three and five years. Although the frequency with which universities experience a turnover at these levels is uncertain they are more novel events than regular occurrences. Thus, these sorts of events likely are characterized as having at least some degree of novelty, disruptiveness, and criticality.

Besides changes in higher-level leadership, another context for change could be within the team itself, such as changes of the team leader or in team membership. Changes in team composition can be as simple as the addition, subtraction, or replacement of a single member or much more complex with multiple team members coming, going, and sometimes the return of members who had previously left (Lewis, Belliveau, Herndon, & Keller, 2007).

In the current study, rather than making specific predictions, we explore how the context of change influences change efforts among teams. We pay special consideration to changes in leadership at the higher levels of the universities and changes in team membership considering the nuances within each of the teams as a special context where the change initiatives are taking place.

Project Background

This study represents a follow-up investigation of institutions participating in the Pathways to Innovation (Pathways) program, begun in 2013 as an initiative funded by the National Science Foundation.[1] The goal of the program is to make high-quality I&E offerings available and accessible to undergraduate engineering students, through two primary strategies: faculty development and institutional change. Teams of faculty and administrators from 50 institutions participated in the program in three cohorts. While NSF funding ended in 2016, a somewhat informal "community of practice" persists with more limited programming.

Participating schools were four-year US institutions with engineering programs. The institutional profile of participating schools was diverse including small and large public and private institutions and research-intensive as well as liberal arts colleges. Several were minority-serving institutions.

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[1] National Center for Engineering Pathways to Innovation (Epicenter), funded by the National Science Foundation and managed by Stanford University and VentureWell (DUE 1125457).

Pathways programming over the 2013-2016 period included comprehensive mapping of the I&E ecosystem, in-person convenings and online gatherings providing information and coaching about specific kinds of offerings to expose students to I&E (eg, design thinking, makerspaces, pitch competitions) and guidance and support in the process of making change. Pathways was designed as a context-specific initiative, in which participating institutions were encouraged to choose interventions that best fit their own environment.

Previous research (Nilsen, Matthew, Shartrand, & Monroe-White, 2015; Nilsen, Monroe-White, Morrison, & Weilerstein, 2016) has reported the work done by the teams, particularly the largest cohort of 24 schools.

Study Participant Profile

Each of the 50 institutions that participated in the 2013-2016 period was invited to participate in this follow-up research; 33 expressed a desire to take part. The participating schools were from all three cohorts of the original project. As with the original set, the institutional profile of participating schools was broad:

Governance	Carnegie Classification	Region	Size (# of undergraduates)
Public: 27 Private: 6	Research (Doctoral w/at least moderate research): 25 Non-Research: 8	Mid-Atlantic/Northeast: 7 Midwest: 9 South: 10 West: 7	< 5,000: 5 5,001 – 15,000: 16 15,001 – 25,000: 4 > 25,000: 8

Source: Carnegie Classifications of Institutes of Higher Education, 2015

Figure 2: Profile of Participating Institutions

In completing interviews, it became clear that the different programmatic experience of the third cohort (in the formal program for only about six months) made analysis of team performance for the entire set of 33 schools very difficult if not impossible. For this reason, this paper focuses on the data gathered from the first and second cohorts. 24 institutions from those two cohorts provided all or most of the data sought; a few declined to answer specific questions.

Study Description

The participants for this research were the leaders/co-leaders of the project teams (about 2/3 of the schools taking part in this research used a co-leader structure for at least a portion of the project; both co-leaders may or may not have chosen to take part in this follow-up investigation). Each participant was asked to:

- Complete an online survey on "social style," based on the work of Merrill and Reid (Welsh Local Government Association, 2011). Participants were given 20 sets of four adjectives. In each set, they were asked to indicate which word best described them in a professional setting.
- Complete an online survey on their experience in the original project. The survey instrument gathered information on:
    - The role of the leader and each team member at the institution (departmental affiliation and/or administrative position, current status on the team and at the institution);
    - History of the participant's leadership and role on the team (when and how they originally became a leader; whether they were a sole leader or a co-leader);
    - The current status of the team;
    - Use of and opinion regarding the effectiveness of agile strategy techniques by the team;
    - Existence of and impact of various events at the institution during the project, including:
        - Change in president
        - Change in engineering or business dean
        - Change in provost
    - Self-evaluation of the success of the team's efforts.
- Participate in a 30-60 minute interview via videoconference with one of the researchers. These interviews included:
    - Collecting updated information on the interventions pursued by the team, including which were completed, which in process, and which had been cancelled;
    - Reviewing information provided in the online surveys;
    - Asking participants to reflect on how the following factors may have impacted their work:
        - Team size and composition;
        - Leader structure (single leader vs. co-leader);
        - External circumstances.

Category	Description	Example
Courses	Efforts to either design a new course or to substantially revise an existing offering	Re-organizing an introductory engineering course around a set of real-life scenarios and the use of design thinking
Credentials	Efforts to introduce a new program of study available to undergraduate engineering students	A major, minor or certificate in innovation engineering

Makerspaces	Efforts to launch or substantially expand a space on campus in which students can work together to design and/or build	A new space within the school's library, outfitted with informal group workspace as well as 3D printers and other tools
Informal learning	Efforts to provide learning experiences that do not offer course credit	"Pop-up" workshops that teach students how to use the tools in a makerspace
Competitions	Efforts to launch or substantially expand an event for students to demonstrate their innovation and entrepreneurship skills	A pitch event in which students present startup ideas based on prototypes they have designed and built
Infrastructure	A wide-ranging category that captures efforts that provide supporting resources for an I&E ecosystem, including physical assets and policy changes	A new university policy that clarifies the circumstances under which students can control the IP for products they invent
Consolidations of I&E	Efforts to launch a centralized home for I&E efforts (both physical and virtual) throughout the college of engineering or the entire university	A new Center for Entrepreneurship on campus.

Source: Nilsen et al., 2015

Figure 3: Taxonomy of Interventions

Findings

Projects undertaken/implemented

Earlier work reported on the number of projects undertaken and implemented by the full set of 50 participating schools in the original project, categorized as to variety of interventions (Nilsen, 2016). The schools participating in the follow-up research provided updated information on their work, which was analyzed using the same taxonomy as that shown in Figure 3. Figure 4 shows the data on projects (interventions) undertaken and completed for the schools participating in this research as of June 2016 and April 2017. In this context, "completed" means that the team's project had moved into (at least) an implementation phase as of those points in time - for example, a course or credential was launched, or a new makerspace was opened. While some kinds of projects are episodic (such as a competition), others (such as a new IP policy) are ongoing.

The number of total projects undertaken by the 24 participating schools has increased from 272 to 322, a relatively modest increase of 18%. However, the proportion of projects that have been completed rose 52%, from 54.5% to 70.1%.

	June 2016			April 2017		
	In progress	Completed	Total	In progress	Completed	Total
New or redesigned courses	31	33	64	20	55	76
Credentials	17	7	24	10	16	26
New or expanded makerspaces	14	12	26	10	20	30
Competitions	7	16	23	18	47	65
Non-credit learning	20	33	53	4	19	23
Consolidated or re-organized I&E activity	3	9	12	4	11	15
Infrastructure	30	37	67	27	56	83
Other	2	1	3	2	2	4
Total	124	148	272	95	227	322
% complete	54.4%			70.1%		

Figure 4: Projects Undertaken & Completed by Participating Institutions

To analyze the impact of various factors on team performance, the schools were first divided into quartiles. Quartiles were first determined by the total number of projects the team had undertaken. Each cohort of schools was divided into quartiles independently, so that teams that had been at work for two years were not compared to those with three years' work behind them. This metric has obvious drawbacks – it does not account for the ambitious scope of some types of interventions, such as new credentials; nor does sheer quantity of projects equate to campus impact - but it does provide one window into the productivity of the teams.

Because of the drawbacks of this metric, the division into quartiles was repeated, this time using the number of projects completed. This does not address all of the drawbacks, but does capture the extent to which teams were able to complete what they started.

The two sets of quartiles were nearly identical – only four schools of the 24 were in a different quartile with respect to the number of projects started than with respect to the number of projects completed. Because the number of projects completed appears to offer some advantages as a

measure of performance, the data described below use this definition for the highest and lowest quartiles.

It could be argued that the number of projects – whether started or completed – is not a useful measure of success. However, given the overall aim of the Pathways program – to fully embed I&E in undergraduate engineering – quantity does matter. A few offerings may be of very high quality and benefit a small number of students, but transformation requires a multi-pronged ecosystem approach. In the same vein, we did not attempt to determine the degree to which learning outcomes were achieved by individual students – although many of the teams have embedded assessment in projects they undertook, especially where the project involved course or curriculum development.

All of the teams experienced at least some success in introducing new I&E offerings at their institution, and none of the team leaders participating in the research felt that their project had been unsuccessful. However, in order to shed some light on whether the factors that the research team had hypothesized might be associated with team performance were in fact significant, the highest-performing quartile (6 institutions) was compared to the lowest-performing quartile (6 institutions). Figure 5 describes the number of projects undertaken and completed, for both cohorts, for both the highest and lowest quartile.

	Highest Quartile	Lowest Quartile
Mean number of projects undertaken		
Cohort 1	17	5.5
Cohort 2	25.5	7.6
Mean number of projects completed		
Cohort 1	14.5	3.5
Cohort 2	19.3	3.0

Figure 5: Projects Undertaken and Completed as of April 2017

Factors for success

Team composition

Three factors in team composition were considered:

- Gender diversity: whether the team had at least one woman;
- Role diversity: whether the team included both faculty and non-faculty (staff or administrative) members.
- Team stability: the extent to which the team changed over the course of the project (both original members leaving and new members coming in.

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	Highest Quartile	Lowest Quartile
Women on team	67%	67%
Both faculty and non-faculty on team	33%	50%
Team stability*	46% (range: 0 – 65%)	28% (range: 0 – 100%)

* Team stability was measured as the % of team members that had either entered in the midst of the project or exited sometime during the project. Nearly every team had both over the course of their involvement.

Figure 6: Team Diversity

Leadership

Five factors were considered with regard to team leadership:

- Leadership structure: whether the team was led by a single leader or by co-leaders;
- Gender: whether at least one leader on the team was female;
- Tenure status: whether team leaders were tenured, on the tenure track (but not yet tenured), or non-tenure and not pursuing tenure.
- Leadership stability: whether the team's leader and/or co-leaders remained constant throughout the project.
- Social style: the social style(s) of the leaders, as determined by the online survey.

Single vs. Shared Leadership

	Highest Quartile	Lowest Quartile
Single Leader	33%	67%
Co-Leaders	67%	33%

Figure 7: Leadership Strucure

Gender

	Highest Quartile	Lowest Quartile
At least one female leader	50%	0%
No female leader	50%	100%

Figure 8: Gender Distribution in Leadership

Leader tenure status

	Highest Quartile	Lowest Quartile
At least one tenured leader	67%	50%
At least one tenure track (but not yet tenured) leader	17%	0%
At least one non-tenured/non tenure-track leader	33%	33%

Figure 9: Leader Tenure Status

Leadership Stability

	Highest Quartile	Lowest Quartile
No change in team leadership	33%	33%
At least one leadership change	67%	67%

Figure 10: Leadership Stability

Leader Social Style

	Highest Quartile	Lowest Quartile
Driving	50%	60%
Analytical	25%	0%
Amiable	25%	20%
Expressive	50%	20%
Balanced	0%	20%

(Notes: The predominate style was defined as the style that scored at least 2 points higher than the next-highest. In some cases the highest styles were too close to distinguish one from another; in the case of two "tied" styles, both were counted; in the case of three or four "tied" styles, that leader is categorized as "balanced." Additionally, not every research participant chose to complete this survey)

Figure 11: Leader Social Styles

Use of agile strategy

Participants were asked about the extent to which they felt that Strategic Doing, as an agile strategy methodology, had had an impact on their team's performance, as well as their use of the approach.

	Highest Quartile	Lowest Quartile
Enabled faster progress	67%	60%
Enabled more progress	67%	20%
Not a factor	0%	0%
A hindrance	0%	0%
Consistent use of SD principles*	7.7/10	2.2/10

*Consistent use of SD was scored by asking leaders to report on the extent to which 10 specific aspects of the methodology were used consistently.

Figure 12: Use of Agile Strategy

Contextual factors

Given the continuously changing nature of the university, some of the teams felt that there had been a significant transition in their institution that had influenced their team's performance. In particular, we examined three possible contextual factors:

- Presidential transition: participants were asked whether a presidential search or new president had occurred during the year prior to their team's start in the project through the present, and if so, whether that change had helped, hindered, or had no effect on their work.
- Dean transition: likewise, participants were asked whether a dean search or new president had occurred during the year prior to their team's start in the project through the present, and if so, whether that change had helped, hindered, or had no effect on their work. The instrument asked about both the engineering dean and the business dean, since so many of the participating teams had intentionally included members of both disciplines on their teams.
- Provost transition: in a similar fashion, participants were asked about a provost search or new provost.

With regard to these factors, Figure 13 shows the extent to which high-performing teams experienced such changes as positive (eg, a new dean had helped their work), and the extent to which low-performing teams had experienced the changes as negative.

	Highest Quartile	Lowest Quartile
Presidential transition was a significant factor	50%	40%
Dean transition was significant factor	50%	40%
Provost transition was a significant factor	0%	20%

Figure 13: External Contextual Factors

Discussion of findings

The teams in this study have continued to launch and complete a wide variety of I&E offerings, across all of the categories of interventions that were reported in earlier research. The success of the teams – particularly those teams in the highest quartile - underscores the importance of this and further research, in an effort to better understand the various factors underlying team performance.

The significant increase in the number of completed efforts (52%, compared with an 18% increase in the number of projects overall) suggests that those seeking to make change are well-advised to play the "long game." It takes time for I&E efforts to gain traction on campus, and

some types of efforts (eg, courses, credentials, and physical spaces) require approvals and/or resources that require patience to see through to successful launch.

There were significant differences in the number of projects begun (and completed) between the two cohorts – but not in a way that might have been expected. On the contrary, the first cohort attempted and completed fewer projects when compared to the second cohort – a difference most apparent in the highest quartile. We did not attempt to determine what might account for this difference. Three possible factors would be 1) changes in the program between the first and second year (while not dramatic, there were adjustments made for the second cohort based on the experience of the first); and 2) an enhanced "cohort cohesiveness" with a larger group that spurred all teams on to bigger achievements; and 3) a potential difference in the motivations and/or attitudes of the teams that applied to "pioneer" the program in the first cohort.

In looking at specific factors that may have contributed to teams' ability to implement change, it is important to note that given that the initiative engaged only 50 teams, and that only 33 are participating in this follow-up research. The sample sizes for the data collected are thus necessarily quite small. The findings should therefore not be considered determinative but rather suggestive of ways in which particular variables may help or hinder the effort.

Team composition was similar between the two quartiles in terms of the presence of women on the team and the presence of both faculty and non-faculty, providing little insight about these factors. What can be said is that neither factor guarantees success. In terms of team stability, it appears that at least some "churn" is acceptable and possibly even desirable for a high-performing team. This is consistent with the idea in agile strategy that the opportunities available to a network change as new people enter or others leave the network.

Several aspects of team leadership are noteworthy:

- Co-leading arrangements seem to be more associated with high performance than single leader team composition.
- The presence of a woman leader also seems to be associated with higher team performance.
- A change in leadership for a team need not mean that the team can no longer perform at a high level;
- The high-performing teams' leaders exhibit a wide variety of social styles, leading to a preliminary conclusion that success is possible regardless of leader social style.

Most teams – both high- and low-performing – regard the use of agile strategy as valuable in their teams' work. However, the consistent use of aspects of the approach vary considerably between low- and high-performing teams, with consistent use of the approach strongly associated with higher performance.

With regard to the use of agile strategy, it should be noted that earlier research (Nilsen et al., 2016) reported a discrepancy between the attitudes of team leaders and team members in this regard, with team leaders much more likely to report that Strategic Doing was an important contributor to their team's success. We did not attempt to pursue or resolve this paradox in this study, but it continues to present an opportunity for future research.

External events – transitions in university or college leadership or new strategic plans – do seem to have had at least some impact on the teams. High-performing teams, in particular, report that these changes were positive developments. We did not explore the extent to which this was disproportionately a matter of perception for high-performing teams.

Areas for continuing and additional research

There is much yet to learn about the dynamics of making change in engineering education. While the data presented here shed some light on some of the factors that may have an impact on whether a change team is able to work effectively, many questions remain to be explored, including:

- Is change related to I&E unique, or are the lessons gleaned applicable to engineering education (or even higher education more generally) as a whole?
- Given the range of projects deployed by the teams, are there particular strategies to be gleaned from the high-performing teams about which kinds of projects should be undertaken and when?
- Are there combinations of factors that might make a team particularly likely to be successful? Likewise, are there combinations of factors that make success very difficult to achieve?
- If agile strategy is a useful tool in making change, as indicated here, how can it best be deployed?
- Given that contextual factors such as leadership transitions are not within the control of a change team, what can we learn from high-performing teams about navigating those changes in ways that are beneficial?
- Do the preliminary findings about leadership configuration (ie, that co-leaders may be somewhat better than single leaders, and having at least one female leader may strengthen the team) hold up when investigating a larger set of initiatives?
- If success is possible regardless of the leader's social style, are there other specific leader attitudes or behaviors that can foster these kinds of transformations?
- Are there factors other than those explored here, related to team composition or university context, that help explain team performance?
- How do the factors explored here play out when teams are pursuing specific kinds of transformation – for example, curricular transformation vs. policy change?

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