

Infusing Innovation and Entrepreneurship into Engineering Education: Looking for Change as Seen by ASEE Members, 2012to2015

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BACKGROUND

During the Fall of 2012 and Spring of 2015, SageFox Consulting Group, external evaluators for the National Center for Engineering Pathways to Innovation (Epicenter),¹ undertook a study in order (a) to establish a baseline that could be used by Epicenter to assess change over time in I&E initiatives within this community, and (b) to provide information to the Epicenter team that would assist in setting priorities and allocating resources. Within the context of the larger effort of evaluating Epicenter, it became clear that the study would provide a unique opportunity to address three key research questions that are the focus of this paper.

1. What is Innovation and Entrepreneurship in the context of engineering education?

Definitions of I&E have been elusive as part of engineering education, but are critical in the dialogue of what offerings and pedagogies an institutions see as relevant and strategic for their engineering programs.² In engineering there is a legacy of seeing innovation being associated with design. Stemming from the business domain, entrepreneurship typically is thought of in reference to customers, markets, and ventures. Building off the work of Ferguson and Ohland to map “the innovative behavior of engineers and the relationship of that innovative behavior with the creative, problem solving, design and entrepreneurial behavior of engineers”,³ we queried engineering educators to see what terms came most readily to their minds when thinking about ‘innovative and entrepreneurial engineers,’ in terms of characteristics, actions, and mindsets. Using information provided by respondents, we investigated how views differ based on level of experience or knowledge associated with I&E as part of engineering education?

2. What role does the community think I&E should have as part of undergraduate engineering education?

Engineering schools and departments are challenged to prioritize and find space for all of the competing foci, such as sustainability, global, green, research or civic engagement, that can potentially engage their undergraduate students. Our study was aimed at gaining a perspective on the current status of offerings and the relative importance of I&E from both highly and less engaged members of the ASEE community. Drawing on the work of Byers et al. on the role of of I&E in engineering education⁴ and Shartrand et al.’s work on the nature of entrepreneurship programs,⁵ we established a baseline of current student engagement in I&E across curricular and extra-curricular offerings as well as a desired level of what the ideal levels of student engagement ought to be.

3. What are the practices and institutional factors that promote or inhibit implementation of I&E?

With an assumption, borne out by the results, that I&E is a desirable offering for engineering undergraduates, we sought to identify the array of potential barriers to achieving the desired levels of student engagement mentioned in #2, using the work of

Ruth Graham around “distilling the common features of success and failure”⁶ in implementing change within engineering departments, we explore also the differences between public and private practitioners of high and low I&E engagement in their views of what is and is not working in terms of institutional practices and challenges.

We sought to measure the changes in attitudes and perceptions at both an individual and institutional level. By analyzing responses over time, we hope to take note of where change has occurred already and where it needs to happen next.

METHODS

In order to answer these questions, in collaboration with Epicenter’s research group (the Fostering Innovative Generations Studies, FIGS, team) we developed and administered a survey focused on I&E in undergraduate engineering education to communities within ASEE including Campus Reps, ENT Division members, and subscribers to ASEE’s *Connections* and *Capitol Shorts* newsletters. The core questions of the survey were originally developed and validated with a set of early Epicenter participants in Fall 2011.

In 2012, we received responses from 144 faculty and administrators, representing more than 90 higher education institutions from the following populations:

- ASEE Campus Reps: 62 respondents. Invitations and two reminders were sent weekly for three weeks to all 327 Campus Reps. Response rate: 19%
- Epicenter Tahoe 2012 Retreat attendees: An invitation and two reminders over the course of five days were sent to all 60 registered attendees of Epicenter’s 2012 Retreat at Fallen Leaf Lake, with 41 responses coming back. Response rate: 68%
- ASEE Newsletter subscribers: The entirety of the ASEE population was invited via an item in the ASEE Connections Newsletter, and reminded a month later. We received 60 responses out of more than 12,000 members, with a response rate of less than 1%.

In the spring of 2015, we repeated the study, receiving 171 responses from faculty and administrations representing more than 100 institutions. Survey invitations were sent to the follow groups:

- ASEE Campus Reps: 67 respondents. Invitations and two reminders were sent weekly for three weeks to all 314 Campus Reps. Response rate: 21%
- ASEE ENT Division members: An invitation and one reminder after two weeks were sent to all members of ASEE’s rapidly-growing ENT division, with 71 responses out of an unknown total population.
- ASEE Newsletter subscribers: The entirety of the ASEE population was invited via an item in the ASEE Connections Newsletter, and reminded a week later via ASEE’s Capitol Shorts Newsletter. We received 33 responses, with a response rate of less than 1%.

Defining ‘High’ and ‘Low’ Engagement in I&E for Individuals and Institutions

We hypothesized that respondents’ level of engagement and familiarity with I&E would be a significant factor associated with their answers to these survey questions. In order to gauge a respondent’s level of engagement, we scored each response to a subset of questions as described below.

Questions 3, 7, 13, and 14 were scored according to the rubric laid out in the table below.

Table 1: Items used to Score Personal Engagement

	Response	Score
3. Are you a member of ASEE’s Entrepreneurship (ENT) Division	Yes	20
7. Have you engaged in an entrepreneurial endeavor in the last three years?	Yes	20
13. To what degree do you teach entrepreneurship and innovation?	A little	30
	Core part	40
14. Based on your role at your institution, how well are you able to comment about I&E in engineering education at your institution?	Well	20
	Some	10

A score of higher than 50 qualified an individual as ‘highly engaged,’ (referred to as ‘hi’ in the tables below); all other individuals were grouped into the ‘lesser engaged’ cohort (referred to as ‘lo’ in the tables below).

Highly engaged respondents are much more likely to be members of ASEE’s ENT division, in both 2012 and 2015. About 80% of highly engaged respondents in both 2012 and 2015 were faculty members; whereas administrators much more likely to be in the lesser engaged group in 2012, this gap shows evidence of narrowing in 2015, where the difference we see in administrators’ personal I&E engagement (27% lo vs. 17% hi) is not statistically significant.

Table 2. ASEE affiliation by year and level of personal I&E engagement

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
ASEE member	94%	95%	**	99%	96%	
ENT member	47%	4%	***	78%	9%	***
Campus Rep, ASEE	41%	58%	**	20%	60%	***

** = $p < 0.01$, *** = $p < 0.001$

Table 3. Faculty/administrator affiliation by year and level of personal I&E engagement

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Faculty	78%	53%	**	80%	65%	*
Admin	18%	43%	***	17%	27%	
Both	4%	4%		4%	8%	

* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

In most other respects, see Tables 4–6 below, the highly engage and lesser engaged groups are comparable. Most respondents have more than 20 years experience since their highest degrees. Public schools are represented by 58% of responses, in both 2012 and 2015; with private schools at 41% and 40% respectively in each year. Most respondents from both years hail from PhD-granting institutions.

Table 4. Years since highest degree by year and level of personal I&E engagement

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
0 to 5	12%	5%		15%	10%	
6 to 10	9%	6%		9%	13%	
11 to 20	31%	31%		23%	19%	
more than 20	48%	57%		54%	58%	

$p > 0.05$ for all items in table above

Table 5. Private/public institution by year and level of personal I&E engagement

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Private	51%	32%	*	45%	35%	
Public	49%	65%		54%	63%	

* = $p < 0.05$

Table 6. Highest degree granted by institution by year and level of personal I&E engagement

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Bachelors	4%	6%		6%	5%	
Masters	15%	18%		17%	16%	
PhD	81%	74%	***	76%	75%	

*** = $p < 0.001$

OVERVIEW OF RESULTS

In 2012, based on the responses of 144 faculty and administrators, representing more than 90 higher education institutions, we found:

- Most schools offered extracurricular activities and many have elective courses focused on I&E.
- Only a few had I&E as part of the core curriculum.
- There was almost universal interest in increasing the presence of extracurricular and elective course offerings and a majority view that I&E should be part of the core curriculum.
- On most campuses, the number of faculty engaged in supporting I&E education was said to be limited.
- Most saw their university leadership as supportive of I&E, and engaged in early or more advanced stages of strategic planning.
- Common challenges included finding space in the engineering curriculum, overcoming faculty and, to a lesser degree, administrative resistance, identifying funds and building expertise.

In 2015, we were unable to find much evidence of change: faculty and administrators face many of the same issues, have the same needs, and are working with the same depth of intensity and enthusiasm. Though we found consistent evidence of inertia, which is characteristic of engineering education and is distinct from resistance to change, students continue to engage in I&E primarily through extra-curricular offerings and most institutions have a few highly-engaged faculty who are champions of I&E on their campuses. In 2015, faculty continue to see their administrators as highly supportive of I&E-related efforts, and when asked to name the barriers they, i.e., the faculty, face in implementing I&E, 'administrative resistance' fell significantly from 23% to 6% ($p=0.0003$).

Q1. What is Innovation and Entrepreneurship: Definitions

There is a degree of consensus around the definition of entrepreneurship that has remain steady from 2012 to 2015: Creativity, product development and opportunity recognition were the three top selections in both years. Yet, highly (personally) engaged respondents were much more likely to select 'value creation' as one of their top five responses, while respondents with low personal engagement tended toward market awareness and risk tolerance. Regardless of level of engagement, venture creation remains low on the list.

Table 7. Which of the following do you associate most closely with entrepreneurial engineers? (select 5)

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Creativity	64%	77%		71%	81%	
Value creation	63%	44%	*	69%	47%	*
Opportunity recognition	67%	61%		65%	55%	
Product development	52%	61%		60%	68%	
Market awareness	39%	55%	*	47%	60%	
Risk tolerance	46%	51%		39%	51%	
Venture creation	27%	42%		34%	32%	
Customer development	21%	17%		22%	8%	*
Economic development	22%	27%		14%	31%	*
Self-efficacy	27%	27%		23%	25%	
Endurance	30%	26%		16%	18%	
Need for autonomy	13%	14%		10%	17%	
Social orientation	12%	8%		10%	3%	

* = $p < 0.05$

What's changed since 2012

‘Creativity’ is an even stronger associative characteristic for I&E, regardless of respondents’ personal I&E engagement, and ‘product development’ and ‘market awareness’ also saw increases across highly/lesser engaged sub-cohorts from 2012 to 2015. Those who are not highly engaged in I&E are more likely to hold a product/design-centric view of I&E. Both highly and lesser engaged cohorts see venture creation as a less significant piece of I&E within engineering education.

Q2. What role does/should I&E play in engineering education: How Students Engage – Current and Desired

We feel able to confirm that I&E education, especially within engineering, is not a fad, and that interest in the subject, and the community around I&E, remains very high. The ENT division has been active for many years and continues to grow, Epicenter has engaged more than 50 institutions through the Pathways program (a two-year process of teams working to define strategic opportunities for enhancing I&E programs)⁷ and 131 institutions through the University Innovation Fellows program, new entrepreneurship centers are opening on campuses every month, and President Obama continues to put the support of the federal government behind I&E-related initiatives across the educational landscape.

Respondents continue to see the value of integrating I&E into all parts of the student experience, including the core curriculum. Both in 2012 and 2015, respondents endorsed offering I&E to students in a variety of ways: via required courses (62%), electives (95%), and extracurricular

activities (96%). Respondents' characterization of the current state of I&E engagement among the engineering undergrads at their institutions are, on the whole, in line w/ the above-listed level of desired activity. We note that the desired breakdown of required/elective/extracurricular experiences and we note the proportions are similar: about 1.5x more elective/extracurricular engagement than required-course engagement.

Table 8: Student engagement, current and desired, % positive responses (represents the % responding 4 or 5 on a five-point Likert scale)

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Students currently engage via core courses	35%	26%	**	51%	38%	
Students currently engage via elective courses	73%	54%	**	71%	68%	
Students currently engage via extracurricular activities	67%	90%		73%	74%	
I&E should be available via core courses	77%	49%	***	66%	59%	**
I&E should be available via elective courses	100%	96%	*	95%	94%	*
I&E should be available via extracurricular activities	93%	97%		98%	96%	*

* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Respondents' characterization of the current state of I&E engagement among the engineering undergrads at their institutions are, on the whole, in line with the above-listed level of desired activity. Respondents indicated the proportion of pathways I&E students should have access to. In Table 8, above, we see the desired breakdown of required, elective, and extracurricular experiences and we note that the proportions are similar: about 1.5x more elective/extracurricular engagement than core course engagement. So it seems the ratio of offerings is correct, that there is and should be an emphasis on extracurricular and elective opportunities, and that both regardless of level of engagement there is a desire to see and overall increase in the availability of I&E pathways to students.

What's changed since 2012

While both highly and lesser engaged cohorts gave their near-unanimous support to I&E pathways in the extracurricular and elective course spaces in both 2012 and 2015, there is a new level of agreement in 2015 around the degree to which I&E should be offered as part of the required curriculum for engineering undergraduates: Down from 77% to 66% for highly engaged and up from 49% to 59% for the low group, in 2012 and 2015 respectively.

Q3. What are the practices and institutional factors that promote or inhibit implementation of I&E?

Respondents continue to note a large gap between current and desired practices that could advance I&E initiatives and identified numerous areas where they would find more resources useful.

- At the institutional level, respondents want assistance in developing policies that encourage I&E education, information about successful models, and identifying possible funding sources.
- In support of faculty and curriculum, respondents see a need for professional development in relevant pedagogies, access to content that can be embedded in existing courses or, to a lesser extent, stand alone, tools for assessing student learning, and for those already engaged, participation in a community of fellow practitioners and thinkers.

Table 9: Gap in institutional practices, current and desired.¹

	2012		2015	
	hi	lo	hi	lo
n =	67	77	83	88
Encouraging industry experience for faculty and Ph.D. students	1.3	1.1	1.2	1.1
Funding for I&E education	1.8	2.0	1.8	1.5
Having policies that encourage I&E education	1.6	1.7	1.5	1.3
Providing students with opportunities to do research in engineering education	0.7	1.1	1.0	0.8
Teaching engineering educators how to teach I&E	1.6	2.0	1.6	1.8

p > 0.05 for all items in table above

The inertia against change is here quite evident; and where we do see some change from 2012 to 2015, much of that change is more readily described in breaking these data down by public and private institutions.

The Public-Private Gap

While the overall data continue to show the inertia in engineering education, especially around institutional policy and funding, these data can be broken down to illustrate a fundamental difference in circumstances between public and private institutions. The gap between the current and desired state for each of the five items above is at minimum 1.2x larger at public schools

¹ Respondents were asked ‘Please rate each of the following in terms of importance in advancing entrepreneurship and innovation education for engineers’ and ‘Please rate how well your department currently practices each of the following’ on 1–5 Likert scales (Not important to Very important, and Very poor to Very well). In order to calculate the gap between current and desired practice, the latter score was subtracted from the former. The integer values reflect the magnitude of this gap; smaller values are better, i.e., indicate a smaller gap.

than at private ones. Public schools note a 1.8x larger funding gap, and 1.5x larger gap in encouraging industry experience for faculty, and a 1.3x larger gap in I&E-friendly policies.

Table 10: Gap in institutional practices, current and desired, by public/private inst.²

	2012			2015		
	private	public		private	public	
n =	59	83		68	100	
Encouraging industry experience for faculty and Ph.D. students	1.2	1.2		0.9	1.3	*
Funding for entrepreneurship and innovation education	1.7	2.0		1.2	2.0	***
Having policies that encourage entrepreneurship and innovation education	1.3	1.9	**	1.2	1.6	*
Providing students with opportunities to do research in engineering education	0.8	1.0		0.8	1.0	
Teaching engineering educators how to teach I&E	1.6	1.9		1.6	1.8	

* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Not only is there a notable gap between public and private institutions, it appears this gap is wider today than it was three years ago.

Barriers to Change: Challenges

Both faculty and admin in 2015 note that there are still challenges to making I&E a core part of the ENG curriculum at their schools.

Table 11: Challenges, % responding 'yes'

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Are there challenges to making I&E a core component of undergraduate engineering education (% yes)	87%	75%		72%	81%	

$p > 0.05$ for all items in table above

Asked to enumerate these challenges, respondents listed 'lack of room in the curriculum' most frequently in their open-ended responses. 'Administrative resistance' has all but vanished as a barrier to change, and there is also a significant decline in 'lack of expertise' as a barrier.

² See footnote #1, above, for a description of how this gap was calculated.

Table 12: Challenges (open-ended responses categorized), % mentioning

	2012			2015		
	hi	lo		hi	lo	
n =	67	77		83	88	
Lack of room in curriculum	39%	49%		32%	58%	*
Faculty resistance	43%	16%	**	39%	22%	
Lack of funding	27%	15%		16%	17%	
Expertise	29%	16%		13%	12%	
Admin resistance	25%	20%		5%	7%	
Student demand	4%	2%		2%	0%	
Other	2%	13%	*	14%	3%	*

* = $p < 0.05$, ** = $p < 0.01$

We note interesting differences in the perceived barriers as reported by highly engaged individuals compared to those who are less engaged. The ‘ahead of the curve’ thinking from highly engaged respondents gives us an interesting perspective on the barriers/challenges faced and how those challenges may have shifted over time. Highly engaged respondents are much less likely to list ‘lack of room in curriculum’ as a barrier in 2015. These highly-engaged educators have developed the expertise and have the initiative to ‘hack’ the core curriculum to make a place for I&E, rather than working to find a place for it. They are also more likely to note resistance from other faculty (who are not as engaged).

Here, as above, it is helpful to break these data down by public/private institutions in order to see the underlying funding gap that has grown since 2012:

Table 13: Challenges, in detail (open-ended responses categorized, % mentioning each issue)³

	2012			2015		
	private	Public		private	public	
n =	59	83		68	100	
Lack of room in curriculum	43%	44%		44%	46%	
Faculty resistance	35%	25%		37%	27%	
Lack of funding	22%	20%		9%	21%	*
Expertise	29%	18%		9%	13%	
Admin resistance	29%	18%		2%	9%	
Student demand	2%	4%		2%	0%	
Other	6%	9%		7%	10%	

* = $p < 0.05$

There is a marked gap (more than two-fold) around funding between private and public institutions: it is not surprising that private institutions enjoy more agile access to capital than

³ Respondents were asked to describe the challenges they face in an open-ended format. These responses were categorized and quantified.

their state-backed counterparts. Here, as above, it appears too that this gap between public and private institutions with respect to funding has widen from 2012 to 2015.

What's changed since 2012: Perception of barriers and institutional practices by level of engagement

There is an underlying gap in the desired and current levels of funding for I&E programs, activities, and development between public and private institutions. Since 2012, private institutions have done much better in terms of closing that gap than their public counterparts, where a lack of funding continues to be a major barrier to furthering I&E in engineering education. As noted above, administrative resistance is now only a minor challenge to I&E implementation. Here too we see a reduction in the perception of lack of expertise as a barrier.

CONCLUSIONS

At the heart of Epicenter is the goal to change engineering education across the nation. Measuring that change is as challenging as the goal is audacious, especially given size and diversity of the community. As we learned from our array of evaluation work associated with Epicenter, local and regional factors mediate the I&E experience on campus. Yet, in broad strokes, there is a shared sense of the definition, importance of I&E and a common set of high impact practices and barriers to be considered.

1. While entrepreneurship and innovation as concepts encompass a variety of component definitions, creativity has emerged as an associated concept which can speak to individuals regardless of the level of I&E engagement. Venture creation is not at the center of I&E in engineering education. While there are still differences between highly/lesser engaged views, these differences are shrinking. These differences, however, may be important to make explicit as institutions develop new programs and offerings focused on I&E.
2. Faculty and administrators of all levels of I&E engagement agree strongly that students should have access to I&E in both extracurricular activities and elective courses, in 2015 as they did in 2012. Regarding I&E opportunities within core/required courses, highly engaged faculty/admin are likely to advocated for I&E within these core courses than their counterparts, though the gap between highly and lesser engaged individuals appears to be shrinking.
3. Within the realm of institutional practice, we see evidence of change in engineering education. Whereas private universities have responded with more agility in closing the gaps between current and desired levels of institutional practices (in particular around funding), public institutions in 2015 continue to encounter many of the same roadblocks as in 2012. Yet, we are pleased to be able to report that among these challenges, resistance from administrators is no longer viewed as a barrier to I&E implementation.

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