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Divergence and Convergence in Engineering Leadership, Entrepreneurship, Management, and Policy

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Abstract

A little over half (28 of 54) of the divisions of ASEE focus on the intersections between STEM disciplines and different contexts of engineering education and practice. These 28 divisions emphasize three broad areas: (1) humanistic content and goals; (2) particular groups of students, faculty, practitioners, or other stakeholders; and (3) specific arenas of activity and organizational contexts. Four of these "Engineering and. . ." divisions include engineering leadership, entrepreneurship, management, and policy. The divisions share goals such as connecting the technical and non-technical dimensions of engineering and transforming engineering education so that it more effectively prepares graduates for workplace success. Previous research suggested that interest in "Engineering and …" permeates ASEE and is concentrated in but not limited to the division most closely associated with the topic. This paper describes a transferable method that combines quantitative and qualitative methods to identify areas of convergence using papers published in the Leadership Development (LEAD) and the Engineering Entrepreneurship and Innovation (ENT) as evidence. These areas of convergence are: (1) program design and effectiveness, (2) individual capabilities (including traits and thinking tools), (3) teams and groups, and (4) identity and culture. Program design and effectiveness dominate the discourse of both divisions, suggesting that the two groups face similar challenges. Areas of apparent divergence include more concern with mindsets and innovativeness in ENT and more emphasis on team skills and mentorship in LEAD. These findings present opportunities for collaboration that could benefit all "Engineering and …" divisions and help overcome the inertia that characterizes engineering education. The permeation of topics across ASEE and the convergence of themes across divisions also suggest that forming a new division might perpetuate disciplinary siloes, rather than support knowledge integration across the "Engineering and . . ." divisions.

1.0 Introduction

The named divisions of the American Society for Engineering Education (ASEE) reflect the full range of STEM disciplines as well as the intersections between those disciplines and multiple contexts of engineering education and practice. These intersections are apparent in the divisions of ASEE that focus on something other than a STEM domain. As Table 1 below demonstrates, a little over half of the divisions (28 out of 54[1]) focus on intersections of different kinds. In this paper, we refer to these divisions collectively as "Engineering and. . ." divisions.

"Engineering and. . ." Divisions of ASEE	
Emphasis	**Divisions**
Humanistic Content and Goals (Intersections with Other Areas of Expertise)	1. Engineering and Public Policy 2. *Engineering Communicators Constituent Committee* 3. Engineering Economy 4. Engineering Ethics 5. Engineering Leadership Develoment 6. Engineering Management 7. Entrepreneurship and Engineering Innovation 8. Equity, Culture, and Social Justice in Education 9. Liberal Education/Engineering and Society 10. Technological and Engineering Literacy/Philosophy of Engineering
Groups of Students, Faculty, Practitioners, or Other Stakeholders	11. College-Industry Partnerships 12. Engineering Libraries 13. Faculty Development 14. Military and Veterans 15. Minorities 16. New Engineering Educators 17. Pre College Engineering Education 18. Student 19. Women in Engineering
Arenas of Activity/Organizational Contexts	20. Community Engagement 21. Continuing Professional Development 22. Co-operative and Experiential Education 23. Design in Engineering Education 24. Educational Research and Methods 25. First-Year Programs 26. Graduate Studies 27. International 28. Two-Year College

Table 1. List of "Engineering and. . ." Divisions. The categories used to organize the divisions are not exclusive. The reflect differences in emphasis rather than the existence of separate knowledge domains.

[1] The number of divisions vs. constituent committees and interest groups seems to fluctuate based on the context in which the list is generated (ASEE website vs. PEER). By some counts, there are 55 divisions. In any case, the proportion of "Engineering and. . ." divisions remains essentially the same.

This paper focuses on four "Engineering and. . ."divisions that explicitly connect engineering with expertise that is relevant to engineers but not typically required in engineering education:

1. Engineering Leadership Development (LEAD)
2. Entrepreneurship and Engineering Innovation (ENT)
3. Engineering Management (EMD)
4. Engineering and Public Policy (EPP)

We selected LEAD and ENT because they are relatively new (2014/2015 and 2006, respectively), have grown rapidly both within and outside of academia, and have no clear alignment with traditional academic disciplines. In contrast, EMD and EPP are relatively older (1977 and 1981, respectively), have maintained approximately the same volume of papers during the period covered by PEER (the ASEE document depository), and align more clearly with academic specialties. The mission and goals of the selected divisions are shown in Appendix I.

To experts working in the four fields[2] (leadership, entrepreneurship, engineering management, and engineering and public policy), the differences among the four are clear and significant, especially if we consider each of them as separate bodies of expert knowledge. Most engineering curricula and extracurricular activities treat these non-technical areas as distinct from each other, but the divisions' websites, calls for papers, and publications reveal several commonalities, including the goals of (1) connecting the technical and non-technical dimensions of engineering and (2) transforming engineering education in ways that support success for individual engineers and have the potential to increase the positive economic and social impact of the engineering profession. Courses and programs in these four areas also share some challenges. They often depend on contingent faculty and compete for resources with disciplinary curricula and research programs. Because of the competitive environment in which they operate, the faculty who design and teach in them are often under pressure to provide evidence of the value they add and challenged with finding a place in perpetually overcrowded undergraduate curricula.

The history of engineering education demonstrates that curricular transformation in engineering is difficult at best. As the president of the Carnegie Foundation put it in his preface to *A Study of Engineering Education* (1918), "It is sometimes easier to start a new school than to try an educational experiment in an old one" (Mann, p. viii). The research reported here is motivated by the belief that collaboration among the "Engineering and …" divisions can help overcome the inertia that characterizes engineering education. In the context of higher education, collaboration seems good in principle but is often difficult in practice because of systemic factors, that is, factors outside the immediate control of individuals. Perhaps the most important of these is the territorial model that dominates the organization and administration of higher education. Defending one's unique intellectual territory (that is, justifying allocation of resources based on doing something that is not being done by others) is often an existential imperative that disincentivizes collaboration. The ultimate goal of our project is to identify the shared concerns and intellectual foundations that warrant the effort that collaboration entails. We also aim to to highlight the features that distinguish the "Engineering and. . ." divisions from each other. As a step toward that ultimate goal, we developed a research approach that draws on data available

[2] The names of the divisions and the subject domains that are associated with them are not identical; however, for purposes of simplifying the discussion, we use the acronyms of the divisions as a shorthand way of naming the subject domains they cover.

through PEER to identify four areas of divergence in the discourse in a subset of the "Engineering and. . ." divisions.

This research built on previous work suggesting that the discourse on engineering leadership (LEAD), entrepreneurship (ENT), engineering management (EMD), and engineering and public policy permeates ASEE and is concentrated in but not limited to the division most closely associated with the topic (Neeley 2016). In the work completed to this point, we used the papers published in LEAD and ENT to identify four common themes that should also be useful for analyzing papers from EMD and EPP: (1) program design and effectiveness, (2) individual capabilities (including traits and thinking tools), (3) teams and groups, and (4) identity and culture. These areas of convergence exemplify the value added by LEAD, ENT, EMD, and EPP as non-traditional components of engineering education and suggest possibilities for mutually beneficial collaboration. The relatively small but significant divergence in content that emerged from the analysis has the potential to function as a springboard for more sharply defining the distinctive mission of the "Engineering and. . ." divisions. The remaining sections of this paper discuss previous research on convergence and divergence in these four topic domains, define our research questions and methods, summarize our results, and discuss the implications of those results, including directions for future work.

2.0 Literature Review: Evidence of Convergence

2.1 Quantitative Research on the Blurring of Boundaries in ASEE

One might imagine that creating a new division would concentrate the discourse on the topic that provides the focus for the new division. A study of papers published in the proceedings of ASEE in 2014 and 2015 (Neeley, 2016) used the search function of PEER to investigate the extent to which the discourse on leadership, entrepreneurship, engineering management, and public policy was concentrated in the division most closely associated with the that topic. PEER provides a total of all papers containing each term and breaks them down by the division in which they were published. The data generated through PEER showed that papers containing the terms leadership, entrepreneurship, "engineering management," and "engineering and public policy" were pervasive across all divisions of ASEE.

The data on leadership are particularly suggestive. In 2015 (around the time LEAD officially became a division) leadership was a topic in all divisions of ASEE, and the number of papers on leadership outside of LEAD was 2.5 times larger than the number within LEAD. These results suggest the formation of a new division reflects widespread interest in the topic but does not limit the discourse on the topic to that division. This finding does not undermine the justification for forming new divisions, but it does suggest that forming a new division does not completely solve the problem of generating a comprehensive body of knowledge on the topic. These circumstances create challenges for newcomers to the field and suggest the potential for greater impact of the scholarly contributions of LEAD. It seems likely that the same challenges and opportunities exists for ENT, EMD, and EPP.

2.2 Commonalities in the Missions and Interests of LEAD, ENT, EMD, and EPP

As mentioned in the introduction, each of these divisions can lay claim to expert knowledge distinctive to their field. On the other hand, they all see their fields as related to but distinct from engineering as traditionally understood and face the challenge of making their relevance apparent. The oldest of the four, Engineering Management (EMD), was established in 1977[3] "to promote educational programs in engineering management. . .[which] *prepare engineers to gain the management skills for leadership roles* [emphasis added] in complex engineering activities in industry, government, education, and the military." Engineering and Public Policy (EPP), which became a division in 1981, also has a broad remit, which includes promoting "public policy curricula in engineering education through the development of courses, modules, programs, and case studies" and "dialog on policy issues affecting engineering education and research." The Entrepreneurship and Engineering Innovation Division (ENT), which became a division in 2005, aims "to foster and disseminate approaches to educate and stimulate faculty at all levels on entrepreneurship, including partnerships with business schools as well as the business and technology enterprise communities." The newest of the four divisions, Engineering Leadership Development (LEAD), became a division in 2015 "to provide a *primary point of discussion* [emphasis added] and dissemination on the value and impact of engineering leadership education."

These divisions' websites, calls for papers, and publications reveal several other commonalities that are worthy of systematic investigation:

- Connecting and communicating across boundaries, especially disciplinary boundaries
- Amplifying the contribution of engineering expertise in a variety of domains
- Providing engineers with a competitive advantage in the workplace
- Coordinating effort among individuals and groups who share interests but not organizational structures
- Communicating with a range of stakeholders
- Fostering creativity, innovation, and problem solving
- Developing individual traits and characteristics to complement technical expertise
- Justifying their distinctive subject domains as a part of engineering
- Emphasizing systems thinking in specific contexts such as business, government, and law

To greater and lesser degrees, all four divisions seek to overcome recognized limits of traditional engineering education and to foster diversity and inclusion in engineering. (The mission statements and 2023 calls for papers are included in the appendices for this paper.)

Research published outside of ASEE suggests that the four divisions have shared intellectual foundations. Bhupatiraju, Nomaler, Triuzi, and Verspagen (2012) researched patterns in the discourse of "the three fields of Science and Technology Studies (STS), Innovation Studies (INN) and Entrepreneurship (ENT)" (p. 1205). They tested the hypothesis that "instead of 3 separate literatures, there is really only one (large) social science literature about knowledge and innovation" and found that "the three fields although they share research topics and themes, have developed largely on their own and in relative isolation from each other" (p. 1205). Given the similarities between the topics of the four ASEE divisions and the three fields they analyzed, it seems reasonable to infer that similar dynamics may be at play in ASEE.

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[3] ASEE does not keep centralized records on the dates when new divisions are established, so the dates must be inferred from the materials in each division's website. It is possible that the divisions have information that could provide more certainty, and we would welcome corrections.

2.3 Increasing Growth of Interest and Investment in Leadership and Entrepreneurship

Another reason the relationships among the four topics are worth investigating is that both leadership and entrepreneurship have experienced significant growth in interest and investment over the last decade. This is not surprising given that both areas are emphasized in *The Engineer of 2020* (2006), which has exerted noticeable influence on the ways engineering schools define their missions and market their programs (Neeley, Zajec, and Stup, 2022).

The growth in leadership is most noticeable in ASEE. The 2016 study referenced above revealed that the discourse on leadership within ASEE is much larger than that on the other three topics. In "The History of Engineering Leadership Development in Academia," Handley, Lang, Mittan, and Ragonese (2022) report over 50 engineering leadership programs in existence (p. 24) and describe an organizational infrastructure that includes the Community of Practice for Leadership Education for the 21st Century Engineer (COMPLETE) and the LEAD division. Their historical account traces the evolution of engineering leadership from unique extracurricular activity to structured academic programs integrated into engineering schools. Donald and Jamison (2022) also document growth in "scholarly attention to engineering leadership. […] As growing numbers of faculty, staff, and students appreciate the value of EL, programs have grown in number, expanded their scope, and become more formalized" (p. 84).

Entrepreneurship (including engineering entrepreneurship) appears to have experienced even more remarkable growth. In "The Chronology and Intellectual Trajectory of American Entrepreneurship Education 1876-1999," Katz (2003) reports that "In 1994, more than 120,000 American students were taking entrepreneurship or small business courses" and that these courses are part of "an American infrastructure. . .consisting of more than 2200 courses at over 1600 schools, 277 endowed positions, 44 English-language refereed academic journals and over 100 centers" (p. 384). In both leadership and entrepreneurship, increased funding has been a significant factor with the National Science Foundation (NSF), the KEEN program, and private donors all investing significantly. It appears that engineering management and public policy have not enjoyed the same level of funding, despite sharing many of the goals of the other two domains and having knowledge bases that are relevant to the other two. While engineering management and engineering and public policy are not emphasized in *The Engineer of 2000* and similar publications, both fields are highly relevant to achieving the goals set forth in those publications. If EMD and EPP were able to strengthen their connection with LEAD and ENT, their potential for growth might well increase.

3.0 Research Questions and Methods

The findings outlined above prompted three research questions:

1. Do the papers in these four divisions in the entire period captured in PEER (1996-2022) conform to the pattern that emerged from frequency analysis of the 2014 and 2015 papers?
2. To what extent do the four divisions seem to be discussing the same topics and exploring the same themes?
3. What distinguishes the discourse of each division from the others?

To address these questions, the research team developed and applied an iterative method in which the results of quantitative analysis (frequency analysis and topic modeling) provided direction for qualitative analysis (thematic coding) and vice versa. The flowchart on the next page (Figure 1) provides a high-level view of our research approach. The steps in the blue boxes primarily involve quantitative analysis, and the ones in green primarily involve qualitative analysis. Before describing the methods in detail, we discuss how topic modeling and thematic analysis inform each other. The papers used to generate the initial thematic codes are listed in Appendix II.

A frequency analysis of documents in PEER is potentially very useful for discerning patterns, trends, and relationships in the complex organizational ecosystem of ASEE. It can provide insight not just into what is happening within divisions, but also what is happening across divisions. The sheer volume of papers in PEER in which the target terms appear (over 18,000) complicates the task of discerning meaningful trends within the discourse of ASEE. In other words, frequency analysis can tell us whether a particular word or phrase is in a document or not, but it tells us little about the meaning that is attached to those words and phrases. Topic modeling uses statistical algorithms that are readily available in open-source libraries to process large bodies of text and generate quantitative data on how often words occur, which words tend to appear together, and the documents in which those groups of words have the strongest presence. The groups of words that tend to appear together constitute a topic. The output of the algorithmic analysis is illustrated in Box 1 below.

Topic 0:
learning page skills student time figure process development use problem
Paper ID #21094 Economic and Pedagogical Analysis of an Alternative Model of Engineering Education D
Paper ID #15578 Taking the Role of Others to Increase the Success Rates of Innovations Prof. Bernd S
Paper ID #11955 A Systematic Review of Technological Advancements to Enhance Learning Dr. Elizabeth
Paper ID #23566 The T-Shaped Engineer as an Ideal in Technology Entrepreneurship: Its Origins, Histo
AC 2008-837: MAKING THE POLICY CASE FOR ENGINEERING EDUCATION RESEARCH Norman Fortenberry, National

Box 1: Sample Output for a Single Topic. The second line contains the word cluster that defines the topic. The papers listed below the word cluster are the five in which the presence of the topic is strongest.

A human reader then used knowledge of the subject domain to deduce an umbrella term that unites the cluster of co-occurring words (keywords). The umbrella term is called a "label." Words are related and weighted by frequency, but the most common word does not necessarily capture the meaning of the cluster as a whole, another reason why human interpretation is needed. Thematic analysis, in contrast, is a primarily qualitative research method, but it is also concerned with identifying common themes, which are "topics, ideas and patterns of meaning that come up repeatedly" (Caulfield, p. 9). Thematic analysis as outlined by Braun and Clarke (2006) begins with familiarization, which entails immersing oneself in the data to get an experiential, holistic understanding of it. The next step, generating initial codes, involves highlighting phrases or sentences in the text and coming up with shorthand labels for their content. In the third step, related words and phrases are grouped together in themes that capture the overarching idea or feeling that unites the composite words and phrases. Analysts test the validity of the themes and codes by using them to analyze sample documents and verify that the themes and codes capture the aspects of the texts that are of most interest. The verified themes can then be used to determine the extent to which the themes are present in a representative body of texts, in our case, a random sample of 10% each from LEAD and ENT. This iterative process is visually depicted in Figure 1, below. Excerpts are presented in the results from papers that were thematically coded and are labled by the sequential number assigned to the paper, e.g (Paper 31) was the thirty-first paper in the list of papers coded thematically.

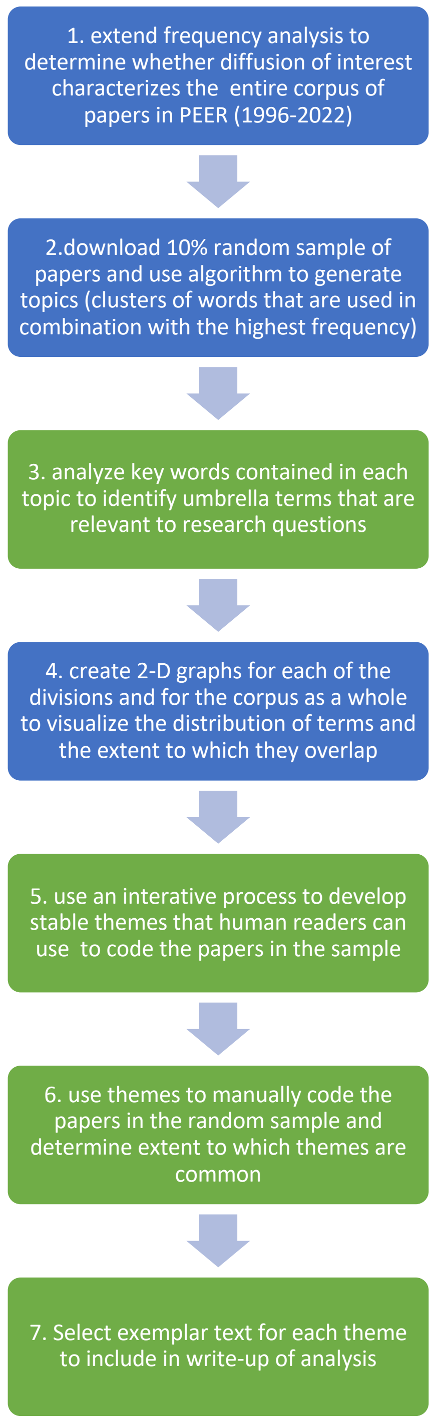

Figure 1. High-Level Depiction of Research Method. The steps in the blue boxes primarily involve quantitative analysis, and the ones in green primarily involve qualitative analysis.

Although the method we developed mixes quantitative and qualitative research methods, the descriptions below separate its quantitative and qualitative aspects to make the underlying logic clearer.

3.1 Quantitative Methods: Frequency Analysis and Topic Modeling

3.1.1 Extended Frequency Analysis Using the Search Functions of PEER

The purpose of the frequency analysis was to determine whether the pattern of diffusion present in the 2014 and 2015 papers (Neeley, 2016) characterized the the papers as a whole during the period 1996-2022. We refined the method described in the 2016 paper and extended the search function of PEER using leadership, entrepreneurship, "engineering management," and "public policy" as search terms. The leadership search excluded the phrase "leads to," which typically appears in contexts that have nothing to do with engineering leadership. The well-matched quotes were included for the searches on "engineering management" and "public policy" because searches without the quotes generated results that contained a high proportion of papers that were not relevant to our purposes. We made some distinctions within the raw search results, including:

- **Search term in *the title versus the text*** on the theory that papers with the term in the title are likely to emphasize the term more
- **Search term *in the division most closely associated with it* versus other divisions** as an indicator of diffusion of interest throughout ASEE
- **The number of divisions total** that had at least one paper on the topic as another indicator of pervasiveness of interest

3.1.2 Topic Modeling: Discerning Patterns in Large Document Collections

To make the topic modeling process more manageable, the research team limited the analysis to papers from LEAD and ENT, which had significantly more papers The initial data set consisted of 683 papers scraped from ASEE's official website in PDF format using a Python script. The script additionally scraped metadata about each paper including title, authorship, date published, and number of downloads and compiled this information into a spreadsheet for each division. Based on this data, graphs of the top authors and top universities in each division were generated and are shown in Appendix III.

A second Python script was used to clean the data for analysis. Papers from each division were converted to plaintext format and minimally processed by removing running headers and hyphenations. Then, the Non-Negative Matrix Factorization (NMF) algorithm was used to perform topic modeling using the scikit-learn package's implementation (Pedregosa *et al.* 2012). The model was given parameters with a maximum of 1000 features, an alpha of 0.1, and an L1 ratio of 0.5 to constrain the topics generated. The model was set to output 5 and 20 discrete topics (or clusters) for each division separately. Further, the combined dataset was analyzed as a whole and generated an output of 5 and 20 discrete topics. After comparing the two sets of output, we conclude that 5 topics were more useful. Additionally, the top 10 most representative words for each topic as well as the 5 papers that represented the topic most accurately were extracted. The full list of 20 topics and the top keywords in each topic are shown in Appendix V.

For each of the 5 topics, the research team created a label that best represented the meaning for each topic. These labels, which are also called "terms," are similar but not identical to the themes we generated for thematic analysis.

To create topic maps, we transformed the vector for each of the 5 topics into 2-dimensional vectors to create graphs of each topic and their relational distance. We plotted these 2D vectors as points on two axes with the cluster sizes corresponding to the number of papers that were categorized into that topic based on the NMF model. These points were labeled using the qualitative terms assigned by the research team. The topic maps for each division are in Appendix VI.

3.2.1 Defining Themes and Subthemes for Coding

We adapted the approach outlined by Braun and Clarke (2006) to define themes and subthemes to be used in the analysis. The labels and other details of the topic models provided a point of departure for identifying themes that are prevalent in the dataset we used as evidence. We refined the labels and topics by reading a few randomly selected papers from each division and noting both subjects that appeared often and the broad categories into which they fell. The themes and subthemes are specific to the four fields analyzed in this project and are presented as results later in the paper

3.2.2 Coding Protocol

Out of the 130 papers in LEAD and 553 papers in ENT, ten percent were randomly selected for thematic coding. We coded paragraphs rather than individual sentences or phrases and coded at the level of themes (rather than subthemes), assigning more than one code to a paragraph as needed and not assigning codes to abstracts and portions of the text whose content were not relevant to our research purposes. Each researcher coded 17 papers individually and one research faculty reviewed the applied codes. If conflicts in assigned codes were identified, they were discussed and resolved by the team members. This process of consensus coding allowed the research team to divide the papers equally, deliberate on codes applied, andreach consensus. After the papers were manually coded, the data were entered in Dedoose®, a software program that allows papers to be uploaded, coded, and analyzed. Analyzing the output from Dedoose® will be part of future work on the project.

4.0 Results

4.1 Determining Whether Further Quantitative and Qualitative Analysis Are Warranted Through More Extensive Frequency Analysis (Research Question 1)

Table 2 below summarizes the results of the frequency analysis for the period 1996-2022. It shows that all 54 divisions of ASEE had at least one paper containing each of the 4 terms. It also shows that 74% of the divisions had papers with leadership in the title of at least one paper, and 43% of the divisions had entrepreneurship in the title. In contrast, the EM and EPP terms appeared in only 20% of the PEER corpus. A comparison of the number of papers on a topic inside and outside the divisions revealed pervasive interest across ASEE. These results both justified moving forward with additional quantitative and qualitative analysis and suggested that the LEAD and ENT papers should be the initial focus of more rigorous analysis.

Search Term Frequency 1996-2022	**Leadership** (est. 2014/2015)	**Entrepreneurship** (est. 2004/2005)	**"Engineering Management"** (est. 1977)	**"Public Policy"** (est. 1981)
Years in PEER	8	18	27[4]	27
Total Divisions with Term: Title vs. Anywhere in the Paper				
Total # of Divisions with Term *in Title*	40 (74%)	23 (43%)	11 (20%)	11 (20%)
Total # of Divisions with Term *Anywhere* in at Least One Paper	54 (100%)	54 (100%)	54 (100%)	54 (100%)
Totals in PEER: Title vs. Anywhere in the Paper				
Total # of Papers in PEER with Term *in Title*	348 (3%)	289 (9%)	168 (6%)	30 (2%)
Total # of Papers in PEER with Term *Anywhere in the Paper*	11,100	3140	2773	1475
Totals with Term in Title: Inside vs. Outside Associated Division				
Total # of Papers with Term *in Title* Inside Associated Division	98	159	80	16
Total # of Papers w/Term *in Title* Outside Associated Division	250	130	88	14
Totals with Term Anywhere: Inside vs. Outside Associated Division				
Total # of Papers with Term *Anywhere in the Paper* Inside Associated Division	130	553	280	92
Total # of Papers w/Term *Anywhere in the Paper* Outside Division	10,870	2587	2493	1384

Table 2. Frequency Analysis Across Four ASEE Divisions.

[4] PEER was created after the Engineering Management and Engineering and Public Policy Divisions were established, which is why the dates are included here.

The results of the more extensive frequency analysis also support a number of other inferences that are worthy of additional explortation:

1. The discourse on leadership seems to take place predominantly outside of the division most closely associated with that term, with only 28% of papers with the term in the title being published in LEAD, and 72% of papers with the term in the title (suggesting a stronger association with the term). The discourse on leadership is over 3 times larger than that on entrepreneurship and engineering management and roughly 10 times larger than that on public policy.
2. For the other 3 search terms, the distribution is more balanced with roughly half of the papers with the term in the title inside the associated division and the other half outside of the division.
3. In the case of all 4 topics, there is a big disparity between the frequency of the terms in titles and the frequency of the terms anywhere in the paper. At one level this is not surprising given that there are many more words in the text of the paper than in the title. On the other hand, it also suggests that authors may not be consciously linking their content to one of the 4 terms when they compose titles.
4. When we look at the broadest category (papers with the term anywhere), similar patterns emerge. The discourse on leadership outside of LEAD is much larger (99%) than that within LEAD (1%), and the discourse on leadership is many times larger than that on the other three topics.

4.2 Themes and Subthemes for the LEAD and ENT Corpus

The four numbered themes listed below were generated for the LEAD and ENT papers and used in coding the sample papers. The subthemes indicate the different ways in which each theme manifests itself in the documents and relate to decisions about program design, educational outcomes, pedagogical strategies, and the intellectual underpinnings of programs. Thus, they embody some of the most significant results of our work.

1. **Program Design and Effectiveness**
    a. Motivation for establishing program (gaps: DEI, retention, workplace readiness)
    b. Major decisions (programs/courses, major/minor/concentration/certificate)
    c. Experiential learning (learning through experience in realistic settings) vs. intellectual foundations in lectures and readings
    d. Learning from people who have been successful in non-academic contexts
    e. Assessing effectiveness/outcomes
    f. Fitting into engineering (constraints: crowding, integration, funding; evolution over time)
2. **Individual Capabilities**
    a. Traits (Possessed by Individuals)
        i. Ethical sensitivity
        ii. Tolerance for ambiguity/uncertainty; agility/adaptability to change
        iii. Self-awareness and knowledge (capability/learning style assessment, affective domain, confidence and self-efficacy*)*
        iv. Networking, relationship building
        v. Creativity

   b. Thinking Tools (Strategies for Seeking Out and Organizing Knowledge)
      i. Systems thinking/big picture view; synthesis and problem definition
      ii. Understanding of human behavior (individually and in groups)
      iii. Structured reflection
      iv. Making analogies
      v. Communication (broadly defined—writing, reading, speaking, listening; managing process; adapting approach to circumstances; persuading and influencing others)

3. **Teams and Groups**
   a. Coordination, cooperation, collaboration
   b. Multidisciplinary teams, knowledge integration
   c. Negotiation and conflict management
   d. Relationship between individual capabilities and group functioning

4. **Identity and Culture**
   a. Duality/sociotechnical differentiation (technical/nontechnical; either/both; simplistic/complex; deterministic/contingency)
   b. Stage of career/role in organization
   c. "Typical/average engineer" as leader/entrepreneur (norm vs. exceptional)

4.3 Topic Models

Tables 2-4 display the five topics extracted using the NMF topic modeling algorithm for (1) LEAD, (2) ENT, and (3) the two divisions considered as a whole. Appendix X lists the five most-representative papers in each topic for each division. Figures 2-4 show the distribution of papers across the five topics for the same groupings. Because the figures provide a more holistic understanding of the topic, they appear before the tables. Appendix V shows the full 2-dimensional topic maps, which mathematically represent each topic and the combined topics by an n-dimensional vector, where n is the maximum number of components set. To graph these topics in a human-readable format, each topic vector was transformed into a 2-dimensional vector and graphed as a point in 2D space.

4.3.1 Results for LEAD

Figure 1 shows that LEAD is dominated by papers about program design. Nearly 90% of the papers in this division fall into this topic. The next most represented topics are learning, identity, mentorship, and team skills. While many papers touch on these topics to a significant degree, few papers discuss these topics predominantly, according to quantitative analysis.

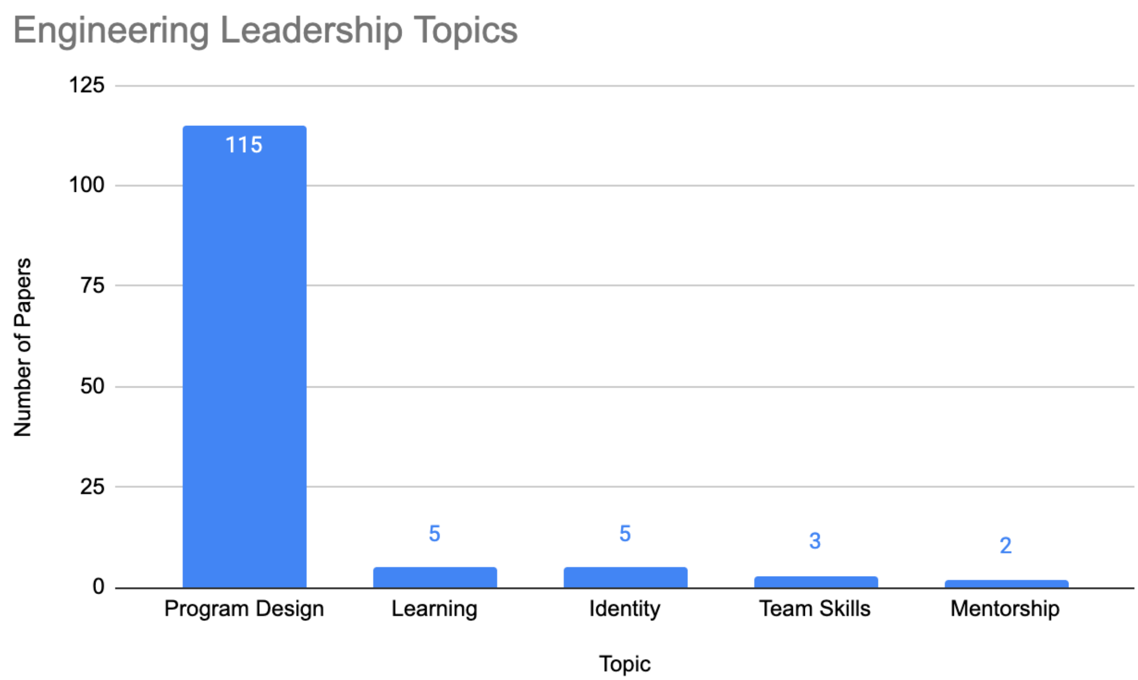

Figure 2. Distribution of Engineering Leadership Topics.

Table 2 shows the top ten meaningful words extracted in each category for LEAD. Topics 1 and 5 (program design and mentorship) fall broadly into the thematic code group of program design and effectiveness; the key words in both topics relate to the structure and relationships built into "Engineering and. . ." programs. Topics 2 and 4 fall under the theme of identity and culture, as the key words focus on an engineer's sense of self and career. Topic 3 falls best under the teams and groups theme, as the key words relate to the features of individuals and groups that contribute to teamwork.

	Topic 1: Program Design	Topic 2: Learning	Topic 3: Team Skills	Topic 4: Identity	Topic 5: Mentorship
Keyword 1	student	engineers	kgi	identity	mentors
Keyword 2	course	technical	mbti	self	peer
Keyword 3	team	career	training	model	mentoring
Keyword 4	project	paths	group	variables	college
Keyword 5	faculty	organizational	team	experiences	student
Keyword 6	programs	situated	profile	analysis	year
Keyword 7	leader	orientations	personal	leader	retention
Keyword 8	experience	social	instrument	group	training
Keyword 9	page	findings	seminar	data	organization
Keyword 10	group	sample	type	college	interview

Table 2. Terms Associated with Engineering Leadership Topics.

4.3.2 Results for ENT

Figure 3 reveals similar patterns for ENT. A plurality of papers—over 40%—mainly discuss program design. The other four topics in the top five differ from LEAD and thus highlight what distinguished the divisions from each other. Many papers also fall into the entrepreneurial experience or entrepreneurship identity topics, which together account for another 44% of papers. Finally, the innovativeness and mindset topics account for the remaining proportion of papers. Compared to LEAD, it is apparent that papers are less focused on program design according to quantitative analysis.

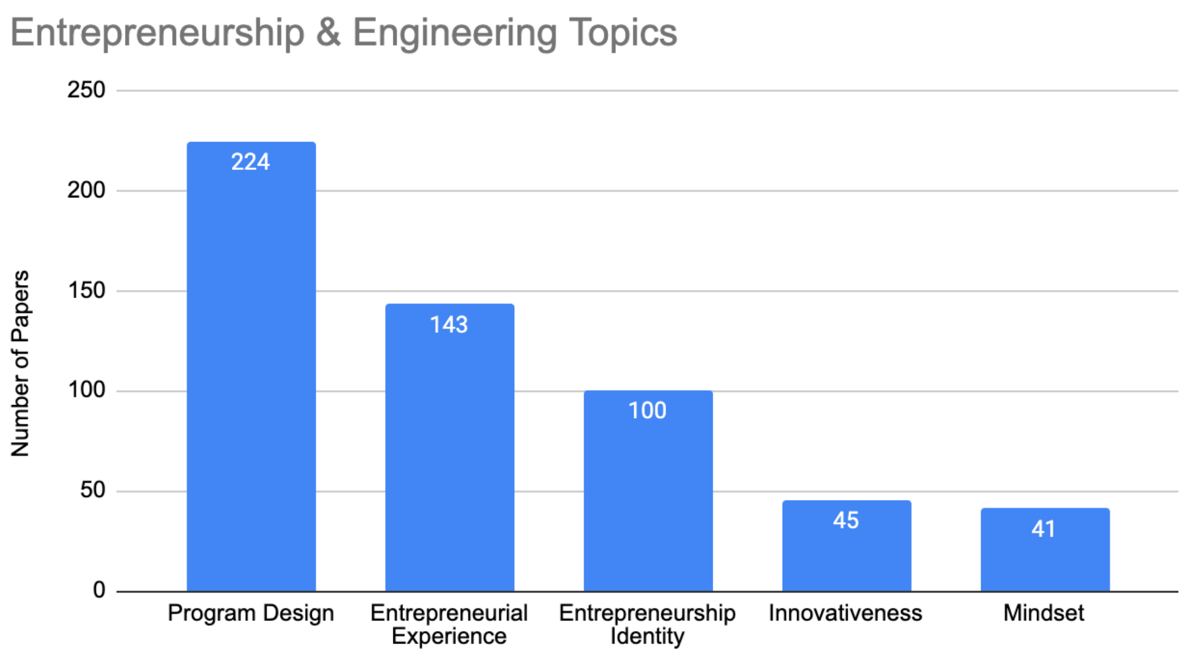

Figure 3. Entrepreneurship & Engineering Innovation Topics.

Table 3 shows the key words for the five topics within ENT. Topics 1, 2, and 5 fall best under the program design and effectiveness theme, as they focus on the features, strategies, and frameworks used by entrepreneurship and innovation programs. Topic 3 is characterized by the identity and culture theme, as the key words relate to an entrepreneur's self and mindset. Topic 4 relates to the individual capabilities theme as the key words focus on an individual's thinking and personality.

	Topic 1: Program Design	Topic 2: Entrepreneurial Experience	Topic 3: Entrepreneurship Identity	Topic 4: Innovativeness	Topic 5: Mindset
Keyword 1	design	entrepreneurship	entrepreneurship	innovation	module
Keyword 2	project	business	entrepreneurial	creativity	eml
Keyword 3	course	program	self	process	keen
Keyword 4	team	technology	efficacy	innovators	mindset
Keyword 5	learning	faculty	study	participants	learning
Keyword 6	class	page	items	thinking	entrepreneurial
Keyword 7	product	entrepreneurial	mindset	creative	curiosity
Keyword 8	problem	programs	survey	ideas	value
Keyword 9	process	entrepreneurs	career	problem	minded
Keyword 10	semester	commercialization	gender	competencies	courses

Table 3. Terms Associated with Entrepreneurship & Engineering Innovation Topics.

4.3.3 LEAD and ENT Combined

Figure 4 shows the five topics LEAD and ENT analyzed as a whole. The five topics generated here are not the same as the five in either division when they were analyzed alone. Compared to the individual analyses, the combined topic extraction led to more balanced topics in terms of representation. Notably, entrepreneurship, innovation, and leadership each have their own topic. The other two topics, program design and education, are general topics that cover both divisions. These two topics are the most highly represented in this analysis. Table 4 shows the key words for the five topics within both divisions as a whole. Topics 1, 3 and 5 all relate to program design and effectiveness. Topics 2 and 4 relate mainly to individual capabilities.

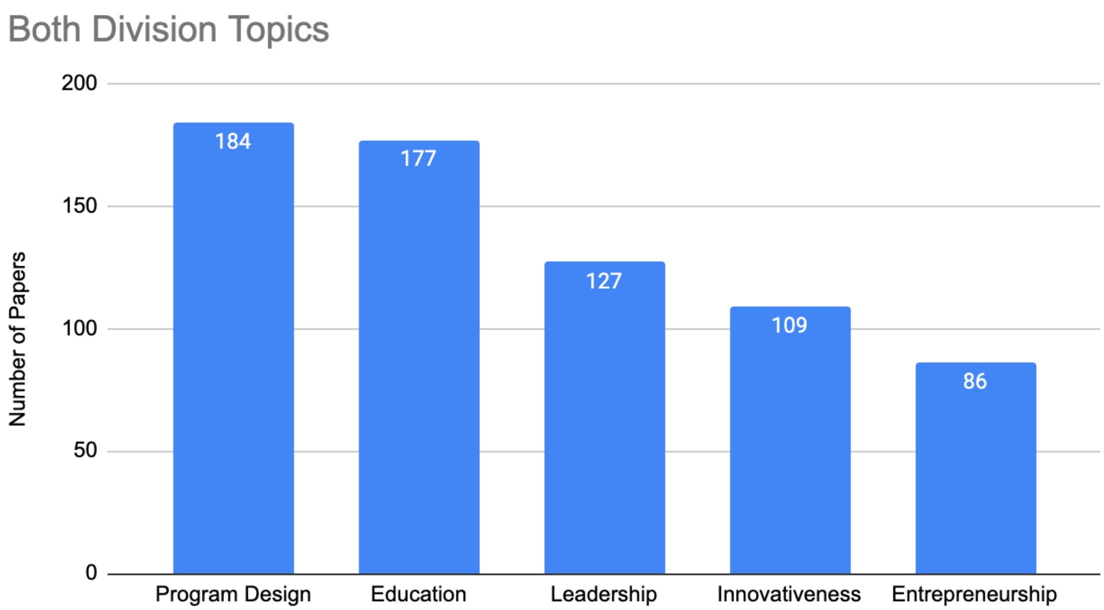

Figure 4. Topics for Both Divisions: Leadership and Entrepreneurship.

	Topic 1: Program Design	Topic 2: Leadership	Topic 3: Education	Topic 4: Entrepreneurship	Topic 5: Innovativeness
Keyword 1	program	leadership	course	entrepreneurship	innovation
Keyword 2	business	leader	design	entrepreneurial	innovative
Keyword 3	technology	skills	project	business	creativity
Keyword 4	faculty	program	learning	entrepreneurs	design
Keyword 5	team	engineers	module	mindset	process
Keyword 6	entrepreneurship	team	mindset	programs	participants
Keyword 7	product	professional	entrepreneurial	study	thinking
Keyword 8	page	self	team	efficacy	problem
Keyword 9	teams	learning	eml	faculty	creative
Keyword 10	course	management	class	self	learning

Table 4. Terms associated with Topics for both Divisions.

4.3.5 Summary of Topics LEAD, ENT, and Both Divisions Combined

Table 5 provides a comparison of the three sets of topics and highlights areas of convergence and divergence. The most striking convergence is the appearance of program design as first in all three topic models. Identity is included as a topic for both ENT and LEAD. Team skills appear only in the list for LEAD, and mindset only in the list of ENT. Innovativeness appears in the ENT and combined topic lists.

THE THREE TOPIC MODELS COMPARED			
Rank	LEAD	ENT	COMBINED
1.	Program Design	Program Design	Program Design
2.	Learning	Entrepreneurial Experience	Leadership
3.	Team Skills	Entrepreneurial Identity	Education
4.	Identity	Innovativeness	Entrepreneurship
5.	Mentorship	Mindset	Innovativeness

Table 5. Comparison of Topics for LEAD, ENT, and Both Divisions Combined.

4.4 Thematic Coding

The results of thematic coding showed that the four themes are treated pervasively and consistently in the papers of both divisions, which suggests significant convergence of concerns and interests. The discussion below organizes observations and text excerpts according to the four themes used for coding. As noted earlier, these are related to but different from the terms generated in the topic modeling.

4.4.1 Program Design

The papers in both divisions sought to establish motivations for designing programs in leadership and entrepreneurship that were often overlapping and connected. Many papers discussed leadership and entrepreneurship as secondary skills that employers sought and would position students for long-term success.

> The strategic plans of engineering programs at certain universities are aimed at intensification of innovations, development of entrepreneurship and leadership. In practice, the idea of building the knowledge in innovative entrepreneurship along with the leadership motivation that directs students towards organization of start-ups, becomes more popular among universities. (Paper 23).

> As employer's expectations for engineering graduates to acquire professional skills increase, academia faces challenges in meeting these needs and helping students to be fully prepared. While technical skills, such as math and programming, are well integrated into academic programs, faculty members have been found to face difficulties in meeting industry demands for professional skills. (Paper 12).

> This work aims to gain insight into engineering faculty members' perceptions of students' career preparation by exploring views of students' competence in the areas identified as crucial to engineering practice. (Paper 3)

Another key attribute in the theme of program design focused on assessing student and faculty perceptions of specific programs. However, these assessments rarely compared outcomes between students enrolled in the program against others outside of the program or against programs from other universities. This suggests that while the internal validity of the studies is generally well controlled, conclusions about external validity and broader generalizations are difficult to support. Furthermore, many of the studies included course evaluation data as measures of satisfaction and offered only this form of near-term data as outcomes for the course or module. A shared finding in many papers was the notion that entrepreneurship and leadership can be taught and are not inherent skills or capabilities.

> Results indicated positive, statistical change in four out of six intended dimensions: students' confidence, self-awareness, and ability to recognize their strengths and weaknesses were all significant, as was the students' perception of the success of the program. Analysis of the remaining two dimensions, students' preparedness to work in teams and student's ability to perceive the value in cooperation for group success, also indicated improvement in the intended direction. These results reflect an all-around improvement in students' perceptions of their own competence. (Paper 8).

> Using one day in-class mini-lessons was a positive experience for students. Students fully engaged with the activities throughout, and this offers a unique chance for recruitment into the full seminar program. The full seminar course was an overwhelmingly positive experience for the 12 students that participated. (Paper 18).

> Most important among these insights is the finding that leadership can be taught. (Paper 7).

> The program operates under the assumption that leadership can be taught, and every student has the potential to be a leader in their career (Paper, 46).

Many programs were designed to offer experiential learning and to bring in guest speakers as aspirational mentors. The intention was for students to identify new career paths based upon the success of professionals in leadership positions and successful entrepreneurs.

> When developing a project focus for the new Touchstone Program, the university focused on best practices already established in community engagement programs. Student learning outcomes resulting from community-engaged/service-learning opportunities are exemplified in the best practices of existing engineering programs (Paper 18).

> Finally, we have introduced engineering leadership engagement projects to the senior Civil Engineering Capstone Design Course. Specifically, the project centered on a local creek, called Bowman Creek, that the City of South Bend Public Works (Paper 9).

> A series of speakers are presented throughout the semester. These distinguished engineering, civic and business leaders range from a hospital executive to a business engineer executive to a CEO of a large technology dependent mining industry to Mayor Pete Buttigieg (Rhodes Scholar) Mayor of South Bend as Civic leader encouraging community application of engineering talent to serve purposes that stir student passions (Paper 9).

> Scholars are mentored by instructional faculty, industry sponsors, and seminar speakers. The Scholars also attend on-site networking events offered by industry sponsors and have personal coaching sessions by industry executives and managers (Paper 15).

4.4.2 Individual Capabilities

The papers discussed an array of individual capabilities that are either taught to empower students to be better entrepreneurs or leaders or discussed as traits that could be fostered through different experiences and pedagogical strategies. The programs often focused on one or two capacities in the program design and assessment, while other capacities were secondary and complementary to the program. The discourse of both divisions recognized ethical awareness and understanding people's perceptions and behaviors as essential to students' growth and future success. Many learning objectives and programmatic design spoke to these quite directly:

> Understand the impact of ethics and morals on leadership and professional responsibility (Paper 28).

> Understand change processes and overcoming inertia to change (Paper 17).

> Recognizing the importance of engineers engaging with community, industry and academic employers alike have identified a strong need to develop teamwork and communication skills in engineering graduates in order for them to succeed (Paper 41).

> Video student leader doing a couple inspirational talks on something they are passionate about---speaking from the heart---no notes and no power point. Have a professional communications coach from the university review this constructively with feedback on how better to connect and influence and tell powerful stories (Paper 8).

Other capabilities were identified as key learning outcomes and assessment criteria:

> students' confidence, self-awareness, and ability to recognize their strengths and weaknesses were all significant, as was the students' perception of the success of the program (Self-reflection, Paper 33).

> It is connecting at eye-level with those in every condition, recognizing that as humans we share the melody of a heartbeat (Ethical sensitivity, Paper 62).

> The programs together created the opportunity to add value above commodity engineering skills through instilling communications skills and self-awareness (Paper 45).

> Eventually, they learned to stop analyzing personality differences, and instead became more self-aware and compassionate, adjusting their own leadership styles (Self-Awareness, Ethical Sensitivity, Paper 37).

4.3.3 Teams and Groups

The programs in both entrepreneurship and leadership acknowledged the role of teams and groups in the educational program. Many teamwork activities were designed to address individual capacities, as well as to understand group dynamics and the differences and strengths of different people on the team. Many of the quotes below were coded for other analytical aspects, but foregrounded teamwork. The emphasis on teamwork should not be surprising, and this points to the shared intellectual roots and pedagogical lessons that can be learned across these divisions.

> Analysis of the remaining two dimensions, students' preparedness to work in teams and student's ability to perceive the value in cooperation for group success, also indicated improvement in the intended direction. These results reflect an all-around improvement in students' perceptions of their own competence in teams (Paper 33).

> Structured rotation of leadership roles on student teams, in addition to balancing team rosters, could possibly mitigate the […] phenomenon (Paper 24).

> One such [approach to] accomplish this goal [would be] via a cross-functional interaction of engineering and business students, or by linking engineering students with lead-users from another community (Paper 17).

> Students […] responded very positively to the question assessing whether students could see the value in cooperation for group success (Paper 55).

> The program begins with an off-site team-building activity at the beginning of the academic year. This strengthens personal interactions, trust, confidence and team work (Paper 42).

4.4.4 Cultures of Engineering

In many respects the cultures of engineering are being challenged by the "Engineering and …" programs that seek to differentiate the graduates of their programs from "typical" engineering graduates. In this way, many leadership and entrepreneurship papers portrayed entrepreneurs and leaders as exceptional, which could be viewed as feeding into notions of exceptionalism or elitism. The papers also wrestled with the conventional career trajectories of engineers and the roles they play within their current or future organizations. In some respects, this reinforced the duality between social skills and technical skills, although some authors highlighted how leadership and entrepreneurship bring forth more integrated sociotechnical skill sets. Many of the papers discuss the potential of entrepreneurship and leadership to draw in more diverse people and in many cases the research shed light on gender discrimination in the profession.

> To explore faculty members' perceptions of students' career preparation, this study explores professional skills (e.g., people and management skills) and technical skills (e.g., math and science skills) as leadership-enabling competencies that students must develop in order to excel throughout their engineering careers (Duality, Paper 29).

> Dr. Dan proposed that leadership education should be provided to students who plan to be leaders: And I don't think that we should, we should say that everybody has to be a leader. I think what we need to do is we need to find, you know, where the students find out who they are…. Leadership is important, but I think it's more important to align the students with who they are and the areas they're going into. Dr. Dan explained that not all students want to take leadership positions in their careers (Exceptionalism, Paper 29)

> The first cohort of Scholars was selected from applications submitted from a general call. These students were all excellent and deserving, however the decision was made to try to encourage students from all backgrounds, hence the practice of more targeted invitations as a recruiting strategy (Exceptional, Diversity, Paper 51).

> We can do this in a number of ways—all of them grounded in the recognition that engineering is a socio-technical, rather than purely technical profession (Duality, Paper 44).

> Five 'pictures' frame the discussion of findings: 1) Gender Distinctions in Leader or Entrepreneur Constructs, 2) Variations in Leader and Entrepreneur Creation of Team, 3)Traditional and Contemporary Ways Women Emerge as Leader, 4) Family Influences on the Leader, and 5) Emotional Balancing Act of Leader (Diversity, Paper 17).

> We make the assumption that EL educators aim to reach a representative cross-section of engineering students, but it is important to note that this paper offers no proof that this reach is not presently being achieved. We merely caution of the possible effects of cohort non-representativeness (Diversity, Paper 37).

> Women, in particular, described gendered mobility patterns favouring male colleagues. The female invisible engineers' explicit attention to gender contrasted with a general reluctance among other senior engineers of all genders in our sample to share their observations about inequitable reward systems (Diversity, Paper 22).

5. Discussion and Implications: Convergence in Concerns, Divergence in Content

The results presented above were derived almost entirely from the data in LEAD and ENT papers. A similar analysis of the EMD and EPP papers is underway. While the results of that analysis may differ, the LEAD and ENT results have implications for EMD and EPP as well. The results of our analysis demonstrate that there is much convergence at the level of generalized concerns and challenges in both LEAD and ENT. Perhaps the most striking of these is the attention that papers in both divisions devote to program design. At one level this is not surprising given the amounts of effort and innovation that are required to get leadership and entrepreneurship programs established in an engineering context, but it also suggests that many of the publications in the field are directed toward the sponsors at the program's home institution rather than the scholarly communities engaged in engineering leadership and entrepreneurship. These circumstances suggest several opportunities for collaborative efforts that could benefit the "Engineering and. . ." community as a whole.

5.1. Program Design and Effectiveness

Most of the concerns related to this theme arise from the fact that LEAD and ENT are not parts of engineering education as traditionally understood. There is no established template, and there are lots of options to be considered. Knowing what the options are does not necessarily make choosing easier, but it does allow for more focused thinking. Because thinking in meaningful ways about leadership and entrepreneurship requires an understanding of the non-academic contexts in these capabilities are exercised, programs in these areas require faculty and pedagogical strategies that differ from those that are traditional in engineering and may be difficult to obtain and integrate in an academic context. This category also reflects the ways in which "Engineering and. . ." endeavors respond to changing paradigms and pressure as well as a sense of challenges and possibilities in engineering education. In the case of entrepreneurship, the most important of those pressures comes from embracing a neoliberal approach to higher education in which public-private partnerships are important sources of funding—and justifying higher education investments often means connecting academia to economic growth. In the case of leadership, the most important pressure arises from a desire to overcome/undermine stereotypical views of engineering and optimize the contribution of engineering in a variety of contexts, promote career success, attract a broader range of people into engineering, and differentiate engineering programs from others in a competitive environment.

Assessment is an intrinsically important part of engineering education, but it becomes even more important when it comes to justifying investment in non-traditional curricula and programs. People who are designing and developing new programs are not likely to question the value of assessing outcomes and thus may not think critically about (1) whether the results of assessment processes produce evidence that can be just to support arguments for funding and (2) whether evidence of effectiveness is likely to ultimately be persuasive to sources of potential funding. In other words, maybe the problem is that “Engineering and . . .” programs often either implicitly or explicitly identify gaps and limitations in traditional programs, and decision-makers will be reluctant to embrace them because of the message they send about engineering, rather than the benefits that accrue (or not) to students in the programs. Regardless of whether the program is in leadership, entrepreneurship, management, or public policy, “Engineering and. . .” programs face significant organizational and cultural challenges, especially challenges with funding. If program builders are able to see the challenges they face as part of a larger pattern, they should have a better understanding of those challenges, more ideas about how to break the pattern, and a better chance for establishing the long-term stability of their programs and courses.

5.2 Individual Capabilities

One of the biggest differences between the “Engineering and. . .” domains and traditional engineering education is the emphasis those broader domains place on the development of character traits and transferable skills as opposed to domain-specific knowledge that can be easily assessed through testing. Items in the traits subcategory focus on character, values, attitudes, the kind of person an engineer is, and the way an individual relates to the world around them including other people. The traits bear significant resemblance to virtues in the Aristotelian sense: they are characteristics and capabilities that are developed through mutual shaping of individuals and the environments in which they are educated and act. They are developed through experience and processes of reflection. The experiences can be carefully designed, and the reflection processes can be skillfully structured, but the development of these traits is not the result of teaching or learning as traditionally understood in engineering.

The theme called “thinking tools” is probably the least conventional of the subthemes. The distinguishing feature of these “tools” is that they are not knowledge-domain specific. They are instead structured approaches to seek out and organize information, see underlying patterns in human behavior, and make connections between entities that seem disconnected from each other. Making such connections can be invaluable as a source of creativity and a way to reach different audiences and stakeholder groups. Again, while the specific content being sought out might different significantly across the four divisions, the processes for gathering, organizing, and gaining insight from know are fundamentally the same even if not recognized as such.

5.3. Teams and Groups

The codes under this theme establish the depth and diversity of the meanings casually assigned to terms like “teamwork” and “group work.” The “coordination, cooperation, collaboration” code captures both the multiple ways that group activity can be framed and raises questions about *why* we want or need to work with others. “Multidisciplinary teams” and “knowledge integration” highlight the interdisciplinary character of all “Engineering and. . .” endeavors as well as the challenges of bringing different forms of knowledge together for the achievement of particular goals. “Negotiation” and “conflict management” focus on the need to deliberately manage differences within groups, while “relationship between individual capabilities and group functioning” calls attention to the ways in which groups considered as a whole and the individuals within the group mutually shape each other.

5.4. Identity and Culture

This theme is perhaps the most complicated and relates in significant ways to the first theme's concern with the relationship between the categories "technical" and "non-technical" in engineering. Whether we conceive of "duality/sociotechnical differentiation" in terms of non-technical/technical, either/both, simplistic/complex, or deterministic/contingent, all of these codes reflect the reality that difference and similarity are intimately intertwined in all contexts outside of academia. The last two codes reflect the way that what it means to be an engineer can change and evolve over an individual's career as they assume new roles and responsibilities. One of the most important aspects of identity is captured in the question of whether we see engineering identity as incorporating leadership and entrepreneurship as integral parts of that identity or as something that emerges in special circumstances for special people. In sum, how we think about "Engineering and. . ." depends a great deal on how we conceptualize engineering to begin with. The recognition of an intersection or connection provides an occasion to reflect on and develop a more nuanced understanding of the entity we are connecting with.

5.5. Features that Distinguish the Divisions from Each Other and Help Define Their Distinctive Mission (Research Question 3: Identifying Significant Differences That the Divisions Could Use to Clarify Their Missions)

The distinctions captured in Table 5 are more suggestive than definitive. A few other distinctions emerge from consideration of indiviuals terms in the topics. For example, business, technology, and commercialization appear only in Topic 2 in the list for ENT. The mindset topic for ENT reflects the influence of the KEEN program and its emphasis on entrepreneurially minded learning. The LEAD teams topic includes the Klein Group Instrument for Teams (KGI) and the Myers-Briggs Type Indicator (MBTI) as the top two keywords, which suggests that these kinds of individual and team assessment tools are widely used in LEAD but not in ENT. Innovativeness appears in both the ENT topic list and the combined topic list, but neither innovativeness nor creativity appears as a keyword in any of the LEAD topics. These apparent differences may reflect different ways of talking about the same thing rather than a difference in content, a possibility that is worth investigating.

5.6. Limitations and Future Work

The most significant limitations in the analysis described above arise from the fact that does not include analysis of EMD and EPP papers. The list of themes and subthemes may need to be modified or expanded to accommodate the two additional divisions, a result that would most likely improve the effectiveness of the themes as a tool for coding and a guide to the decisions that have to be made in the design of programs and courses in all four fields. Once this analysis is completed and the results are entered in Dedoose, we will have quantative data about the frequency and co-occurrence of the themes sorted by division and compiled for the whole. These results should help us refine our articulation of areas of convergence and divergence. Beyond completing the rest of the analysis, we will need to begin conversation among the "Engineering and. . ." divisions considered in our project and other divisions in that space, especially the Liberal Education/Engineering and Society (LEES) division, which also promotes interdisciplinary enterprises that attempt to integrate humanistic content and goals into engineering education. The humanities and social sciences as traditionally understood have much to contribute to achieving the outcomes of educational programs in the four fields included in this study, even though the possibilities for that contribution may not be readily apparent.

6. Conclusion and Next Steps

The results presented in this paper demonstrate that the method we developed reliably identifies areas of convergence in the themes that dominate the discourse of LEAD and ENT. It seems likely that the method will generate equally useful results when applied to EMD and EPP. The results so far suggest that the areas of convergence as much greater than a casual examination of the names of the four divisions suggest. The thematic overlap provides lots of opportunities for collaboration. Having a clear view of what the "Engineering and. . " divisions have in common—and of ourselves as involved in a collective enterprise—should help us deal more effectively with the challenges we face as groups who are trying to facilitate knowledge integration and connect engineering education with the contexts and demands of engineering practice. The research reported here is a step in that direction. It also raises questions about the purposes of organizational differentiation in ASEE. Engineering educators, like human beings generally, are inclined to seek the company of others who share their interests and views. Engineering education has historically been very responsive to changes in the larger organizational and cultural contexts of engineering. These factors may well account for the proliferation of divisions within ASEE. The dispersal of the discourse on topics of shared interest can be viewed as an unintended negative consequence of bringing attention to important but often overlooked intersections of engineering with the world outside of academia. We are *not* promoting elimination or combination of divisions as a way of dealing with these challenges, and we most assuredly are not proposing the creation of a new division. We are, however, suggesting that we might draw on the insights of organizational behavior regarding the relationship of differentiation and integration in complex organizations and explore the ways that the "Engineering and. . ." divisions can collaborate to implement effective integrative strategies in ASEE and in organizational contexts beyond ASEE,

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Appendix I: Mission Statements, Calls for Papers, and Sample Papers for All Four Divisions

Engineering and Public Policy Division

This division fosters an understanding of policy issues with significant technological components among engineering faculty, students and professionals in government and industry. It provides a communications link for those heavily involved in engineering and public policy education while at the same time, reaching out to the larger ASEE membership.

2023 Call for Papers

The ASEE-Engineering and Public Policy Division (EPPD) invites abstracts for papers, proposals for full sessions, panel discussions and other session formats for the 2023 annual conference, to be held in Baltimore, Maryland, June 25-28, 2023. The mission of the EPPD is twofold:

1. To promote public policy curricula in engineering education through the development of courses, modules, programs, and case studies. This includes teaching subjects such as public policy, how policy affects the practice of engineering and vice versa, and how teaching students about public policy affects their careers.

2. To promote dialog on policy issues affecting engineering education and engineering research at institutions.

We welcome submissions related to any of the diverse areas of public policy that impact engineering education. Papers and proposals on all topics germane to policy and engineering education will be considered. Example topics include:

- Case studies of faculty experience with policy in your professional practice, service, research, and teaching
- Case studies on how public policy influences engineering and how they are used in courses (final paper to include summary of module and materials)
- Strategies for including public policy issues in traditional courses
- Development of new programs that involve elements of public policy
- How public policy on education has steered engineering education
- Accreditation requirements and their influence on engineering education
- Using engineering analytics to influence policy

  The EPP Division is interested in sponsoring sessions that bring together different divisions to address common areas of policy implications, as well as sponsoring distinguished lecture or panel sessions germane to the division’s mission. Please contact the program chair with ideas or requests for co-sponsorship. More details on submissions in the pdf.

All paper submissions are publish-to-present. Submissions may include case studies, research reports, classroom applications, exploratory topics, and works-in-progress. Papers describing activities in professional practice (e.g., involvement in a policy-related fellowship) can be narrative in structure. Recommended paper length is 3 to 12 pages in ASEE conference proceedings format, with research based papers anticipated to be longer.

All abstracts must be submitted through the ASEE paper management system. At least one author for each accepted paper is required to register for and present the paper at the conference.

Information for authors, including due dates and formats for abstract and paper submission, can be found on the ASEE website: https://www.asee.org/events/Conferences-and-Meetings/2023-Annual-Conference/Paper-Management/Deadlines.

Engineering Leadership Development Division

This unit aims to provide a primary point of discussion and dissemination on the value and impact of engineering leadership education. Although engineering leadership is a nascent field, the number of such programs continues to grow as a function of interest from universities, students, and employers. LEAD will provide resources to enhance the understanding of leadership traits for engineers, create a forum for best practices in the field, and encourage efforts to improve engineering leadership pedagogy.

2023 Call for Papers

The **Engineering Leadership Development Division (LEAD)** of the American Society for Engineering Education (ASEE) seeks paper abstracts for the **2023 Annual Conference in Baltimore, MD, June 26- 29, 2022**. The LEAD Division is committed to advancing our shared understanding of engineering leadership theory and practice to enhance the contributions of engineering students and professionals to their respective institutions, industries, and society. Integral to these objectives is our commitment to fostering the development of inclusive, diverse, and equitable engineering leaders, educators, and researchers.

All paper submissions are publish-to-present. Papers submitted to technical sessions are peer-reviewed through the LEAD Division, and those accepted will appear in the ASEE Conference Proceedings. The first step in proposing a paper is to submit an abstract to the ASEE paper management system by **Monday, October 31, 2022**. Abstracts should be 250-500 words and will be peer reviewed. If your abstract is accepted, the first draft paper deadline is Tuesday, January 31, 2023**.** Paper submissions may include **research** studies or **practice** reports. We accept works in progress. We encourage papers that synthesize and identify trends in research of interest to the Division, especially those aligned with our four strategic initiatives: Inform, Design, Explore, and Assess.

Topic Area—The following topic areas align with our Division's four strategic initiatives and current research trends and needs. For each of the Key Question areas, papers should include more than simple descriptions of programs. Evaluations, assessments, and studies are of particular interest for the 2023 conference.

1. ***Inform:*** *Document the need for and value of engineering leadership (EL) education in university and workplace contexts.* ***Key Question for 2023:*** *How is EL being integrated across the curriculum?*
2. **Design:** Demonstrate evidence-based practices for designing, implementing, and sustaining EL programs. **Key Question for 2023:** *What diverse models/theories of leadership are being incorporated into EL programs or curricula?*
3. ***Explore:*** *Examine leadership theory and/or practice in engineering education or workplace settings.* ***Key Question for 2023:*** *How do you describe, assess, and/or test the transfer of EL development from academic settings to the workplace?*
4. **Assess:** Evaluate the impact of curricular interventions, EL development models, or EL programs on engineering students and professionals. **Key Question for 2023:** *What assessment tools are EL programs using, and what are the findings from applying those assessment tools?*

The LEAD Division accepts abstracts for the following two **submission types:**

1. **Research papers** present new findings, situated in the context of prior research and existing models to reveal relationships, patterns, or insights relevant to engineering leadership. Papers should include an introductory problem statement; a review of relevant literature; a description of the research methodology; results; and implications of the work in furthering the LEAD Division's strategic priorities. We encourage authors to consider aspects of diversity, equity and inclusion in their research design and reporting of results. Research papers may take the form of literature reviews, meta-analyses, empirical studies, or theory development. As the field of leadership studies is broad, we strongly encourage authors to cite research from fields outside of engineering, including but not limited to psychology, sociology, business, education, and the humanities.

2. **Practice papers** highlight and analyze innovative engineering leadership education practices in industry or classroom contexts. These papers are not required to include an exhaustive literature review, but authors are encouraged to cite relevant literature, theories, or frameworks that inform the highlighted practice. Authors should include some measure of effectiveness and identify implications for EL education and/or training in other contexts. Practice papers may take the form of case studies, curricular innovation, EL assessment tool development, or program evaluation. We encourage authors to consider aspects of diversity, equity and inclusion in their program design and reporting of results.

Both research and practice papers can be submitted as **Work-in-Progress (WIP) papers**. WIP papers are **3-5 page** extended abstracts reporting on projects that are not yet fully developed and/or are only supported by preliminary data. For example, papers describing innovative practices without a formal evaluation of effectiveness are acceptable as WIPs.

Full papers published in the ASEE conference proceedings are typically **10-15 pages** long, while WIP papers are typically **3-5 pages** long. Out of respect for our reviewers, please keep to these page limits.

Abstracts will be peer-reviewed by members of the LEAD community. They should be **250-500 words in length** and **include:**

- Submission type (research, practice, WIP-research, or WIP-practice). WIPs should include "Work in Progress" in the title using the following form: [TITLE]: A Work in Progress.
- LEAD Division strategic priority (Inform, Design, Explore, or Assess)
- Guiding question, problem statement, or key project objectives
- Project context
- Theoretical perspective, conceptual framework, or instructional approach being used
- Research methods, evaluation, or assessment practices
- Preliminary findings
- Implications for engineering leadership research and/or practice, and
- Significance to LEAD division members

Depending on the number of papers submitted, some papers, such as WIPs, may be moved to a poster- presentation format. We welcome studies utilizing quantitative, qualitative, or mixed research methods. Please refer to the ASEE paper rubric for important paper qualities and follow the formatting guidelines detailed in the 2023 ASEE Author's Kit. We seek high levels of relevance with our Division's interests and expect high standards of academic quality, especially with papers we eventually publish. We encourage student-authored papers. Papers will be evaluated according to the ASEE paper rubric and relevance to the LEAD strategic priorities.

Engineering Management Division

The Engineering Management division encourages educational exchange, friendly cooperation, and mutual help among its members. Its purpose is to promote educational programs in engineering management, galvanizing the inclusion of courses on engineering management in traditional engineering curricula, and providing a forum for discussion by all engineering educators on the role of management in engineering. Engineering Management programs are designed to prepare engineers to gain the management skills for leadership roles in complex engineering activities in industry, government, education, and the military. The Engineering Management Division is also committed to strengthening the inclusion and education of diverse individuals and embracing diverse ideas in the professions of engineering and engineering technology. The Engineering Management Division recognizes that diversity is strength in creativity, broadness of new ideas, and embracing new perspectives to arrive at the most truly innovative, resource-smart solutions possible.

2023 Call for Papers

The Engineering Management Division (EMD) of the American Society for Engineering Education (ASEE) seeks paper abstracts for the 2023 Annual Conference in Baltimore, MD. EMD is a publish-to- present division. Both abstracts and papers must be accepted to be eligible for presentation at the conference. Submissions are blind reviewed through EMD and accepted

papers are published in the ASEE Conference Proceedings.
We invite you to be active in the planning process and help us make this an engaging and successful conference for us all. You can start by forwarding this call to all your colleagues, even those who are not active in or a member of ASEE. We value collaborative, multi-authored submissions.

Theme:
Workforce Readiness: Preparing our graduates for the jobs of today & tomorrow

The first step is to submit an abstract (250 – 500 words) by October 31, 2022 through ASEE's Paper Management System for authors. The abstract should provide a clear statement of the work's objective and its relevance to engineering management education.

Topics may include any applications of engineering management as it relates to education and the development of future engineering managers. All topics in the Engineering Management Body of Knowledge (EMBOK) are welcomed including, but not limited to: Leadership and Organizational Management, Strategic Planning, Financial Resource Management, Project Management, Supply Chain Management, Management of Technology, etc. Suggested topics in education include, but are not limited to: engineering management program organization, approaches to outcome assessment and program/course effectiveness, workplace applications of engineering management skills and concepts with educational implications (including academic-industry collaboration), engineering management education success stories, innovative teaching practices in engineering management, asynchronous or synchronous learning networks, diversity, equity and inclusion. Sessions may be jointly organized with these divisions: Engr. Economy, Industrial Engr., Systems Engr.

EMD accepts these submission types:

1. Researchpaper-Informedbyareviewoftheliterature,itfollowsthescientificmethod,states

   research questions, collects data and performs qualitative, or quantitative, or mixed methods analysis to make original contribution to the literature in the form of new model, process, theory, predictions, or inferences.

Practicepaper-Presentsnovelpracticeandinnovativestrategiesinengineeringmanagement education, supported by relevant measures and metrics for effectiveness and supported by citations from the literature. Some examples are: case studies, research-based instructional strategies, active-learning assignments, project-based learning, laboratory experiments, course and program evaluation methods.

Entrepreneurship and Engineering Innovation Division

The mission of this division is to foster and disseminate approaches to educate and stimulate faculty and students at all levels on entrepreneurship, including partnerships with business schools as well as the business and technology enterprise communities.

Call for Papers
Entrepreneurship and Engineering Innovation Division

The ENTREPRENEURSHIP AND ENGINEERING INNOVATION DIVISION (ENT) invites abstracts for papers and posters to be presented at the 2023 Annual Conference & Exposition in Baltimore, MD, June 25 - 28. The submission and review process are blind; please, do not include names of authors or institutions within the title or body of the Abstract. Abstracts are generally 250-500 words.

The ENT Division accepts full papers and works-in-progress for publication and presentation at the conference. Full papers represent work that, at the time of the draft paper submission, will present completed work that will allow for analysis of results and conclusions. Works-in-Progress (WIP) represent work that is not yet ready for a full paper but may be of interest to the ENT community. WIP may be presented as regular talks or as poster presentations. For WIP submissions the paper **must** have the phrase “Work-In-Progress: ” in front of the remainder of the title.

If an abstract is accepted, authors are invited to submit a full draft paper. Draft papers are reviewed and either accepted, accepted with further revisions, or rejected. If accepted, at least one author must pay the appropriate ASEE registration fees and attend the conference to present the paper. The ENT Division is Publish to Present. As in previous years, monetary awards are given to authors of the Entrepreneurship and Engineering Innovation Division best full papers. These awards are presented at the division reception held during the ASEE Conference.

We encourage authors to submit papers that may be nominated by reviewers for the ASEE Best Diversity, Equity, and Inclusion Award. Please review the award rubric before submitting (https://diversity.asee.org/deicommittee/best-paper-rubric/). Reviewers will nominate papers for this award during the review process.

Papers that address the following, or related, themes are invited:

1. Student Learning
    1. Teaching innovation or entrepreneurship as part of an engineering program
    2. Integrating innovation or entrepreneurship into core engineering courses
    3. Learning environments that foster innovation and entrepreneurship
    4. Engineering education and the entrepreneurial/innovative mindset
    5. Assessment of entrepreneurship and innovation competencies
    6. Entrepreneurial and innovative internships and co-op experiences
2. Diversity and Global Issues
    1. Enhancing diversity via entrepreneurship and innovation education
    2. Entrepreneurship and innovation as a means to empower underrepresented groups within engineering education
    3. Ethics associated with entrepreneurship and innovation education
    4. Engineering entrepreneurship/innovation in developing economies
    5. Sustainable entrepreneurship/innovation related issues and programs
3. Faculty and Programs

1. New innovation and entrepreneurship programs and program models
2. Strategies to teach innovative and entrepreneurial engineers
3. Developing entrepreneurial and innovative faculty
4. Cross campus collaboration beyond engineering (business, humanities, etc.)
5. Assessment of innovation and entrepreneurship courses and programs

We encourage papers that include either a quantitative or a qualitative research approach. All abstracts and papers must be submitted through ASEE's Monolith system. Conference and submission information is available through the ASEE website: https://www.asee.org/events/Conferences-and-Meetings/2023- Annual-Conference.

Appendix II: Sample Papers Used to Create Initial Themes

Allain, S. (2022). MELP, an innovative master of engineering degree bridging engineering, law, and policy. ASEE ID #38045

De Weck, O., Rahaman, R. & Schindall, J. (2022). Integrating Technical Leadership and Communications Programs at MIT: Challenges and Opportunities. Paper ID #38131
Rottmann, C., Moore, E., & Radebe, D. (2022) Who identifies as an engineering leader? Exploring influences of gender, race, and professional experience. ASEE ID #38126

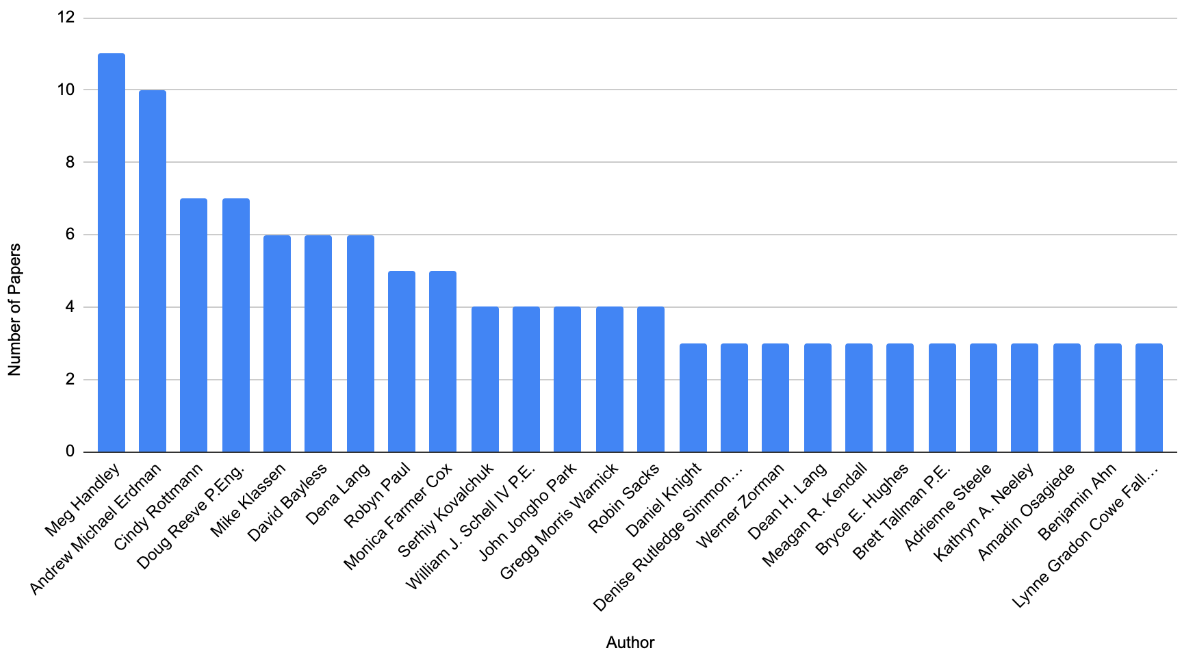
Argarpoor, J. & Lewis, N. (2022). Is engineering management really an engineering field of study? ASEE ID #36548

Pintu, J., Munim, Z. & Sokolov, A. (2022). Measuring the systems engineering management skills of undergraduate students using a new valid and reliable instrument. ASEE ID #38135.

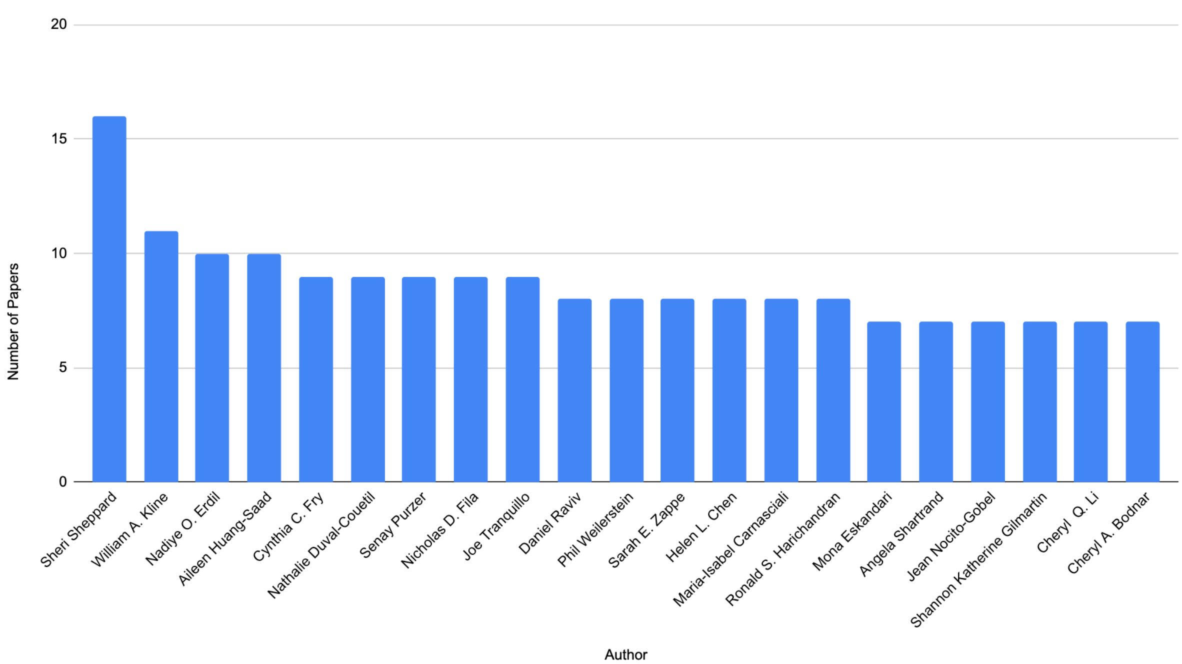
Thompson, S., Cheville, A. & Forsyth, J. (2022). Addressing convergent problems with entrepreneurship-minded learning. ASEE ID#37806

Appendix III: Top Authors and Universities.

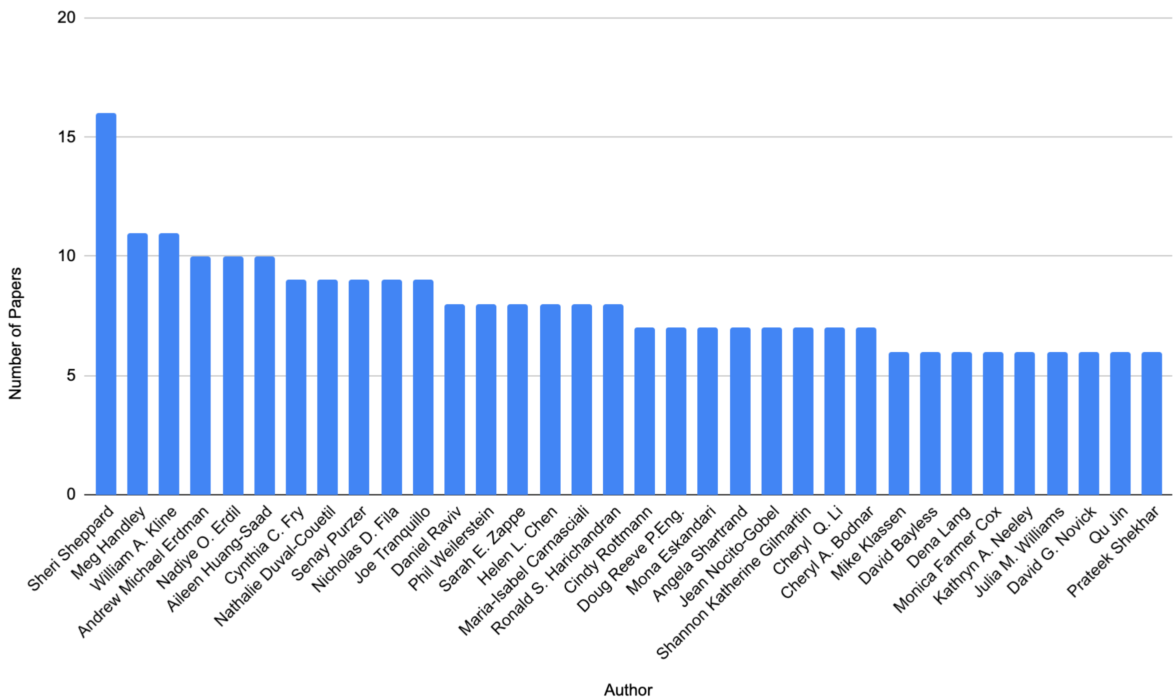
Top Authors in Engineering Leadership Division



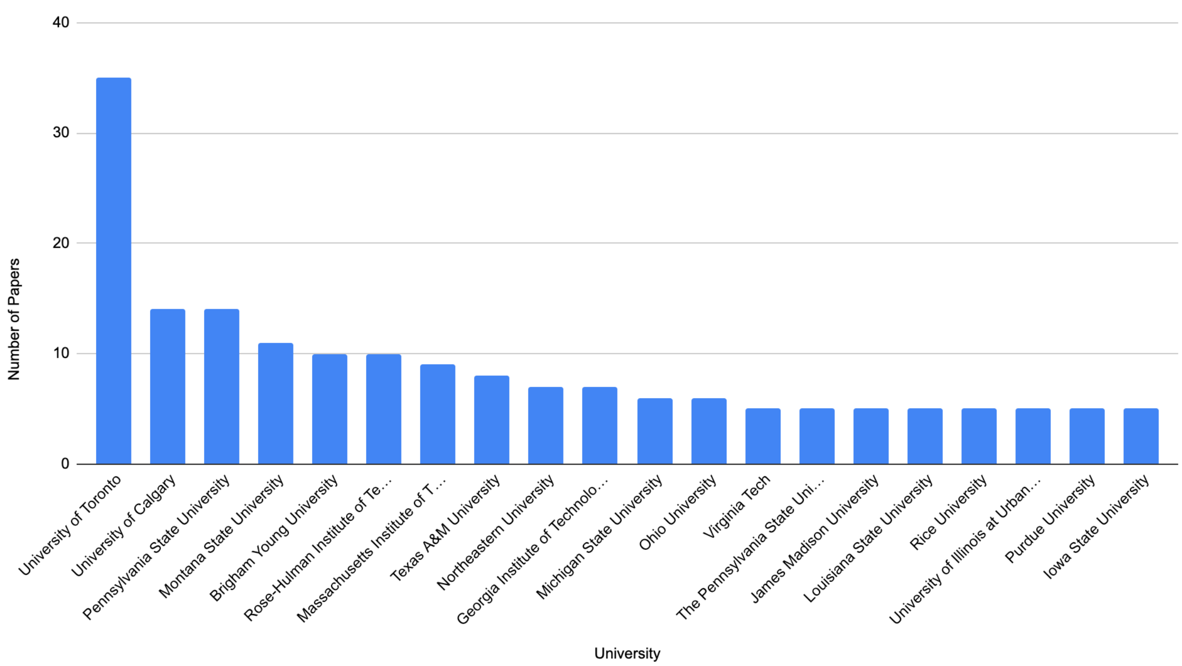
Top Authors in Entrepreneurship & Engineering Innovation Division

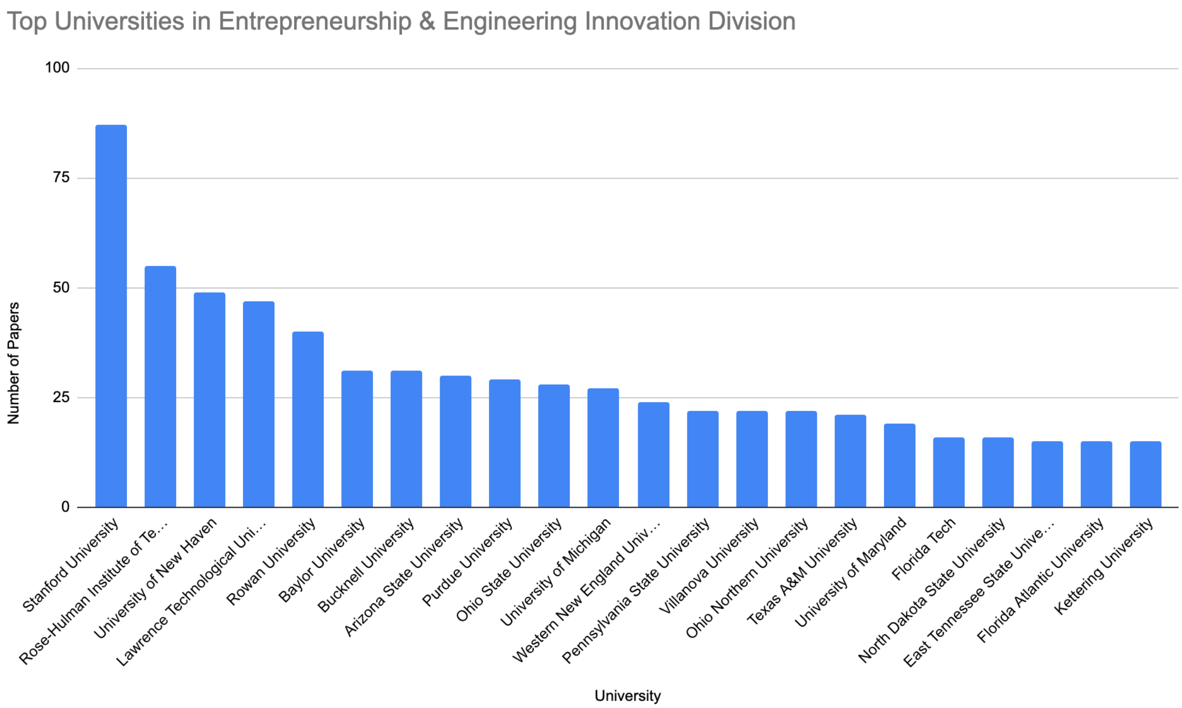


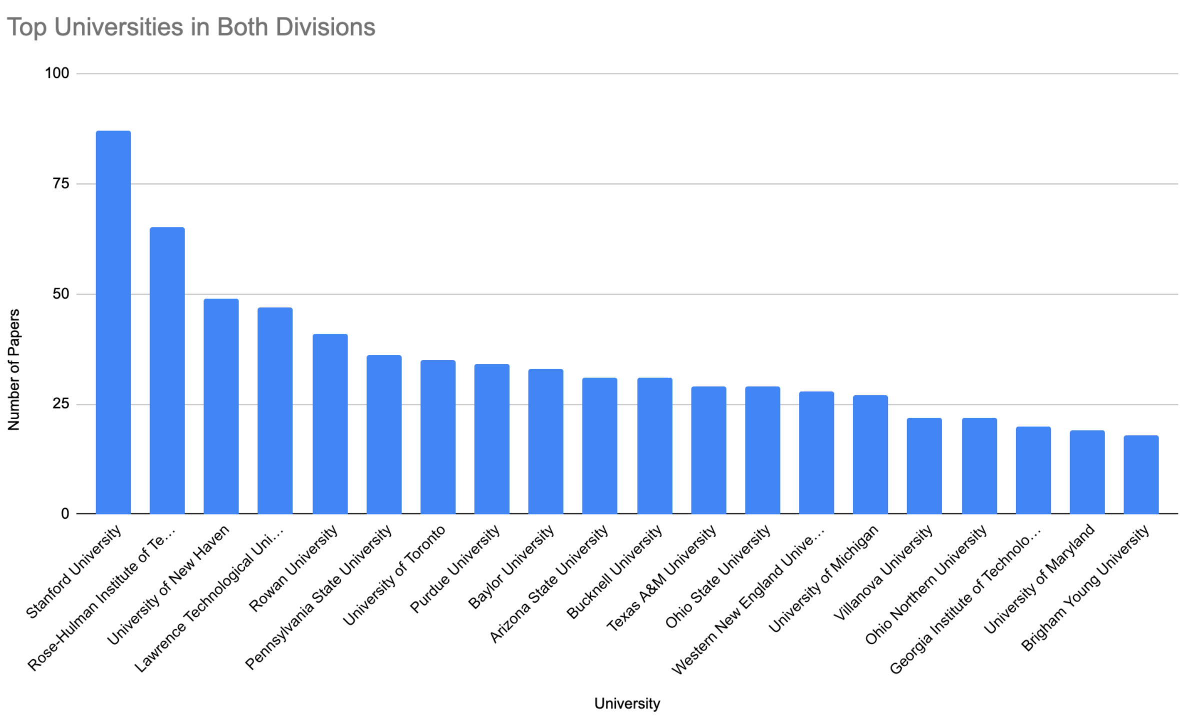
Top Authors in Both Divisions



Top Universities in Engineering Leadership Division




Top Universities in Entrepreneurship & Engineering Innovation Division
Number of Papers
100
75
50
25
0
Stanford University
Rose-Hulman Institute of Te…
University of New Haven
Lawrence Technological Uni…
Rowan University
Baylor University
Bucknell University
Arizona State University
Purdue University
Ohio State University
University of Michigan
Western New England Univ…
Pennsylvania State University
Villanova University
Ohio Northern University
Texas A&M University
University of Maryland
Florida Tech
North Dakota State University
East Tennessee State Unive…
Florida Atlantic University
Kettering University
University


Top Universities in Both Divisions
Number of Papers
100
75
50
25
0
Stanford University
Rose-Hulman Institute of Te…
University of New Haven
Lawrence Technological Uni…
Rowan University
Pennsylvania State University
University of Toronto
Purdue University
Baylor University
Arizona State University
Bucknell University
Texas A&M University
Ohio State University
Western New England Unive…
University of Michigan
Villanova University
Ohio Northern University
Georgia Institute of Technolo…
University of Maryland
Brigham Young University
University

Appendix IV: Topic Lists with Top Papers

Engineering Leadership: Top Papers in Each Topic

Topic: Program Design

1. Paper ID #13341 The Touchstone Engineering Leadership Development Program
2. Paper ID #13734 Implementation of an Undergraduate Engineering Curriculum to Prepare 21st Century Leaders
3. Paper ID #11557 Development of the James Madison University Undergraduate Engineering Leadership Program
4. Paper ID #7423 Leadership Development in Tight Times: Scaling up courses without watering them down
5. Paper ID #23184 Convergent Approaches for Developing Engineering Leadership in Undergraduates

Topic: Learning

1. Paper ID #21682 Examining the Engineering Leadership Literature: Community of Practice Style
2. Paper ID #25598 Counting Past Two: Engineers' Leadership Learning Trajectories
3. Paper ID #11903 The Ebb and Flow of Engineering Leadership Orientations
4. Paper ID #19462 Leading from the Bottom Up: Leadership Conceptions and Practices Among Early Career Engineers
5. Paper ID #29286 Wisdom through Adversity: Situated Leadership Learning of Engineering Leaders

Topic: Identity

1. Paper ID #13092 Training for Leadership and Team Skills from Freshman Year Forward
2. Paper ID #16052 Completing the Pass: Leadership 'On' and 'In' the Field
3. Paper ID #18372 Observations of the Application and Success of Leadership Development Tools with Undergraduate Engineering Education
4. Paper ID #32453 Adapting an NSF-Funded Professional Skills Curriculum to Train Engineers in Industry: A Case Study
5. Paper ID #28554 Using a Structured Approach to Reflective Journaling in Engineering Leadership Development

Topic: Team Skills

1. Paper ID #25196 Exploring the Relationship Between Students' Engineering Identity and Leadership Self-Efficacy
2. Paper ID #20047 An Approach to Understand the Role of Identity in Engineering Leadership
3. Paper ID #33843 How Do Human Interaction Labs Contribute to Engineering Leadership Development Growth?
4. Paper ID #32495 Exploring the Role of Ambiguity Tolerance in an Engineering Professional's Identity as a Leader

5. Paper ID #14655 Sports, arts and concrete canoes: Engineers learning to lead outside the formal curriculum

Topic: Mentorship

1. Paper ID #33724 Unanticipated Outcomes: Social and Academic Benefits for STEM Peer Mentors
2. Paper ID #6386 Engineering Students Perspective on Mentoring and Leadership
3. Paper ID #10415 Utilizing a Student Organization to Create a Self-Sustaining Mentorship Program in Engineering
4. Paper ID #27481 Fostering a Relationship with a Corporate Sponsor to Grow an Engineering Leadership Development Program
5. Paper ID #7314 Purdue University's Engineering Leadership Program: Addressing the Shortfall of Engineering Leadership Education

Entrepreneurship & Engineering Innovation: Top Papers in Each Topic

Topic: Program Design

1. Paper ID #10438 Combining Discipline-specific Introduction to Engineering Courses into a Single Multi-discipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning
2. Paper ID #27270 An Analysis of Freshman Teamwork Experiences in Required Design and Entrepreneurial Thinking Project-Based Learning Courses
3. Paper ID #16150 The Evolution of a Course on Creativity and New Product Development
4. Paper ID #16484 Fostering an Entrepreneurial Mindset through a Sophomore-Level, Multidisciplinary, Engineering Design Studio Experience
5. Paper ID #19814 Entrepreneurial Thinking in a First-Year Engineering Design Studio

Topic: Entrepreneurial Experience

1. AC 2010-44: 25 Years Of Technology Entrepreneurship
2. AC 2007-824: Developing An Angel Investor Forum To Complement An Engineering School's Entrepreneurship Initiatives
3. 2006-76: Developing Engineers With An Entrepreneurial Spirit
4. Paper ID #8732 Leveraging University Entrepreneurship Center Programs as a Means to Enrich Engineering Education
5. AC 2009-239: A Model For Technology Commercialization: Mississippi State University

Topic: Entrepreneurship Identity

1. Paper ID #33900 Students' Self-Perception of Their Entrepreneurial Characteristics
2. Paper ID #21294 The Entrepreneurial Engineer: A Quantitative Analysis of Personality Factors in the Social Cognitive Career Theory
3. Paper ID #9023 Comparing Engineering and Business Undergraduate Students' Entrepreneurial Interests and Characteristics
4. Paper ID #11693 Development of Entrepreneurial Attitudes Assessment Instrument for Freshman Students

5. Paper ID #19539 The Roots of Entrepreneurial Career Goals among Today's Engineering Undergraduate Students

Topic: Innovativeness

1. Paper ID #27496 What Do Students Learn about Innovation?
2. AC 2011-740: Creativity And Innovation: A Comparative Analysis Of Definitions And Assessment Measures
3. AC 2012-4817: Teaching Students To Be Technology Innovators: Examining Approaches And Identifying Competencies
4. Paper ID #23135 Critical Incidents in Engineering Students' Development of More Comprehensive Ways of Experiencing Innovation
5. Paper ID #15428 The Interface between Cognitive Science and Innovation

Topic: Mindset

1. Paper ID #24668 EML Indices to Assess Student Learning through Integrated e-Learning Modules
2. Paper ID #15493 Developing Entrepreneurial Mindset in Industrial Engineering Classes: A Case Study
3. Paper ID #28932 An Entrepreneurially Minded Learning (EML) Module Involving Global Markets for Medical Devices Implemented in an Engineering Physiology Course
4. Paper ID #14885 Integrating e-Learning Modules into Engineering Courses to Develop an Entrepreneurial Mindset in Students
5. Paper ID #14951 Inclusion of Entrepreneurially Minded Learning (EML) Modules in 2ndYear Core Engineering Courses

Combined Topics: Top Papers in Each Topic

Topic: Program Design

1. AC 2007-893: Early Stage Technology Development And Commercialization: An Investment In Innovation That Yields An Economic And Educational Impact
2. AC 2007-2797: Improving Entrepreneurship Team Performance Through Market Feasibility Analysis, Early Identification Of Technical Requirements, And Intellectual Property Support
3. AC 2009-239: A Model For Technology Commercialization: Mississippi State University
4. 2006-76: Developing Engineers With An Entrepreneurial Spirit
5. AC 2008-485: Embedding Business Students Into EET/TET E4 E-Teams

Topic: Leadership

1. Paper ID #23040 Understanding the Perceived Impact of Engineers' Leadership Experiences in College
2. Paper ID #15201 Charting the Landscape of Engineering Leadership Education in North American Universities
3. Paper ID #22141 What is Engineering Leadership? A Proposed Definition

4. Paper ID #23184 Convergent Approaches for Developing Engineering Leadership in Undergraduates
5. Paper ID #7314 Purdue University's Engineering Leadership Program: Addressing the Shortfall of Engineering Leadership Education

Topic: Education

1. Paper ID #18562 Teaching Entrepreneurial Mindset in a First-Year Introduction to Engineering Course
2. Paper ID #16484 Fostering an Entrepreneurial Mindset through a Sophomore-Level, Multidisciplinary, Engineering Design Studio Experience
3. Paper ID #22875 Entrepreneurial Mindset (EML) Modules for Chemical Engineering Courses
4. Paper ID #30098 Using the Entrepreneurial Mindset to Master Kinematics and Human Body Motion in a Biomechanics Course
5. Paper ID #10438 Combining Discipline-specific Introduction to Engineering Courses into a Single Multi-discipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning

Topic: Innovativeness

1. Paper ID #27496 What Do Students Learn about Innovation?
2. Paper ID #23135 Critical Incidents in Engineering Students' Development of More Comprehensive Ways of Experiencing Innovation
3. Paper ID #30805 Integrating Innovation Curriculum: Measuring Student Innovation to Assess Course and Program Effectiveness
4. AC 2011-740: Creativity And Innovation: A Comparative Analysis Of Definitions And Assessment Measures
5. Paper ID #15428 The Interface between Cognitive Science and Innovation

Topic: Entrepreneurship

1. Paper ID #32286 Engineering Students' Perceptions of Entrepreneurship: A Qualitative Examination
2. AC 2008-1583: Impacts Of Entrepreneurship Centers And Programs On The Preparation Of Entrepreneurial Engineers
3. AC 2007-3112: Implementing Engineering Entrepreneurship Education At Lafayette College
4. Paper ID #18557 Entrepreneurial Motivations for High-Interest Students
5. Paper ID #18034 University Innovation & Entrepreneurship Ecosystem for Engineering Education: A Multi-case Study of Entrepreneurship Education in China

Appendix V: Full List of 20 Topics

Engineering Leadership: Topic Modeling Results

Topic #	Keyword 1	Keyword 2	Keyword 3	Keyword 4	Keyword 5
1	student	project	programs	experience	page
2	engineers	career	technical	paths	organizational
3	team	project	members	leader	teams
4	identity	self	variables	model	experiences
5	module	team	goal	capstone	state
6	programs	universities	reported	cultural	participate
7	coaching	coach	employee	managerial	comparison
8	mentors	peer	mentor	mentoring	college
9	civil	asce	construction	infrastructure	competencies
10	faculty	el	perceptions	industry	responses
11	kgi	mbti	training	group	team
12	mbti	population	cohort	general	personality
13	utep	olin	el	texas	faculty
14	course	class	pre	instructor	post
15	authentic	values	safety	culture	behavior
16	minor	global	courses	purdue	experiential
17	coe	eld	eldm	minor	alumni
18	recruiters	career	behaviors	confidence	company
19	micron	culture	leader	senior	global
20	division	science	technology	chair	policy

Entrepreneurship & Engineering Innovation: Topic Modeling Results

Topic #	Keyword 1	Keyword 2	Keyword 3	Keyword 4	Keyword 5
1	learning	skills	project	problem	figure
2	entrepreneurship	entrepreneurial	business	entrepreneurs	programs
3	efficacy	self	items	career	gender
4	innovation	innovative	innovators	process	innovations
5	program	summer	internship	campus	programs
6	module	modules	learning	online	integrated
7	design	project	product	projects	senior
8	course	class	semester	business	courses
9	team	teams	members	project	semester
10	keen	mindset	entrepreneurial	curiosity	kern
11	business	technology	product	commercialization	page
12	stem	year	lean	science	school
13	faculty	workshop	workshops	participants	members
14	canvas	design	value	product	features
15	story	class	gender	women	leader
16	creativity	creative	problem	solving	thinking
17	eml	lab	minded	curiosity	framework
18	patent	ip	property	invention	intellectual
19	em	map	mindset	concept	faculty
20	competition	pitch	judges	elevator	teams

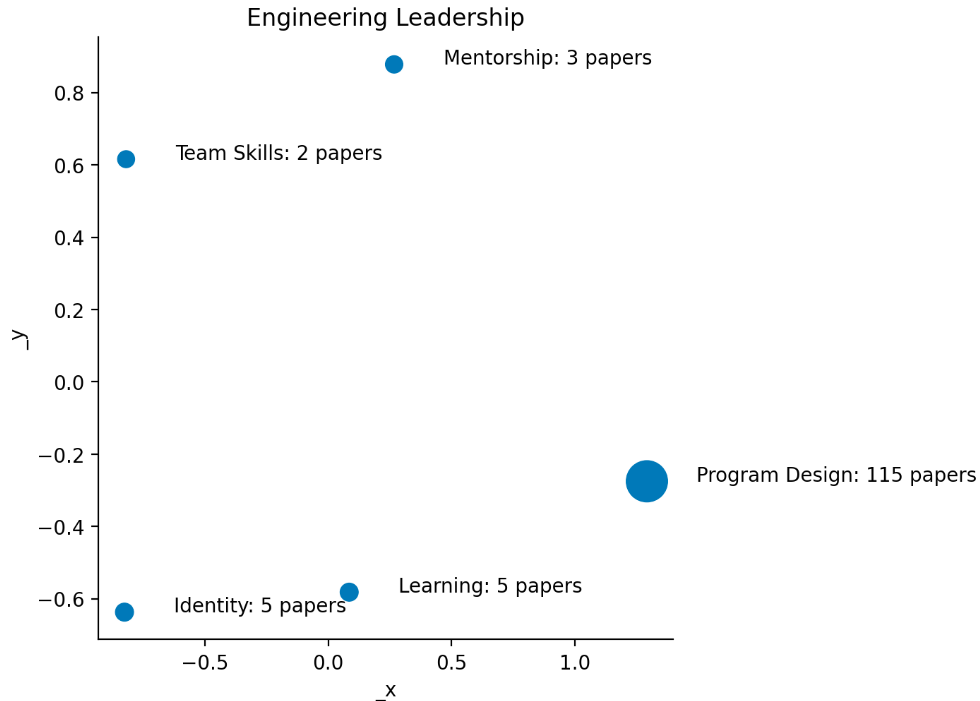
Combined Entrepreneurship and Leadership Divisions: Topic Modeling Results

Topic #	Keyword 1	Keyword 2	Keyword 3	Keyword 4	Keyword 5
1	business	technology	product	page	commercialization
2	leadership	leader	leaders	skills	engineers
3	learning	skills	study	data	survey
4	entrepreneurship	entrepreneurial	business	entrepreneurs	entrepreneur
5	innovation	innovative	innovators	innovations	process
6	program	programs	year	summer	internship
7	team	teams	members	project	leader
8	design	project	projects	product	prototype
9	course	class	semester	learning	courses
10	module	modules	learning	online	customer
11	faculty	members	change	campus	teaching
12	competition	pitch	teams	competitions	rubric
13	keen	mindset	entrepreneurial	curiosity	kern
14	creativity	creative	problem	thinking	solving
15	canvas	design	value	product	features
16	story	gender	women	male	female
17	workshop	participants	workshops	day	techniques
18	eml	lab	minded	curiosity	framework
19	patent	ip	property	invention	intellectual
20	em	map	mindset	concept	entrepreneurial

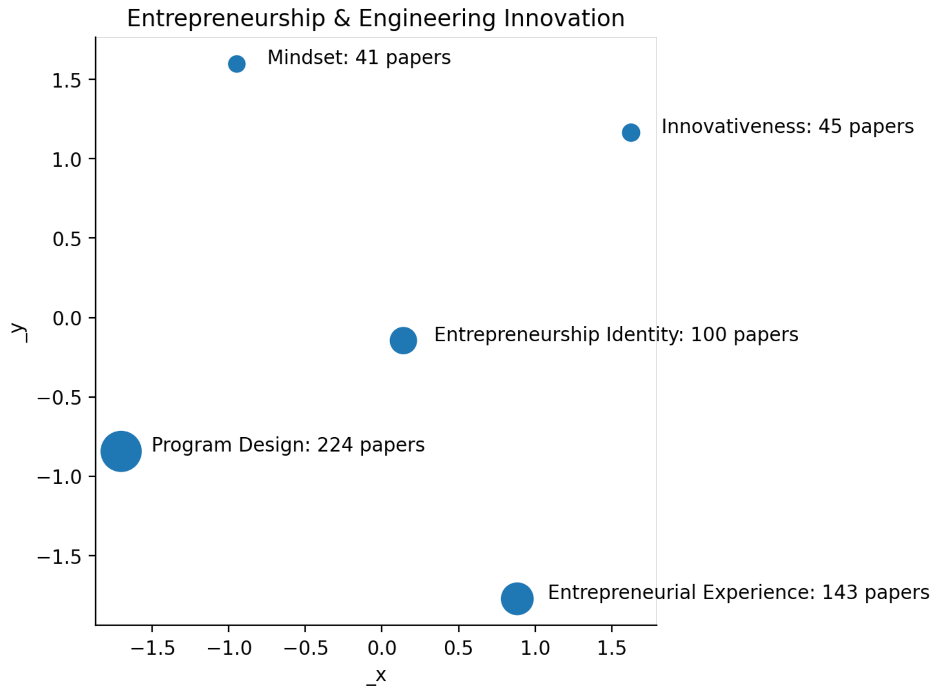
Appendix VI: 2-dimensional Topic Maps

The size of each point represents the number of papers best categorized into that topic, while the proximity of each point to another represents the relative semantic distance between the two topics; topics that are more similar will be positioned closer to each other. The descriptive label for each topic was manually created by observing the top words in each topic as well as the most representative papers for each topic.

Engineering Leadership Topic Map



Entrepreneurship & Engineering Innovation Topic Map



Both Divisions Topic Map