

The First Cohort in a New Innovation, Leadership, and Engineering Entrepreneurship B. S. Degree Program

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Abstract—The College of Engineering at the University of Illinois at Urbana-Champaign has recently launched a new B. S. dual degree in Innovation, Leadership, and Engineering Entrepreneurship (ILEE), a second bachelor's degree option for those completing their degree in a traditional engineering discipline. This is unlike many universities where similar degree programs are situated in colleges of business rather than engineering. The first cohort of sixteen students has joined the program in January 2017. In this paper we first report on the stated goals of the new degree, which is meant to combine the technical expertise in the traditional engineering science-focused disciplines with a deeper set of skills in problem-finding, creativity, innovation, leadership, and externalization. The idea is to ensure training in the dual physical and human dimensions and triple aspects of science, design, and leadership that are present in engineering practice. Next we report on the curriculum design as well as the experiential learning pedagogy that is present in most of the courses therein. Core courses include “Design Thinking/Need-Finding”, “Creativity, Innovation, Vision”, “Emotional Intelligence”, “Innovation and Engineering Design”, and “Technology Entrepreneurship”. Further, we provide a characterization of the students in the first cohort of undergraduate students to be accepted into the degree program. Drawing on their application materials, we perform text analytics using techniques such as topic modeling under Latent Dirichlet Allocation (LDA) and geometric embedding using the word2vec family of methods, to understand the key motivations for students to pursue this degree. Finally we use these text analytics techniques to make a formal assessment of alignment between the stated goals of the degree program and the key motivations of the students. One particular question is to understand the students' relative level of interest in the three legs of the degree, namely innovation, leadership, and entrepreneurship, so as to predict how level of engagement may vary across courses.

Index Terms—innovation education, leadership education, engineering entrepreneurship education, text analytics

I. INTRODUCTION

The University of Illinois at Urbana-Champaign is a public research-intensive university founded in 1867 as a land-grant institution. It is a member of the Association of American Universities and is classified as an R1 Doctoral Research University under the Carnegie Classification of Institutions of Higher Education. There are 31833 undergraduate students (Spring 2017). The College of Engineering is an original

unit at the university, established in 1868. It has 7205 undergraduate students (Spring 2016) and includes departments of: Aerospace Engineering; Agricultural and Biological Engineering; Bioengineering; Chemical Engineering and Biomolecular Engineering; Civil and Environmental Engineering; Computer Science; Electrical and Computer Engineering; Industrial and Enterprise Systems Engineering; Materials Science and Engineering; Mechanical Science and Engineering; Nuclear, Plasma, and Radiological Engineering; and Engineering Physics. Rankings compiled by *U.S. News & World Report*, *Times Higher Education*, and the *Academic Ranking of World Universities* consistently place the college, as well as numerous degree programs therein, among the top five in the world.

The College of Engineering has established a new Bachelor of Science degree in Innovation, Leadership, and Engineering Entrepreneurship (ILEE), which was approved in September 2016 by the Illinois Board of Higher Education as a possibly freestanding degree program, and was launched with an initial cohort of students in January 2017 as a dual-degree program to be completed in conjunction with another engineering degree program. The new degree program is intended for engineering students to better understand the innovative processes involved in identifying complex technical problems and creating, developing, and leading efforts to provide for their engineering solutions. Although most universities have some kind of engineering entrepreneurship program in either an engineering college or a business college, it may be extracurricular [1], a minor program [2], or part of capstone courses [3], but not central to the core disciplinary focus, as embodied in a full B. S. degree. As such, the ILEE degree is believed to be the first degree of its kind in the country.

The ILEE program grows largely out of courses and programs offered since 2000 through the Technology Entrepreneurship Center (TEC) in the College of Engineering; more than 1000 students take at least one course each year, and participation had doubled just since 2012. Some engineering leadership courses also come from the Illinois Leadership Center (ILC). Given these historical roots, the ILEE core curriculum largely draws from courses in TEC and a few from ILC, but with the advent of the new degree program, there is

the possibility of adding course offerings to or perhaps even changing certain requirements of the core curriculum.

One might also consider adding further technical elective courses that meet student interests and needs. The technical electives for the degree program are drawn from across the College of Engineering and the university as a whole. The current list of Approved ILEE Technical Electives includes 47 courses in the College of Engineering; 4 courses in the College of Agricultural, Consumer, and Environmental Sciences; 8 in the College of Business; 2 in the College of Liberal Arts & Sciences; and 2 in the School of Social Work.

With these possibilities in mind, we report on the current curriculum as well as the experiential learning pedagogy that is present in most courses therein. Further, we characterize the first cohort of undergraduate students to be accepted into the degree program. Drawing on their application materials, we perform text analytics [4] using techniques such as topic modeling under Latent Dirichlet Allocation (LDA) [5], [6] and geometric embedding using the word2vec family of methods [7], to understand the key motivations to pursue this degree. In particular, we use these text analytics techniques to make a formal assessment of alignment between the stated goals of the degree program and the key motivations of the students. One particular question we aim to understand is the students' relative level of interest in the three legs of the degree, namely *innovation*, *leadership*, and *entrepreneurship*, so as to predict how engagement may vary across courses and realign the curriculum, at least in terms of elective offerings.

II. THE ILEE VISION

Driven largely by the fact that physicists and other scientists outperformed engineers in wartime research and gained cultural cachet, World War II marked a major acceleration in shifting focus of engineering education from the process of engineering practice to *engineering science* [8] which emphasized knowledge of mathematical and physical science foundations. Indeed, the time in engineering curricula devoted to science/mathematics gradually increased, whereas percentage of other engineering, drawing, and shopwork dropped. In particular, the exponential growth in graduate education after World War II eventually impacted undergraduate education: graduate courses were pushed down into required junior courses to make way for graduate courses at the frontiers of research. In the transformation, concrete experiences and practice-based knowledge were often lost [9].

Yet, engineering has the triple aspects of science, design, and leadership: engineer-scientists focus on research, whereas engineer-entrepreneurs and engineer-managers focus on organization [10]. Moreover there is increasing cultural heroism attached to technology entrepreneurs [11] and so-called makers [12]. Further, some argue there is growing mismatch between the analytical skills being taught in engineering, not only with visions of engineers as creative designers and innovators of future technologies [13] but also the nature of professional engineering practice [14]. A particularly notable aspect of engineering (and other kinds of) creativity is problem-finding,

e.g. in pursuing societal impact [15], as the most radical innovations often come from asking totally new questions or formulating problems in surprising new ways [16], but education is largely focused only on problem-solving.

As such, there is growing interest to push back the needle and augment the engineering science approach to engineering education with curricula that inculcate values and processes of creativity, innovation, entrepreneurship, and leadership. This interest is demonstrated by emerging analyses on how such topics may be incorporated into curricula that are approved by the engineering education accreditation board, ABET [17].

The ILEE degree moves to supplement the engineering science approach to engineering education, especially through experiential learning-based courses [18], which studies in the learning sciences are starting to indicate are effective [19]: moving from sage-on-the-stage and guide-on-the-side models to learner-with-fervor models are said to increase engagement [20]. With incorporation of experiential learning, however, there is also a recognition that syllabi, instructional methods, and especially summative assessment techniques within them must ensure engineering depth and rigor.

A. IBHE Proposal

The main aspects of this vision are articulated in the 25-page new degree proposal put in front of the IBHE and approved in September 2016. In the sequel, this will form an important corpus for text analytics, but in this subsection we quote from key sections to provide some indications of its content.

In describing the purpose of the degree:

The College of Engineering proposes a Bachelor of Science in Innovation, Leadership and Engineering Entrepreneurship (BS in ILEE) degree. The degree program is intended for engineering students to better understand the innovative processes involved in identifying problems and creating, developing, and leading efforts to provide engineering solutions. The curriculum is based on a sound disciplinary engineering technical core with additional aspects of problem identification and innovation, and complex multidisciplinary engineering project management and leadership.

In describing the background:

Currently, engineering students interested in taking leadership, innovation, and engineering entrepreneurship courses must fit them into their academic schedules as free electives, with essentially no recognition by our college or our campus. . . . Further, students who are involved in innovative research projects, including those that develop into technology startup companies, often work on these projects in their spare time, rather than as a central activity within their existing curricula. These students are often some of the most passionate, successful students, whose stories are celebrated throughout our College, Campus, and even receive national attention. . . . As

an institution, we have taken great pride in these students, celebrating them on our news media, in commencement addresses, and across our alumni publications, yet we have relegated their deepest passions to satellite activities, outside of the existing curricula at Illinois. We envision that students would be able to work with faculty members within the College and receive not only guidance and mentorship, but also course credit for such activities using a project-based credit-bearing course model. ... formalizing these courses as part of a unique degree program at Illinois adds credibility and stature to the courses and programs that the students undertake, while placing these activities squarely within the heart of the disciplinary experiences of students in the College of Engineering.

In describing fulfillment of the missions of the university:

The fourth mission of our institution, economic development, is one that is often less emphasized within the existing departments of the College. By creation of the BS in ILEE degree program, this mission is placed central to the core of the College, enabling students, faculty, and alumni to become innovative engineering leaders to develop new, innovative technologies, lead their development and application and creating new ventures.

In listing the learning objectives of the degree:

Provide fundamental understanding and ability to apply the principles and skill sets of innovation, leadership, and entrepreneurship to solve problems of importance to society. Skill areas include: areas of finance, marketing, sales, operations, business plan, product development, opportunity creation and identification, business structure, negotiations, technology, business, and project management, intellectual property, and ethics.

Cultivate the spirit of innovation and entrepreneurship in terms of self-reliance, identification and decision making regarding opportunity risks, and teamwork.

Provide experiential learning opportunities to gain real-world experience.

With this background, we now describe the ILEE curriculum.

III. THE ILEE CURRICULUM

The curriculum for the ILEE degree matches the structure of any other B. S. degree in engineering, with 128 credits that include foundational mathematics and science, general education, and composition. There is a requirement of 19 credit hours of ILEE-approved technical electives. The main point of discussion in this section is the ILEE core of 31 credits. The courses therein are listed in summary form in Table I and laid out in a suggested map in Figure 1, though there is no particular prerequisite structure, enabling students flexibility to take courses when they fit into their schedules.

TABLE I
ILEE CORE COURSES

| Course Title | Credits |
|--|---------|
| Intro to Innovation, Leadership & Engineering Entrepreneurship | 1 |
| Design Thinking/Need-Finding | 3 |
| High-Tech Ventures: From Idea to Enterprise | 2 |
| Creativity, Innovation, Vision | 4 |
| Lectures in Engineering Entrepreneurship | 1 |
| Emotional Intelligence | 3 |
| Innovation and Engineering Design | 2 |
| Developing Breakthrough Projects | 4 |
| Startups: Inc, Funding, Contracts & IP | 3 |
| Technology Entrepreneurship | 3 |
| High Tech Venture Marketing | 2 |
| Leading Sustainable Change | 3 |

The core courses are detailed below. Of particular note is TE 401, *Developing Breakthrough Projects*, a required set of project-based experiential credits (4 hours minimum, 16 hours maximum) that are approved, supervised, and coordinated by a faculty member. This allows students to work on their innovative research projects, some of which may develop into technology startups, while earning transcriptable credit towards the degree. Many other courses also have an experiential flavor, with numerous hands-on activities.

- *TE 298: Introduction to Innovation and Leadership in Engineering* Introductory course, open to all majors, no prerequisites. Students will learn about innovation, identify key attributes of innovation leadership, and practice innovation leadership personally and professionally. Students will identify opportunities and work in teams to address them, practicing leadership and followership and honing their written and verbal presentation skills. Students also complete a personal plan for continuing to develop their innovation leadership skills.
- *TE 250: High-Tech Ventures: From Idea to Enterprise* This class examines the fundamentals of technology entrepreneurship and addresses critical areas of the entrepreneurship process such as: Creating a successful startup and transforming it into a sustainable business; validating an idea and taking it to market; evaluation of new ideas; forming high performance teams; and financing a technology-based startup. This class combines field trips to local startups and businesses as well as the University Research Park and EnterpriseWorks incubator, in-depth case studies, and a hands-on class project.
- *ENG 298: User Oriented Collaborative Design* Students develop detailed concepts and models of authentic new products and services. Our focus is on user-oriented, collaborative approaches to design and seeking holistic solutions integrating user and functional perspectives. We emphasize the importance of process and the development of strategies. Students observe and engage people to develop a deep understanding of their values and the patterns of their lives. They work collaboratively in a studio environment to create a shared understanding of the people they design for (and with) and the product

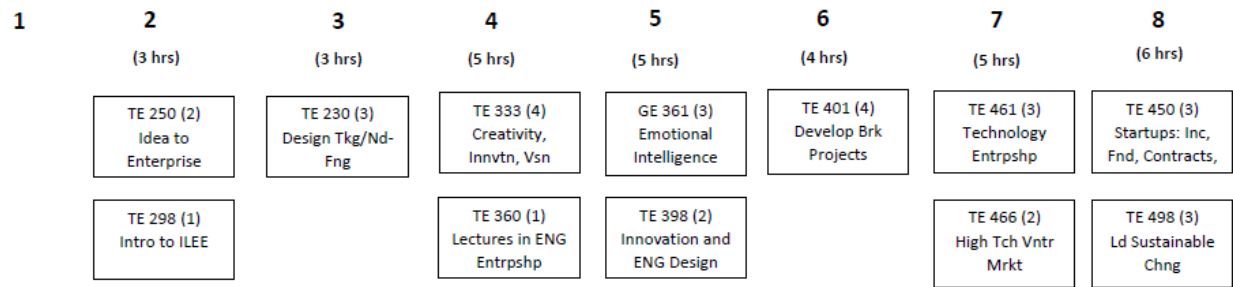


Fig. 1. Possible curriculum map for ILEE dual BS degree.

ideas they develop. Topics covered include design thinking, ethnographic methods, concept development and interaction design. This course offers an intensive design and team work experience, focused on understanding customer needs.

- *TE 333: Creativity, Innovation and Vision* Enhancement of personal creativity via exploration of the nature of creativity, how creativity works, and how to envision what others may not. Practice of techniques and processes to enhance personal and group creativity and to nurture a creative lifestyle. Application to a major term project providing the opportunity to move an idea, product, process, or service from vision to reality.
- *TE 360: Lectures in Engineering Entrepreneurship* Fundamental concepts of entrepreneurship and commercialization of new technology in new and existing businesses. Guest speaker topics vary, but typically include: evaluation of technologies and business ideas in general; commercializing new technologies; financing through private and public sources; legal issues; product development; marketing; international business issues.
- *GE 361: Emotional Intelligence* Understanding emotions in ourselves and others. Assessment and improvement of interpersonal skills and emotional intelligence competencies including self-regulation, motivation, empathetic listening, communication, influence collaboration and cooperation, conflict management, leadership, teamwork, and managing change.
- *TE 398: Innovation and Engineering Design* A course on the engineering process fostering the identification of needs and potential engineering solutions. This course will encapsulate the ideation and problem identification aspects of engineering senior design, and is anticipated to facilitate student innovation.
- *TE 401: Developing Breakthrough Projects* Project-based exploration with teams of students working together in a large innovation and entrepreneurial context. Encourage development of innovative leadership and entrepreneurial skill sets, including financing, marketing, sales, operations, business plans, and management.
- *TE 450: Startups: Inc, Contracts, Fund, IP* Explore legal tools used in constructing and operating companies. Top-

ics include: issues with business formation, intellectual property, NDA, contracts, and other corporate legal issues impacting startups.

- *TE 461: Technology Entrepreneurship* Critical factors affecting technology-based ventures: opportunity assessment; the entrepreneurial process; founders and team building; preparation of a business plan including market research, marketing and sales, finance, and manufacturing considerations.
- *GE 462: Leading Sustainable Change* Theories and process of change; systems thinking concerning change consequences; building coalitions and communities to support change; implementing and managing projects effectively. Processes to plan, implement, manage, and sustain change with an organization through alignment of change strategies with organizational and individual concerns.
- *TE 466: High-Tech Venture Marketing* Cornerstone marketing concepts for innovators and engineers to enable analysis of products and technologies from a marketing perspective: engineering product development and adoption life cycle; objectives and strategies; marketing management; communication skills; sales process and tactics; special considerations for new high-tech engineering products and innovations.

IV. THE FIRST COHORT

The first cohort of sixteen ILEE students were admitted to the degree program to start in January 2017. Twenty students had applied, of which three did not meet GPA requirements and one declined. The home department distribution of students is nine from Electrical and Computer Engineering, four from Computer Science, and one each from Bioengineering, Industrial and Enterprise Systems Engineering, and Civil and Environmental Engineering. Two students are female and the remaining fourteen are male. Half are from northern Illinois, whereas four are international and four are out-of-state domestic students. Most students came with transfer credits (e.g. AP/IB) or tested out (average of 38 credit hours), which will largely allow them to complete the dual degree in four years. Students are in various stages and many have already taken some required ILEE core courses; proposed graduation dates

are as follows: SP18: 3, SP19: 9, FA19: 1, SP20: 2, SP21: 1 (5 years to grad).

As part of the application procedure, students completed a form that included the following.

- 1) Why are you interested in pursuing the ILEE BS Dual Degree?
- 2) What is something related to innovation, leadership, or entrepreneurship that recently caught your attention? Why is it interesting to you?
- 3) What is something you found interesting in one of your recent TEC and/or engineering classes?
- 4) In thinking about innovation, leadership and entrepreneurship, list a few industries/companies/laboratories you find interesting. What products, services, or aspects do you find especially compelling?
- 5) What do you always find time to do?
- 6) Discuss your long range educational and career goals
- 7) What role do you hope the ILEE degree can play in helping attain those goals?
- 8) Please provide any other information (up to 500 words) that you would like to tell us about why you want to pursue the ILEE BS Dual Degree

We use responses to perform text analytics to understand the interests, motivations, and plans of our first cohort of students.

V. TEXT ANALYTICS

Consider the students' ILEE applications as a corpus on which to perform text analytics. We start by performing topic modeling. In natural language processing, a *topic model* is a kind of statistical model used in discovering the abstract and latent semantic structure in terms of *topics* that occur in a collection of documents. It is an unsupervised approach that is commonly used for exploration of language corpora. In particular, we use topic modeling based on the Latent Dirichlet Allocation (LDA) [5], [6] statistical approach.

We take the text from all twenty ILEE applications to create a vocabulary of distinct words that appear in all of them. After removing punctuation and converting to lower case, we end up with a vocabulary of 3203 distinct words, among the total 20943 words in the whole corpus (each application is roughly 1000 words). Applying LDA topic modeling to this corpus yields the topics shown in Figure 2.

Post hoc from the unsupervised learning, we can interpret the topics that emerge as follows. The first topic is concerned with learning from existing ILEE classes as a motivating experience. The second topic is concerned with using technologies including artificial intelligence (AI) and other technological motivations. The third topic is essentially concerned with opportunities for peer interaction and collaboration. The fourth topic is concerned with what the degree program's curriculum may offer. Other interesting patterns may also be observed.

Notably, Topics 6 and 9 are largely focused on entrepreneurship, Topic 10 on a combination of innovation and entrepreneurship, and Topic 8 is focused on personal qualities associated with leadership. In this sense, students seem to

place greater focus on entrepreneurship in their application materials, as compared to the two other legs of the ILEE degree. This indicates that to create a true balance, stronger desire for innovation and leadership may need to be inculcated.

Another text analytics technique we consider is the use of word embeddings that essentially learn semantically meaningful representations for words from local cooccurrences in sentences. This provides a metric structure and therefore an opportunity to measure distances among phrases and terms. In particular, the word2vec family of methods [7] have become very popular, essentially establishing the fact there is indeed an interpretable geometry to language semantics. This basic idea of word embedding can further be used to define a notion of distance among documents through an earth-mover's distance in the word embedding space [21]. Thus, we are able to measure how far students' ILEE application materials are from the IBHE proposal for the ILEE degree. If there is closeness in this distance, then the given student is fairly well-aligned with the founding documents.

Omitting the details of the analysis, we find that there is a fair amount of alignment between all of the students' applications and the founding documents. This is because just like the students' motivations and goals, the stated founding motivation and goals for the ILEE degree are rooted in engineering entrepreneurship more so than innovation or leadership in their own rights.

VI. CONCLUSION

The University of Illinois at Urbana-Champaign has launched a new B. S. degree in Innovation, Leadership, and Engineering Entrepreneurship (ILEE) in the College of Engineering. This paper has described the vision and core curriculum for the degree program. It has also described some basic demographic characteristics of the first cohort of sixteen students that have been admitted to the program in January 2017. Finally, through some initial exploratory text analytics, this paper has tried to perform a formal assessment of alignment between the stated motivations/goals of the program with the stated motivations/goals of the students therein. We find that there is indeed alignment between the program and the students, but that this is in a direction that is not balanced among the three legs of the degree (innovation, leadership, and entrepreneurship). Entrepreneurship is overrepresented, and further, the other aspects of the degree are largely discussed in the context of entrepreneurship. This insight can be used to understand whether there is a need to introduce greater balance or not, through the curriculum core or the set of technical electives that are offered.

As far as we know, text analytics applied e.g. to degree program proposals or student applications, has found little use in assessing educational programs. As such, there is scope for future work in developing better text analytics techniques specifically for this application of formalizing alignment and balance. Such techniques, along with a large battery of other program assessment techniques, will be used to study the ILEE degree longitudinally as it progresses.

| | | | | | | | |
|--------------|---------|------------------|---------|---------------|---------|-------------|---------|
| TOPIC_1 | 0.01699 | TOPIC_2 | 0.00794 | TOPIC_3 | 0.01584 | TOPIC_4 | 0.01118 |
| my | 0.08879 | tech | 0.07826 | he | 0.09806 | science | 0.07940 |
| classes | 0.07835 | ai | 0.05033 | his | 0.07845 | degree | 0.07146 |
| im | 0.07574 | interested | 0.05033 | our | 0.06165 | school | 0.04765 |
| ilee | 0.04963 | teams | 0.05033 | we | 0.05324 | curriculum | 0.03972 |
| learn | 0.04441 | attended | 0.03357 | being | 0.03644 | history | 0.03972 |
| is | 0.04180 | collaboration | 0.02798 | opportunities | 0.03644 | while | 0.03972 |
| both | 0.03919 | dream | 0.02798 | opportunity | 0.02804 | find | 0.02781 |
| its | 0.03919 | photos | 0.02240 | thought | 0.02804 | government | 0.01988 |
| ive | 0.03919 | using | 0.02240 | through | 0.02804 | home | 0.01988 |
| learning | 0.03397 | access | 0.01681 | only | 0.02524 | development | 0.01591 |
| TOPIC_5 | 0.03429 | TOPIC_6 | 0.01247 | TOPIC_7 | 0.06733 | TOPIC_8 | 0.01038 |
| the | 0.33765 | as | 0.08899 | and | 0.21805 | self | 0.05986 |
| people | 0.07892 | startup | 0.07120 | of | 0.20027 | while | 0.04705 |
| and | 0.05176 | pitch | 0.05697 | a | 0.15086 | opportunity | 0.03850 |
| have | 0.04529 | consulting | 0.03562 | in | 0.10672 | favorite | 0.03423 |
| te | 0.03623 | though | 0.03206 | for | 0.08235 | grow | 0.03423 |
| what | 0.03365 | during | 0.02850 | up | 0.02438 | strengths | 0.02995 |
| there | 0.02977 | startups | 0.02850 | education | 0.01582 | being | 0.02568 |
| just | 0.02718 | aid | 0.01783 | it | 0.01450 | continue | 0.02141 |
| way | 0.02459 | entrepreneurs | 0.01783 | google | 0.01055 | process | 0.02141 |
| course | 0.02200 | regards | 0.01783 | companies | 0.00989 | social | 0.02141 |
| TOPIC_9 | 0.01286 | TOPIC_10 | 0.01251 | TOPIC_11 | 0.12105 | TOPIC_12 | 0.03491 |
| skills | 0.14485 | things | 0.07450 | to | 0.24258 | and | 0.13088 |
| entrepreneur | 0.10002 | you | 0.05677 | that | 0.13558 | because | 0.07752 |
| had | 0.06554 | innovative | 0.04968 | me | 0.07366 | degree | 0.07371 |
| develop | 0.04486 | ideas | 0.04613 | in | 0.06193 | will | 0.07244 |
| become | 0.03796 | work | 0.04613 | on | 0.05240 | company | 0.06863 |
| we | 0.03107 | improve | 0.03549 | my | 0.04911 | ilee | 0.05846 |
| read | 0.02762 | called | 0.03195 | be | 0.04691 | start | 0.04702 |
| illinois | 0.02072 | entrepreneurship | 0.03195 | as | 0.03445 | work | 0.04575 |
| motivated | 0.02072 | seen | 0.02840 | this | 0.03005 | part | 0.02670 |
| rather | 0.02072 | good | 0.02486 | how | 0.02199 | different | 0.02542 |

Fig. 2. ILEE topics that emerge from LDA topic modeling analysis of student applications. Here we show the top twelve topics, as indicated by their own top ten words together with their weights.

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