A Multi-institution Investigation into Faculty Approaches for Incorporating the Entrepreneurial Mind-set in First-year Engineering Classrooms

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Abstract

The traditional engineering design process taught in universities across the country focuses on several common design steps, although often placing little emphasis on creating value. In collaboration with KEEN, a network of thousands of engineering faculty working to unleash undergraduate engineers so that they can create personal, economic, and societal value through the entrepreneurial mindset, a large mid-western university is adding multiple entrepreneurial minded learning (EML) elements to an existing first-year course. This paper represents the first phase of a four-phase, 18-month pilot, during which we explored the impact of EML in first-year engineering classrooms on motivation and identity across multiple universities. We used a mixed methods investigation for the current practices of five KEEN-related first-year engineering programs currently incorporating EML elements into their curricula. Researchers visited each site and collected data via focus groups with first-year engineering faculty and observations of EML classrooms. The notes from the focus groups were qualitatively coded and analyzed while quantitative analysis was used for the results from the Global Real-time Assessment Tool for Enhancement (G-RATE) assessment of the classroom observations. We mapped the findings to the KEEN Framework and the Longitudinal Model of Motivation and Identity (LMMI), which combines self-determination theory with possible-selves theory. The results were used to develop a set of best practices that may be incorporated into EML projects and courses such as allowing students some type of choice in their project, whether it is open-ended or highly bounded. These best practices were leveraged during the curriculum development in subsequent phases of the pilot to encourage autonomous motivation and identity development of first-year engineering students.

Introduction

Engineering educators have recognized the importance of creativity and entrepreneurship in a student’s education and have subsequently been revising curricula, including adding more engineering design [1]–[4]. In collaboration with KEEN [5], a network of engineering faculty focused on enhancing engineering education through the entrepreneurial mindset, a large mid-western university decided to embark on the journey of incorporating entrepreneurial minded learning (EML) into an existing first-year course.

This paper details the faculty-focused results of the first phase of a four-phase pilot project aimed at understanding the impact of EML on motivation and identity in first-year engineering classrooms. In the first phase, we investigated the current practices of select KEEN institutions that have already incorporated EML into their first-year engineering courses. Through our work, we used these findings to support the development of EML curriculum in the first year at our institution.

This work was guided by the overarching research question: *In what ways do entrepreneurial minded learning (EML) experiences affect first-year engineering students' motivation and identity development?* Specifically for this paper, we are interested in answering the sub-research question: *How do faculty incorporate EML into their first-year engineering courses?*

Background

Our first-year engineering program uses a common content, project-based approach. This approach to the first year is common among other first-year engineering programs (e.g., [6]–[10]). Regarding EML in the first year, some universities incorporate entrepreneurship and other components of EML. For example, Brown University's Division of Engineering instituted a two-course sequence to merge entrepreneurship with design [11]. Additionally, the Franklin W. Olin College of Engineering redesigned their engineering curriculum to incorporate "entrepreneurial thinking" [12]. Our work builds on past revisions such as these with a particular focus on assessing students' motivation and identity development in EML infused settings.

Theoretical Framework

The Longitudinal Model of Motivation and Identity (LMMI) [13], which combines self-determination theory (SDT) [14] and possible-selves theory (PST) [15], both well-established theoretical frameworks, was used in this study. The LMMI, shown in Figure 1, is a conceptual model that can be used to study individual development, incorporating the strengths of SDT and PST. In the framework, PST serves as the foundation (lower rectangle in Figure 1) for the SDT constructs of competence, autonomy, and relatedness. PST allows individuals to set goals, think to the future, and envision themselves after completing some experience while SDT allows for evaluation of the current context focusing on basic needs. The various SDT constructs lead to increased motivation and identity development while each experience, such as EML, is based on one's own identity and views of themselves in the future (top rectangle in Figure 1).

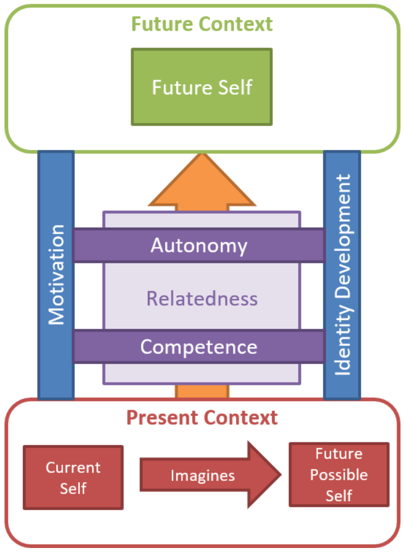

Figure 1: LMMI Conceptual Model Summary

Since we are incorporating EML based on the KEEN Framework, we will also discuss this framework [16]. The KEEN Framework is based on a typical engineering design process, but it first adds to design the ability to identify opportunity by understanding the customer. Adding the ability to recognize opportunity encourages students to be curious about the market, create business models, and assess policy and regulatory issues. Coupling design and opportunity recognition with impact skills, another aspect of the KEEN Framework, allows students to apply creative thinking to ambiguous problems, talk about engineering solutions in terms of economic terms, evaluate feasibility, and understand the motivations and perspectives of teammates and stakeholders. The KEEN Framework depicts that the ability to identify Opportunity, coupled with Design and Impact Skills, leads to developing an Entrepreneurial Mindset, which can be measured with the KEEN Student Outcomes (KSOs), such as the 3C's (Curiosity, Connections, and Creating Value) among others.

Methods

Recruitment and Data Collection

The institutions chosen for this study are members of the KEEN network and have first-year engineering courses that incorporate EML elements into the curriculum. The institutions represented a range of sizes and were both public and private universities. Additionally, we selected institutions that were at different stages of their membership within the KEEN network. Some had been with the network for years and some were new to the network. Table 1 documents the characteristic of each site. We worked with site contacts at each school to obtain IRB approval and to recruit participants for the faculty focus groups and observations.

Table 1: Site Characteristics

Site	Control	Student Population	Geographic Region	Year Joined KEEN	Size and Setting
Site 1	Public	5,962	West	2018	Four-year, medium, primarily residential
Site 2	Private	4,015	Midwest	2005	Four-year, small, primarily nonresidential
Site 3	Private	3,695	Midwest	2005	Four-year, medium, highly residential
Site 4	Public	58,322	Midwest	2017	Four-year, large, primarily residential
Site 5	Public	14,778	Northeast	2016	Four-year, large, primarily residential

For data collections, members of the research team traveled to each institution to collect the data. For the faculty aspects of this work, data collection consisted of focus groups with first-year engineering faculty and observations of EML classrooms.

Focus Group Interviews. At each institution we conducted semi-structured focus group interviews with first-year engineering faculty who implement EML elements into their classrooms. The focus group size was approximately two faculty members with the smallest being one faculty member and largest being four. Demographic information about the faculty participants was not collected to protect their anonymity. During the focus group, one of the researchers lead the conversation while another researcher took notes. The focus groups were audio recorded which would allow the researchers to transcribe any excerpts as needed to confirm and support the data analysis of the notes.

Classroom Observations. At each site visited, one to two classrooms were observed by two researchers, focusing on the EML skills used in the classroom as well as how those skills were introduced (pedagogy). The Global Real-Time Assessment Tool for Teaching Enhancement (G-RATE), based on the *How People Learn* (HPL) conceptual framework [17]–[21], was used to observe the instructor and the frequency of the activities that incorporated the EML skills. The G-RATE tool allows the researcher to observe fourteen different activities divided into four categories (*Assessment, Community, Knowledge,* and *Learner*) as well as a fifteenth activity for *Organization*. The categories and codes are available in the Appendix. Additionally, observation notes, audio recordings of the faculty and students, and video recordings of faculty were captured to address pedagogies used related to EML. If available, syllabi, handouts, and presentations or other materials were provided to the researchers by the instructor to supplement the observation data.

Analysis

The qualitative and quantitative analysis of both the focus group interviews and the classroom observations focused on identifying best practices and mapping practices in first-year engineering classrooms back to the KEEN skillset, mindset, and LMMI.

Focus Group Interviews. The notes from the focus group interviews were the main source of data. The notes were reviewed in detail by one of the researchers where themes and best practices emerged from the findings after basic coding in Dedoose using Table 5 in the Appendix. Elements of EML, SDT, and PST were also noted. The emergent themes were then discussed at length with the other members of the team for refinement, to support the development of comprehensive best practices across sites. Based on the theme generation, it was decided that the audio recordings were not needed to further clarify the notes and themes that emerged as the themes were already clearly identified throughout the analysis of the notes and discussion among team members.

Classroom Observations. For the observations analysis, descriptive statistics of the G-RATE tool outputs were performed. The frequencies of the fifteen codes from the *How People Learn* (HPL) framework (see Appendix A for descriptions of the codes), which are utilized by the instructor in the classroom, were analyzed for each site as well as across sites. The codes were assessed for both frequency of use as compared to the other codes as well as frequency of class time during which the code was used, since the G-RATE tool allows for multiple codes to be assessed at any given time increment. The observations notes taken outside of the G-RATE tool were used during the triangulation process to develop best practices.

Triangulation

The results of the focus group interviews and observations were triangulated to identify common trends as well as differences between sites and courses. The findings were also mapped back to the KEEN engineering mindset and skillsets (i.e. the 3C's and definition of EML) along with the elements of LMMI (i.e. SDT and PST) and the use and frequency of HPL codes to understand first-year engineering students' engagement with EML in the classroom, including how the EML concepts are taught and the impact on their motivation and identity. While outside the scope of this paper, the triangulated results informed our curriculum development during the second phase of our pilot.

Results and Analysis

Focus Groups Results

The focus group interviews resulted in some specific ways that EML elements are being implemented into their first-year engineering curriculum. To establish and practice ***Curiosity***, most of the sites demonstrated this through students forming questions and talking with potential users to seek answers to their questions, particularly Sites 3 and 4. To create ***Connections***, Site 4 accomplished this through a competitive analysis that required the students to decide what is known and available and what is missing in their project or knowledge. ***Creating Value*** was captured at all sites by focusing on the customers in all projects, although this was not always a real customer. For example, sometimes the faculty member pretends to be the persona of the customer. ***Collaboration*** was practiced through teamwork and students were put in teams of a variety of sizes. At Site 1, the students were encouraged to collaborate with their stakeholders through tours of their facilities and ride-alongs, in addition to interviews and emails. Through writing and presentations, first-year students at these sites practiced ***Communication***. Part of ***Character*** included professional development and contributing to society, and some of the results from the projects described at these sites included start-up companies and proposals to funding agencies, which were particularly encouraged at Site 5.

The focus group interviews also resulted in some statements that related to SDT and PST. The students were given a great variety in choice demonstrating ***Autonomy***. This choice was sometimes very broad and sometimes more focused but most included choice in some aspect. ***Relatedness*** was not captured directly during the focus groups; however, it does have some aspects of Collaboration described above. Students were given many different experiences within the first-year engineering courses and beyond to build their ***Competence***, for example, through scaffolding at Site 3. The ***Future Selves of Students*** was captured when faculty discussed how the students were after their EML experiences during senior capstone and when they graduate, which was particularly noticed at Sites 2 and 3. Understanding how these EML elements were implemented in the classrooms provided greater understanding when combining the results with the classroom observations to establish best practices.

Classroom Observations Results

Overall, the codes in the *Community* and *Assessment* categories of the HPL framework were used more frequently and for more time than the codes in the *Knowledge*, *Learner*, and *Organization* categories, as shown in Table 2 below.

Table 2: Percentage of Frequency and Time by HPL Code Category

Category	% Frequency	% Time
Community	40.35%	87.31%
Assessment	41.65%	90.13%
Knowledge	10.01%	21.67%
Learner	0.74%	1.60%
Organization	7.25%	15.68%

Additionally, codes A2 (*Provided verbal/written progress assessment*), C2 (*Provided opportunities to learn from each other*), and ORG (*Organization*) were used by all sites while codes K5 (*Provide assistance understanding key concepts*) and L2 (*Acknowledged concept misunderstanding*) were not used by any site. This can be seen, along with the use of all codes by site, in Table 3 below, where a check mark indicates that the code was used at least once by that site.

Table 3: HPL Code Use by Site

Code	Site 1	Site 2	Site 3	Site 4	Site 5
A1	✓	✓		✓	✓
A2	✓	✓	✓	✓	✓
A3		✓	✓	✓	✓
C1		✓	✓	✓	✓
C2	✓	✓	✓	✓	✓
C3	✓	✓	✓		✓
K1			✓	✓	
K2				✓	
K3		✓		✓	
K4			✓	✓	
K5					
L1					✓
L2					
L3			✓		
ORG	✓	✓	✓	✓	✓

When analyzing the frequency of code use, codes A2 (*Provide verbal/written progress assessment*) and C3 (*Provide team assistance*) were used most frequently (19% each) as well as for the most amount of time (40% each). The figures below depict the total frequency of codes used and the total percentage of time each code was used.

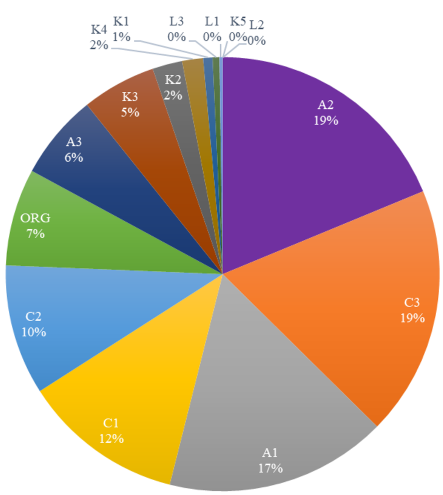

Figure 2: Total HPL Code Frequency for All Schools

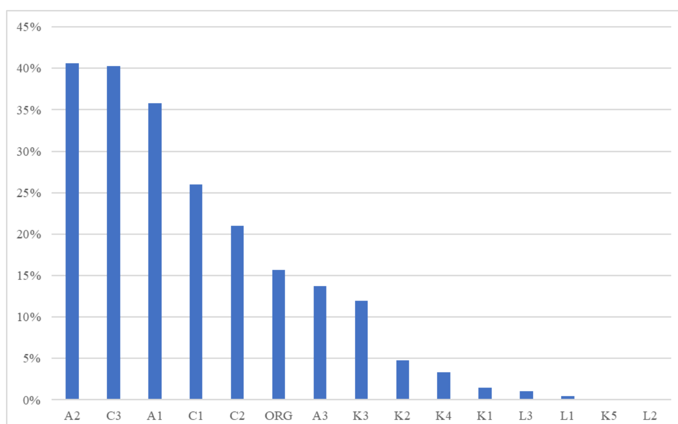

Figure 3: Percentage of Time by HPL Code

Similarly, the frequency of code use and the percentage of time each code was used at each site was also analyzed. These results are displayed in Figures 4 and 5 below.

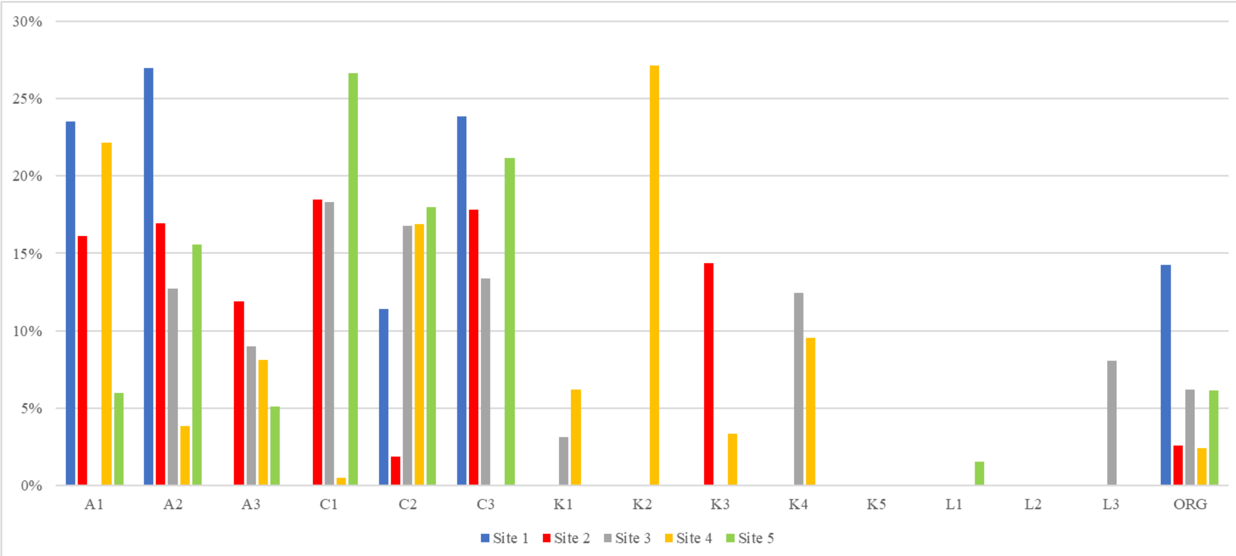

Figure 4: HPL Code Percentage of Frequency by Site

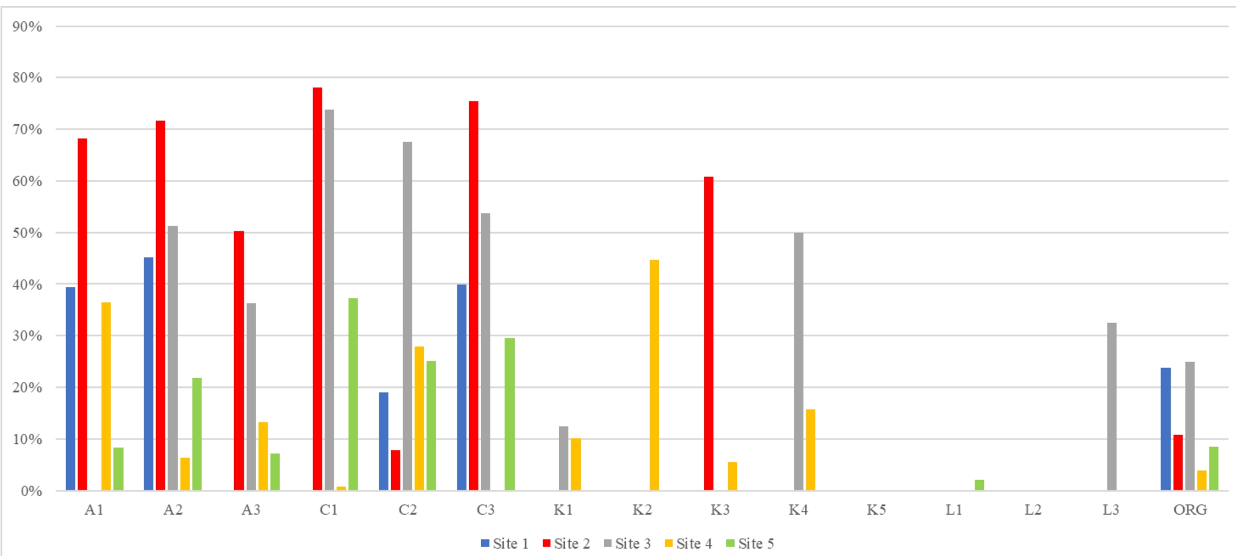

Figure 5: HPL Code Percentage of Time by Site

The key findings for each individual site from the analysis are summarized in the table below.

Table 4: G-RATE Results by Site

<u>Site</u>	<u>Results</u>
Site 1	• A2 and C3 account for 50% of the frequency of use • A2 was used 45% of the time while A1 and C3 were used 40% of the time • ORG was used 24% of the time

Site	Results
Site 2	• C1, C3, and A2 account for 53% of frequency of use • C1 and C3 were used over 75% of the time • A1, A2, A3, and K3 were used over 50% of the time • ORG was used 11% of the time
Site 3	• C1, C2, and C3 account for 48% of frequency of use • C1 was used 74% of the time • C2, C3, A2, and K4 were used over 50% of the time • ORG was used 25% of the time
Site 4	• K2 and A1 account for 50% of frequency of use • K2, A1, and C2 account for 66% of frequency of use • K2 was used 45% of the time • ORG was used 4% of the time
Site 5	• C1, C2, C3, and A2 account for 81% of frequency of use • C1 was used 37% of the time • ORG was used 8.5% of the time

While each site used a different set of HPL codes with varying frequencies in their EML activities, A2 (*Provided verbal/written progress assessment*) and C2 (*Provided opportunities to learn from each other*) were used by all schools and A1 (*Provided thought-provoking questions*), A2 (*Provided verbal/written progress assessment*), and C3 (*Provided team assistance*) accounted for over 55% of total frequency. Therefore, the majority of the classrooms across sites represented community-centered and assessment-centered instruction, meaning that students connected with each other in class and engaged in active feedback with their instructor and with each other. This baseline data highlights that EML classrooms differ from traditional lecture-based courses and are quite interactive. Future research may use the G-RATE to determine if similar interactive activities are occurring in new or partially-infused EML courses or to highlight differences in EML-based instruction by course type (e.g., laboratory or lecture). Observation data may also be analyzed over time to note how changes in pedagogy or curriculum influence a classroom and student outcomes as a result of EML innovations.

Limitations

All classroom observations and faculty focus group interviews occurred toward the end of the semester. During the classes, most students were presenting their final projects or engaging in activities that summarized the content of the course. Additionally, the instructor was not introducing any new material at this point but rather reiterated the content already covered. Therefore, this may explain why the codes K5 (*Provided assistance understanding key concepts*) and L2 (*Acknowledged concept misunderstanding*) were not used by any school and why the codes in the Community and Assessment categories were used by either 4 or 5 of the sites and for approximately 90% of class time. If we were to repeat this study, we would conduct additional observations across multiple classes and at various points in time. Unfortunately, due to our timeline for this research which fed into other aspects of this work, that was not feasible.

Conclusion and Next Steps

The results of this first phase of work were used to inform the development of our revised curriculum in the first year during subsequent phases of our pilot. The second phase of this work included an extensive backwards design workshop focused on EML that leveraged the results of Phase 1. At the beginning of that workshop, the best practices from the site visits were shared with the team working on the course redesign. Faculty from the first phase were also present during this workshop to help facilitate integration of best practices. These faculty continued to bring up elements from these visits into the discussions of the curriculum design. During that workshop, a detailed list of learning objectives for beginning, intermediate, and advanced learners across a variety of EML constructs was created. In the third phase, the workshop deliverables were expanded into actual course activities and assessment complete with detailed rubrics. Again, a faculty member who was a researcher in the first phase of work was included in the course activity development and assessment team. This allowed continuity between the phases of the projects. Currently, the revised curriculum is being piloted and assessed at our university and is considered the first of many EML enhancements to come in our engineering curriculum.

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Appendix

G-RATE Codes

The codes in the table below represent the elements of the How People Learn (HPL) framework [21], which are used in the G-RATE tool and Observation Results.

Table 5: HPL Codes

Assessment	A1 Provided thought-provoking questions
	A2 Provided verbal/written progress assessment
	A3 Confirmed content is understood before new topic
Community	C1 Provided team activities
	C2 Provided opportunities to learn from each other
	C3 Provided team assistance
Knowledge	K1 Provided practical experiences
	K2 Related to everyday situations
	K3 Provided skills that can be applied later
	K4 Emphasized learning new skills
	K5 Provided assistance understanding key concepts
Learner	L1 Acknowledged concepts are difficult
	L2 Acknowledged concept misunderstanding
	L3 Provided problem-solving guidance
Other	ORG Organization