Engineering Faculty Professional Development: Scholarship of Teaching and Learning (SOTL) Dissemination for Curriculum Integrating Entrepreneurial Mindset, STEAM, and Bio-Inspired Design

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1. Introduction

The *Entrepreneurship for All* movement [1, 2] has universities throughout the world developing campus-wide entrepreneurship initiatives in the form of new centers, degrees, minors, courses, accelerator programs, and student organizations. Many engineering faculty are becoming involved in teaching entrepreneurial thinking due to the connection between engineering design and opportunity recognition, often associated with entrepreneurship. However, dissemination and sharing practices have yet to be fully optimized across engineering faculty and their institutions [3].

The dissemination of best teaching practices can be done through a variety of formats. Yet, within the academic setting, journal manuscripts, and conference proceedings are the most well-documented approaches to provide evidence of teaching and research excellence for faculty promotion and tenure (P&T) portfolio documents. For engineering faculty with formal training in engineering education research (EER), demonstrating effective teaching practices can be straightforward [4]. However, engineering faculty with more formal technical or disciplinary training might find it more efficient to document best teaching practices through the scholarship of teaching and learning (SOTL). SOTL investigates student learning and satisfaction based on innovative teaching interventions with the purpose of sharing best practices and lessons learned from an educator perspective [5].

The overarching goal of this paper is to showcase the findings from a cohort-based engineering faculty professional development experience which has two key components: curriculum development and SOTL dissemination. This professional development experience was offered virtually, thus, increasing access to engineering faculty at colleges across the United States. The program was first offered as two disconnected experiences [6, 7]. It was then determined to connect and combine the two professional development experiences; this paper summarizes those findings.

2. Professional Development Overview

Engineering faculty understand the relevance of entrepreneurship to engineering, however, they are often bogged down with the tradition of how engineering courses are traditionally taught, and lack incentives for making changes to curriculum. The purpose of this cohort-based engineering faculty professional development is to further incentivize faculty to create curricular change by providing the opportunity to receive funding but also generate scholarly products that will be recognized in their career advancement (or P&T). The first section (2.1) summarizes the Curriculum Development component of the professional development experience. The second section (2.2) summarizes the Scholarship of Teaching and Learning (SOTL) Virtual Writing Group (VWG) component of the professional development experience.

2.1 Curriculum Development

For the curriculum development, faculty participants completed training on how bio-inspired design and STEAM (science, technology, engineering, arts, math) can be coupled with the entrepreneurial mindset to broaden engineering participation using a transdisciplinary,

humanistic approach. Part of the training included implementing the new curriculum in the engineering classroom and assessing student learning with a photovoice metacognitive reflection tool to better understand student perceptions of the new curriculum.

The focus on bio-inspired design, STEAM, and the entrepreneurial mindset was intentional for the following reasons. First, developing aspiring engineers' entrepreneurial mindsets encourages students to seek the "sweet spot" between customer viability, technological feasibility, and business viability, ideally creating a valuable design with high innovation and impact [8]. Second, bio-inspired design is the development of technologies to improve the environment or human's quality of life, which can create a relevant and engaging learning space [9]. It allows engineering instructors and engineering students, alike, the opportunity to explore how holistic assets can support innovation. The focus on bio-inspired design is intentional as it has immediate connections to nature- and human-centered design, applicable to most (if not all) engineering disciplines. Third, the integration of STEAM with a particular emphasis on the arts encourages transdisciplinary problem-solving [10]. In addition, the use of STEAM promotes connections across a variety of technical and humanities-focused disciplines, bringing together a diversity of perspectives, frameworks, and paradigms. As a result, applying STEAM together with bio-inspired design and the entrepreneurial mindset has the capacity to broaden participation among persons traditionally underrepresented in STEM, including women and minoritized populations.

2.1.1 Curriculum Development - Expectations and Deliverables

To receive the full program stipend, $1,750, engineering faculty participants were expected to (1) Complete eight hours of asynchronous preparatory work using an online learning management system, (2) Attend all required virtual meeting sessions, (3) Design and implement their new curriculum within an engineering class with at least four students, (4) Upload their newly developed curriculum and implementation notes as a card on EngineeringUnleashed.com, and (5) Upload a minimum of four completed student metacognitive reflection submissions to the learning management system.

2.1.2 Curriculum Development - Training Overview

The professional development training followed the backwards curriculum design approach ([11], a structured approach to curriculum development that ensures student learning is guided toward assessments designed to provide evidence students have mastered the learning goal or objectives. Participants received peer and facilitator feedback three times throughout the professional development program.

The **Learning Goal** was provided to the participants [8]. The purpose of the learning goal is to articulate how students will be changed as a result of completing the learning module. From a big-picture perspective, the faculty participants were required to integrate the entrepreneurial mindset, bio-inspired design, and STEAM into a learning module within the engineering classroom.

The **Learning Assessment** was also provided to the participants. The purpose of the learning assessment is to articulate what evidence will be used to demonstrate how students have changed as a result of completing the learning module. The faculty participants were required to have students complete the assessment right after completing the new curriculum. The assessment was a photovoice metacognitive reflection [12] which included 3 photovoice prompts and 3 open-ended metacognitive prompts. Photovoice is a visual and participant-oriented

research methodology that uses imagery, pictures, and/or other visual aids to help students document and reflect upon their experiences. The photovoice reflection required students to respond to the prompt with three images and accompanying narrative (minimum of 200 words) connecting the images to the response.

The **Learning Activities** (e.g., learning intervention) were developed by the individual faculty participants. The purpose of learning activities is apply learning strategies and design educational experiences to enable and promote development of new knowledge. In addition to integrating the entrepreneurial mindset, bio-inspired design, and STEAM (with a particular focus on the arts), the learning activities needed to incorporate the following pedagogical requirements [3]: (1) Professional Skill Development (communication + collaboration), (2) Mindset Cultivation (multiple touch points to allow for practice + feedback + reflection), and (3) Teaching With Intention (promoting IDEA – inclusion, diversity, equity, access). Each faculty participant developed their own learning activities and assignment handouts. All faculty participants were required to showcase their new curriculum intervention via a card on the freely accessible Engineering Unleashed web portal.

2.2 SOTL Virtual Writing Group (VWG)

The main goal of this professional development experience was to execute innovative curriculum revision and also develop scholarly products that could be documented for career advancement purposes. Here, the Scholarship of Teaching and Learning (SOTL) approach was used to help engineering faculty embark on systematic inquiry related to student learning and engagement, and go disseminate the results in a public format (e.g., conference proceeding or journal article).

For the SOTL dissemination, faculty participants completed training on how to write-up and disseminate SOTL research. Part of the training required participants to use the assessment data collected from the newly developed and implemented curriculum to draft an ASEE conference proceeding. Participants worked in small virtual writing groups (VWG) to develop and receive feedback on a manuscript interpreting and showcasing student assessment of learning.

2.2.1 SOTL VWG - Expectations and Deliverables

To receive the full program stipend, engineering faculty participants were expected to (1) attend all required virtual meeting sessions, (2) fill in the manuscript template using the headings provided, (3) write a paper that includes a minimum of 4000 words and minimum of 20 citations, and (4) include the phrase “entrepreneurial mindset” in the title, abstract, introduction, and literature review.

2.2.2 SOTL VWG - Training Overview

Participants were provided a SOTL template which included standard headings as follows: Introduction, Literature Review, Methods, Results, Discussion, and Conclusion. The faculty participants received two one-on-one feedback sessions with a program facilitator and three small group feedback sessions. The small group feedback sessions included 3 faculty participants and 1 facilitator.

During the **One-on-One Session #1**, the faculty participants drafted the **Results** conducted via a thematic analysis of the photovoice metacognitive reflection submissions (submitted at the end of Part 1: Curriculum Development).

During the **One-on-One Session #2**, the faculty participants drafted the **Methods** section to summarize the intervention, student participants, data collection instrument, and data analysis approach (e.g., thematic analysis).

During the **Small Group Session #1**, faculty participants received feedback on the **Introduction** with respect to providing motivation for the study by identifying a problem to be solved, overview of the intervention, introduction to the assessment, and research question.

During the **Small Group Session #2**, faculty participants received feedback on the **Literature Review.** This feedback is based upon the participants' writing, and extent to which the manuscript provides background and expands upon the problem, current approaches to the problem and their gaps, and a summarizes the intervention and justification. The literature review is critiqued with respect to the entrepreneurial mindset, bio-inspired design, and STEAM.

During the **Small Group Session #3**, faculty participants received feedback on the **Discussion and Conclusion** with respect to describing theoretical and practical implications, comparing and contrasting to the literature, summarizing the main takeaway, identifying limitations, and proposing future research.

3. Methods

The participants included 14 engineering instructors from various universities throughout the United States. The gender breakdown was 2 females and 12 males. Various engineering disciplines and course were represented. Of the 14 participants, ten completed the Curriculum Development retrospective post-then-pre survey and nine completed the SOTL VWG retrospective post-then-pre survey. The participants completed two retrospective post-then-pre surveys [13]; one at the end of the curriculum development and one at the end of the SOTL VWG. The survey questions are summarized in Table 1 and Table 2. SPSS was used to conduct Student's t-tests to assess perceived learning gains comparing the before to after.

4. Results

4.1 Perceived Learning Gains (Curriculum Development)

The perceived learning gains were measured using a retrospective post-then-pre survey. Table 1 shows the results of this survey. As can be seen in the results, out of the 19 items, sixteen items had a Student's t-test p-value less than 0.01, and three items had a Student's t-test p-value between 0.01 and 0.05. This implies there was a statistically significant difference between the before assessment and after assessment for these items.

Specifically, concerning the development, implementation, and assessment of a new curriculum that incorporates the entrepreneurial mindset, bio-inspired design, STEAM, and the backward course design, these items resulted in a statistically significant difference between before and after the professional development intervention. Also, regarding the Engineering Unleashed portal, results were statistically significantly different for creating, searching, and uploading cards to the Engineering Unleashed portal.

Table 1. Perceived Learning Gains (Curriculum Development)

1. Development of New Curriculum: Identify to what extent you agree with these statements. I am confident in my ability to DEVELOP engineering curriculum which incorporates…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
The entrepreneurial mindset.	3.5	4.9	0.003 **
Bioengineering or bio-inspired design.	3.2	4.6	0.001 **
STEAM (in particular the Arts).	2.8	4.2	0.000 **
Backward course design planning.	3.8	4.5	0.025 *
Student-centered teaching practices.	3.9	4.5	0.024 *
2. Implementation of New Curriculum: Identify to what extent you agree with these statements. I am confident in my ability to IMPLEMENT engineering curriculum which incorporates…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
The entrepreneurial mindset.	3.40	4.70	0.002 **
Bioengineering or bio-inspired design.	3.00	4.30	0.002 **
STEAM (in particular the Arts).	2.70	4.10	0.000 **
Backward course design planning.	3.50	4.40	0.010 *
Student-centered teaching practices.	3.60	4.60	0.001 **

3. Assessment of New Curriculum: Identify to what extent you agree with these statements. I am confident in my ability to ASSESS engineering curriculum which incorporates…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
The entrepreneurial mindset.	2.80	4.40	0.000 **
Bioengineering or bio-inspired design.	2.90	4.10	0.000 **
STEAM (in particular the Arts).	2.70	3.90	0.000 **
Backward course design planning.	3.40	4.40	0.004 **
Student-centered teaching practices.	3.40	4.50	0.001 **
4. Engineering Unleashed Portal: Identify to what extent you agree with these statements. I am confident in my ability to…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
Create an Engineering Unleashed card.	2.80	4.40	0.002 **
Search the Engineering Unleashed portal.	3.20	4.60	0.001 **
Upload cards to the Engineering Unleashed portal.	3.10	4.60	0.003 **
Connect and network with other engineering educators using the Engineering Unleashed portal.	3.10	4.40	0.009 **
*p-value significance: **<0.01; *<0.05*			

4.2 Perceived Learning Gains (SOTL Virtual Writing Group)

The perceived learning gains were measured using a retrospective post-then-pre survey. Table 2 shows the results of this survey. As can be seen in the results, out of the 15 items, thirteen items had a Student's t-test p-value less than 0.01, and two items had a Student's t-test p-value between 0.01 and 0.05. This implies there was a statistically significant difference between the before assessment and after assessment for these items. Specifically, concerning the writing of the seven major sections in the SOTL paper, these items resulted in a statistically significant difference between before and after the professional development intervention. Also, concerning the virtual writing group and Engineering Unleashed portal, results were statistically significantly different for all items.

Table 2. Perceived Learning Gains (SOTL Virtual Writing Group)

1. Writing a SOTL Paper: Identify to what extent you agree with these statements. I am confident in my ability to write a/an…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
INTRODUCTION section for a SOTL-focused article.	3.11	4.78	0.00 **
LITERATURE REVIEW section for a SOTL-focused article.	2.89	4.56	0.00 **
METHODS section for a SOTL-focused article.	3.11	4.67	0.00 **
RESULTS section for a SOTL-focused article.	2.78	4.56	0.00 **
DISCUSSION section for a SOTL-focused article.	2.89	4.56	0.00 **
CONCLUSION section for a SOTL-focused article.	3.11	4.67	0.00 **
REFERENCES section for a SOTL-focused article.	3.44	4.67	0.01 *
2. Virtual Writing Group: Identify to what extent you agree with these statements. I am confident in my ability to…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
Identify SOTL-focused dissemination outlets.	2.89	4.33	0.005 **
Establish a peer writing group using the protocol provided.	2.78	4.56	0.002 **
Disseminate SOTL-focused research integrating the entrepreneurial mindset.	2.56	4.56	0.001 **
Critique a SOTL-focused article.	3.11	4.44	0.002 **
3. Engineering Unleashed Portal: Identify to what extent you agree with these statements. I am confident in my ability to…			
Statement	**BEFORE (average)**	**AFTER (average)**	**T-Test (p-value)**
Create an Engineering Unleashed card.	2.78	4.78	0.003 **
Search the Engineering Unleashed portal.	3.00	4.56	0.015 *
Upload cards to the Engineering Unleashed portal.	3.11	4.78	0.005 **
Connect and network with other engineering educators using the Engineering Unleashed portal.	3.00	4.44	0.008 **
*p-value significance: **<0.01; *<0.05*			

5. Discussion and Conclusion

This paper demonstrates how priorities of teaching entrepreneurially-minded curriculum can be facilitated by providing more incentives for faculty to make curricular changes. In this case, the authors focused on stipends as well as scholarly outputs that offer value in career advancement, aligned with the promotion and tenure (P&T) processes common at most higher education institutions. Through this program, faculty learned effective and efficient processes for the development and implementation of new curriculum, and dissemination of SOTL. Key aspects of value to the faculty were to better understand SOTL, educational assessment, paper outline, accountability through regular meetings, and written feedback received on drafts.

Simply put, this professional development experience offers another value proposition for engineering educators to leverage involvement in entrepreneurship education through an activity and a potential paper related to

best teaching practices on their P&T portfolio documents. It is recommended that engineering schools and colleges offer these experiences, especially for engineering instructors formally trained in technical and disciplinary areas.

Anecdotal evidence suggests this approach works for the following reasons. First, it promotes accountability. Second, it allows for networking. Third, it encourages collaborations across projects. Fourth, the virtual nature of the program increases accessibility and equity. Fifth, there are multiple incentives (in addition to the four previously mentioned), including a stipend and publication.

6. References

[1] A. Hamouda, "Entrepreneurship for all: an exploration of the impact of entrepreneurship education across disciplines," in *International Conference on Innovation and Entrepreneurship*, 2018: Academic Conferences International Limited, pp. 300-XV.

[2] S. Mosey, "Encouraging Technology Entrepreneurship for All," in *Engineering and Enterprise: Inspiring Innovation*, 2016: Springer, pp. 115-127.

[3] Bosman and Fernhaber, *Teaching the entrepreneurial mindset to engineers*. Switzerland: Springer International Publishing, 2018.

[4] M. Ko, J. F. Mirabelli, A. J. Barlow, K. J. Jensen, and K. J. Cross, "Faculty motivations and barriers for engineering education research," in *American Society for Engineering Education Annual Conference*, 2021.

[5] C. Bishop-Clark and B. Dietz-Uhler, *Engaging in the scholarship of teaching and learning: A guide to the process, and how to develop a project from start to finish*. Stylus Publishing, LLC, 2012.

[6] L. Bosman, N. Duval-Couetil, and K. Jarr, "Mentoring Engineering Educators with an Entrepreneurial Mindset–Focused SOTL Professional Development Experience," in *2022 ASEE Annual Conference & Exposition*, 2022.

[7] L. Bosman and K. Shirey, "Using Bio-Inspired Design and STEAM to Teach the Entrepreneurial Mindset to Engineers," in *2022 ASEE Annual Conference & Exposition*, 2022.

[8] Bosman and Fernhaber, *Teaching the Entrepreneurial Mindset Across the University: An Integrative Approach*. Switzerland: Springer, 2021.

[9] J. K. Nagel, C. Rose, C. Beverly, and R. Pidaparti, "Bio-inspired design pedagogy in engineering," *Design education today: Technical contexts, programs and best practices*, pp. 149-178, 2019.

[10] A. Connor, S. Karmokar, and C. Whittington, "From STEM to STEAM: Strategies for enhancing engineering & technology education," 2015.

[11] G. P. Wiggins and J. McTighe, *Understanding by Design*. Alexandria, VA: ASCD Publications, 2005.

[12] K. Kelly, S. H. M. Lee, H. Bowen Ray, and M. Kandaurova, "Using the Photovoice Methodology to Increase Engagement and Sharpen Students' Analytical Skills Regarding Cultures, Lifestyles, and Markets Internationally," *Marketing Education Review. Summer2018*, vol. 28, no. 2, p. 69, 2018, doi: 10.1080/10528008.2018.1450093.

[13] T. D. Little *et al.*, "The retrospective pretest–posttest design redux: On its validity as an alternative to traditional pretest–posttest measurement," *International Journal of Behavioral Development*, vol. 44, no. 2, pp. 175-183, 2020.