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# Integrating Online Discussions into Engineering Curriculum to Endorse Interdisciplinary Viewpoints, Promote Authentic Learning, and Improve Information Literacy

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**Integrating Online Discussions into Engineering Curriculum to Endorse Interdisciplinary Viewpoints, Promote Authentic Learning, and Improve Information Literacy**

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**Abstract:** Engineering is very much an applied discipline where math and science concepts, skills, and tools can be used to design products or processes with new and/or increased value. Research suggests active learning is an effective method for teaching and learning in the engineering classroom. Moreover, students continue to express increased satisfaction when taught using this experiential pedagogical approach. One approach to active learning gaining traction in the engineering classroom is the use of online discussions. The purpose of this paper is to offer a structured approach for engineering educators to develop online discussion prompts aimed to prepare engineering students for entering the workforce; this structure approach includes an intentional and purposeful focus on three core elements: (1) interdisciplinary viewpoints, (2) real-world and authentic experiences, and (3) information literacy applications. A mixed methods analysis provides evidence towards student exposure and awareness to the three core elements of interdisciplinary viewpoints, real world and authentic experiences, and information literacy applications. In addition, students reported a positive experience participating in online discussions, and improvements in student perception changes related to blended learning and self-regulated learning.

**Keywords:** undergraduate, information literacy, mixed methods

## 1. Introduction

ABET, formerly known as the Accreditation Board of Engineering and Technology, defines engineering as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind." Thus, engineering is very much an applied discipline where math and science concepts, skills, and tools can be used to design products or processes with new and/or increased value. Research suggests active learning is an effective method for teaching and learning in the engineering classroom [1-3]. Moreover, students continue to express increased satisfaction when taught using this experiential pedagogical approach. This has resulted in many "lecture plus lab" course options where students can learn theoretical concepts in a lecture-based classroom and apply practical understanding in a controlled, hands-on laboratory setting. However, engineering faculty continue to struggle with the quality versus quantity dilemma associated with content coverage and curriculum design required for non-lab, lecture-based classroom requirements. In other words, there continually exists a re-evaluation of the need to focus on breadth of content covering many topic areas in comparison to depth of understanding within a few topic areas. One approach to active learning gaining traction in the engineering classroom is the use of online discussions. This pedagogical approach requires a limited amount of faculty time in the classroom, while promoting student engagement in a digital format outside the normal classroom environment. Despite the large amount of research which provides support towards the instructional benefits of online discussions, little research has been established identifying best practices to deploying online discussions for engineering educators.

The purpose of this paper is to offer a structured approach for engineering educators to develop online discussion prompts aimed to prepare engineering students for entering the workforce; this structured approach includes an intentional and purposeful focus on three core elements: (1) interdisciplinary viewpoints, (2) real-world and authentic experiences, and (3) information literacy applications. The following question will be used to guide the research:

- What factors influence engineering student perceptions and learning outcomes associated with the structured approach to online discussions?

The next section, Background, offers a literature review providing an overview of the benefits associated with online discussions, and a summary of relevant education research related to the advantages associated with interdisciplinary viewpoints, real world and authentic experiences, and information literacy. The Background section concludes with an introduction to the proposed structured approach to engineering online discussions. The Methods section provides an overview of the data collection process, including faculty training, courses impacted, and a description of student participants. In addition, the survey instruments and mixed methods analysis approach are explained. The Results section provides qualitative and quantitative evidence and justification for four main takeaways. The Discussion section provides a comparison to previous research available in the literature. The Conclusions section provides a summary, research limitations, and recommendations for future work.

## 2. A Framework for developing online discussion prompts

### 2.1 Interdisciplinary Viewpoints

Interdisciplinary viewpoints offer a holistic perspective for considering approaches to problem solving typical of those in the workforce existing at the intersection of domains and disciplines, where commonality identification is required to produce something new and unique. Interdisciplinary courses and programs (and other associated terms, such as multidisciplinary, transdisciplinary and convergence research) are not new to higher education [4-6]. Koch and colleagues [7] describe how they've brought together first-year students from multiple departments (e.g., engineering, social sciences, human sciences, etc…) to work collaboratively on interdisciplinary study projects. The authors found that student participation resulted in academic engagement and met basic psychological needs related to competence and autonomy. Fernhaber, Albert, and Lupton [8] explain how an interdisciplinary capstone course was offered to students in multiple disciplines (i.e. pharmacy, graphic design, teacher education, and marketing) to write, illustrate and publish children's books. This collaborative and interprofessional experience provided students with access to skill development within the fields of entrepreneurship and innovation. Ludwig and co-authors [9] present findings from the implementation of an interdisciplinary mathematical modeling class targeting students from mathematics and biology. The class offers autonomy in selecting from multiple approaches to project context resulting in student satisfaction as they can work on projects that meet their individual interests. Flannery and Malita [10] offered an interdisciplinary team project teaming up two psychology students with a computer science student, where the psychology students conducted library research and created a preliminary design protocol and the computer science student developed an online version. As a result, students reported an increase in understanding concepts associated with the other discipline, and improved skill development related to leadership, time management and project management. Anderson, Bunnel, and Yates [11] describe how they embedded an interdisciplinary case study into a an undergraduate course on ecology where students were required to wear different "hats" (e.g., agronomist, microbiologist, limnologist, etc…) to investigate eutrophication in Lake Erie. The findings suggest an improvement in student learning outcomes and student satisfaction towards using interdisciplinary approaches to solve complicated science problems. Gilbert and colleagues [12] show how they brought together students from social work and engineering to design and implement global engineering development projects. The results provide evidence for student improvements in considering issues with power balance, economics and project sustainability within an international context.

### 2.2 Real World and Authentic Experiences

Incorporating real world and authentic experiences into the classroom environment offers students access to the development of 21st century skills demanded by industry [13]. Moore and Berry [14] developed and implemented a four-semester design sequence where students work in groups of three to five as an engineering consultant team to address external sponsored projects. The design sequence culminates with a day-long symposium event where student teams make formal presentations, showcasing their newly developed communication and design skills, to sponsor representatives and the campus community. Liu [15] explains how a traditional mechanical engineering senior design course was updated to better prepare engineering graduates for the workforce. The incorporation of industry-sponsored projects and required tool applications of finite element analysis, modeling, and simulation provided students with satisfaction and skill development in problem solving and critical assessment. Okudan and colleagues [16] describe how they assessed a first-year engineering design course for how industry sponsored projects influence student learning outcomes and retention. The authors note how these real world experiences can be particularly helpful for retaining women and minorities in engineering programs. Nedic, Nafalski, and Machotka [17] explain changes made to a typical first-year electrical engineering course. The course was modified to incorporate a real world project-based learning laboratory, and as a result, increased student satisfaction and success, and decreased the attrition rate. Spanjol and co-authors [18] describe the development of an industry-university collaboration aimed to provide a systematic and structured approach to creating a win-win for both engineering students and industry partners. As a result, student teams gain important information literacy and communication skills, improving the efficiency and effectiveness associated with the design process. Although incorporating real world and authentic experiences is common in many engineering programs, as shown here, it is also imperative for other disciplines to provide students access to 21st century skill development. Hollis and Eren [19] describe how they collaborated with a manager at ACH Food Companies, Inc. to develop a real-world learning experience related to new product development for cake mixes. The researchers noted improvement in success skills such as teamwork, critical thinking and communication, which are required for food science professionals to be proficient in the workplace. Fitch [20] explained how a final-year undergraduate course in communications was updated where students worked in teams to develop communication strategies for a non-profit organization. Not only did the experience offer students to participate in service learning, but allowed students to obtain experience interacting with clients on real world marketing projects.

### 2.3 Information Literacy Applications

Information literacy is defined as "the set of integrated abilities encompassing the reflective discovery of information, the understanding of how information is produced and valued, and the use of information in creating new knowledge and participating ethically in communities of learning (ACRL, 2015)." It is widely understood that information literacy includes the capacity to recognize when information is needed, and the related skills to locate, access, evaluate, and use information, effectively and ethically (ALA, 1989; Bawden, 2001, Wertz, Purzer, Fosmire & Cardella, 2013). For engineers, information literacy is tied to the engineering design process (Fosmire & Radcliffe, 2013), notably information gathering, application, and documentation activities. For example, engineers need to learn how others have solved similar problems, seek out apply relevant technical standards and regulations, and document activities, citing their sources, for others to be able understand and validate their design decisions.

Previous connections have been made between the ABET Engineering Accreditation Commission (EAC) criteria and information literacy [21, 22], particularly in the area of lifelong learning, signifying the importance of information literacy to engineering education. While the revised ABET EAC student outcomes for 2019-20 (ABET, 2017) no longer, contain the phrase "lifelong learning," language related to information literacy is included in new student outcomes 4: "*an ability to recognize ethical and professional responsibilities in engineering situations and make* ***informed*** *judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts*" and 7: "*an ability to* ***acquire and apply new knowledge*** *as needed, using appropriate learning strategies*." Many studies discuss collaborations between academic librarians and discipline faculty members to integrate information literacy into engineering courses [23-25].

The authors propose that relationships between engineering education and information literacy can also be established by mapping the KEEN Entrepreneurial Mindset educational outcomes to the Association of College and Research Libraries (ACRL) Framework for Information Literacy for Higher Education (ACRL, 2015). The ACRL Framework is the prevailing document that guides academic information literacy practice in the field of library and information science. Information literacy is expressed in the ACRL Framework through six concepts, or frames, labeled as "Authority is Constructed and Contextual," "Information Creation as a Process," "Information Has Value," "Research as Inquiry," "Scholarship as Conversation," and "Searching as Strategic Exploration" (ACRL, 2015). Using the "Curiosity: What do we mean?" (KEEN, 2018a), "Connections: What do we mean?" (KEEN, 2018b), and "Creating Value: What do we mean?" (KEEN, 2018c) exemplar cards available as free downloads from the KEEN website to gain further understanding of the KEEN outcomes, the authors propose the mapping shown in Table 1.

Table 1: Proposed Mapping of KEEN Entrepreneurial Mindset Educational Outcomes to the Framework for Information Literacy for Higher Education

| KEEN Entrepreneurial Mindset Educational Outcomes | Framework for Information Literacy for Higher Education - Proposed Mapping |
|---|---|
| ***Curiosity*** | |
| Demonstrate constant curiosity about our changing world | Research as Inquiry<br>Searching as Strategic Exploration |
| Explore a contrarian view of accepted solutions | Authority is Constructed and Contextual<br>Scholarship as Conversation<br>Searching as Strategic Exploration |
| ***Connections*** | |
| Integrate information from many sources to gain insight | Research as Inquiry<br>Searching as Strategic Exploration |
| Assess and Manage Risk | Research as Inquiry<br>Searching as Strategic Exploration |
| ***Creating Value*** | |
| Identify unexpected opportunities to create extraordinary value | Information Has Value<br>Searching as Strategic Exploration |
| Persist through and learn from failure | Searching as Strategic Exploration |

### 2.4 Introduction to the Structured Approach to Engineering Online Discussions

The use of online discussions can greatly enhance the learning process. In general, discussion sessions can promote the use of critical thinking skills [26, 27] by encouraging reflection and consideration for multiple student perspectives. When discussion sessions are offered online in an asynchronous environment, application of critical thinking skills increase as students have additional time to think about a response, and the added flexibility to add input when they feel ready [28]. In comparison to face-to-face classes, online classes allow all students to participate and actively engage in the discussion session [29], resulting in a greater sense of belonging as the class community and personal relationships become stronger [30].

The proposed structured approach to online discussions, leverages the benefits previously mentioned, and provides an easy-to-implement learning experience with an enhanced focus towards three core critical thinking elements of interdisciplinary viewpoints, real-world and authentic experiences, and information literacy applications. The framework in Figure 1 provides a structured guide for integrating the three core elements into online discussion prompts.

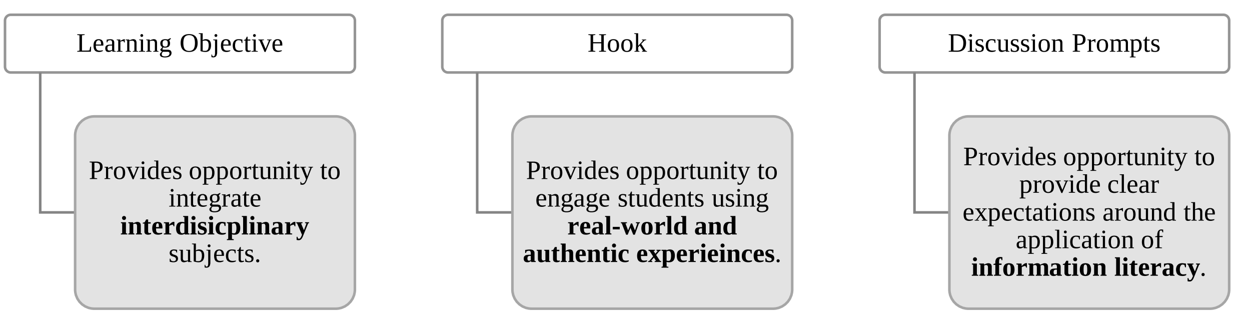


Figure 1: Framework for Developing Online Discussion Prompts

Learning objectives are the foundation of effective teaching, explicit declarations of student expectations upon completion of the learning activity [31-34]. Learning objectives offer the forum for explicitly including interdisciplinary viewpoints into online discussion sessions. One fill-in-the-blank approach is as follows: "By the end of this [learning activity], students should be able to [description of the expectations incorporating a Bloom's taxonomy action verb] within the fields of [engineering topic X] and [interdisciplinary topic Y]."

Hooks are a pedagogical technique use to increase engagement by grabbing students attention [35-37]. Using the context of a real-world and authentic experience in a hook provides students with purpose and value [32, 38] for wanting to learn more. Videos, news clips, and short stories offer a great way to introduce students to an assignment; leveraging situational examples grounded in real-world concepts will result in a great understanding and application of the engineering topic [39, 40].

Discussion prompts can be used to guide the discussion focus [41, 42], and convey expectations related to aspects of information literacy [43]. Ideally, discussion prompts should include expectations for an initial posting and a response posting, the latter which promote greater interaction among student participants.

Here, two examples are provided which put the framework to work.

Example 1: Engineering Opportunities (Topic - The Engineering Profession)

- *Learning Objective:* By the end of this discussion session, students should be able to demonstrate an understanding of the profession and responsibilities of engineers.
- *Hook:* Recently biologists, geneticists, genetic engineers, bioengineers, doctors, and many others successfully removed a disease-causing gene in human embryos. The article link may be accessed here: http://www.npr.org/sections/health-shots/2017/08/02/540975224/scientists-precisely-edit-dna-in-human-embryos-to-fix-a-disease-gene. Here are some perspectives and stakeholders around this issue: (1) You're a scientist who has hypothesized that this technology would work to delete disease causing genes, however, you never pursued it because you believe that science would never be able to stop at just one gene. There hasn't been enough research to truly understand the intricacies of all the human genes, and we should mess with something until we have a better understanding first. (2) You're a bioengineer who is creating pediatric ECMO machines (machines for externally warming the blood, and oxygenating it). Your clients are small children with the exact heart condition this gene-editing technology is proposing to fix. You're getting so frustrated that the ECMO machines are only good for a few weeks for kids while they wait for a heart transplant, which are extremely rare. Plus, the design typically leads to blood clotting, so these children must be on a medication to prevent blood clots, which leads to even more possible side effects. Due to your expertise with the heart, you're being asked to weigh in on the debate for if the government should approve devices or techniques that will work with human embryos (currently illegal). (3) You're a US federal official responsible for advising your state senator for all issues regarding the FDA. Your senator has a constituent and large donor who's 3 out of 4 kids suffer from cardiomyopathy and she's called on a daily basis to push the senator to craft a bill allowing the FDA to move forward with human embryo techniques. The senator has asked you to draft a proposal for what this bill might look like given the concerns of members of the community, and the fact that other countries allow this type of research already so the US scientists working on it will take this potentially lucrative technology somewhere else if a bill doesn't get proposed or drafted.
- *Initial Prompt:* You've read through an article about the state of DNA editing technology, and the perspectives of three stakeholders. Choose one perspective and generate questions that you feel need to be answered in order to make a decision. You should have at least 10 questions and rank them in order from most important to least.
- *Response Prompt:* Compose at least two questions you did not ask that come to mind when you read your peer's generated questions. Additionally, post a thoughtful reflection on class today and the discussion. Your reflection should include your thoughts and opinions about this case, describe the process we used, and today's class in general. Remember that this is a public forum and anything you put here has the potential to be shared.

Example 2: Engineering Design I (Topic - Engineering Ethics)

- *Learning Objective:* By the end of this discussion session, students should be able to demonstrate application of the NSPE code of ethics during the evaluation of an ethical situation (initial prompt) and recognize that an ethical situation may have multi-dimensionality (response prompt).
- *Hook:* Francis Smith submitted plans on behalf of a Developer to the State Department of Transportation for approval and for a permit to work on a local traffic intersection. The scope of work included upgrading accessibility for disabled individuals in all four corners of the intersection. One corner of the intersection had extreme grades in excess of the maximum slopes required for accessibility by disabled individuals

according to the Americans with Disabilities Act (ADA). Francis explained to the reviewer and Developer that there was no reasonable way to regrade the roadway or existing sidewalks to accommodate the maximum slope and offered an alternative which would relocate the intersection. The State DOT proposed a solution that, in Francis's opinion, was not in compliance with the ADA guidelines. The State DOT responded by stating "you accommodate disability accessibility this way or you don't get a permit." Francis continued to maintain that locating the accessibility route as proposed by State DOT was inconsistent with the ADA, would increase the danger to disabled individuals, and could also expose Francis and her firm to professional liability. At the meeting in which Francis stated her views, Frank Downy, a State DOT reviewer, who happened to be physically disabled and not an engineer, verbally indicated that in his opinion, the location proposed by the State DOT was a better location than the alternate relocation proposed by Francis. The NSPE Code of Ethics may be accessed here: https://www.nspe.org/sites/default/files/resources/pdfs/Ethics/CodeofEthics/Code-2007-July.pdf.

- *Initial Prompt:* Respond to the above case study with a discussion of what Francis's next steps should be in this situation. Identify at least three ethical issues and justify Francis's next steps and course of action relating it to the NSPE Code of Ethics through citations.
- *Response Prompt:* Read through your peers' prompts. Choose a response with few or no replies. Speculate on the State DOT's perspective, and provide at least one counter-argument to a peer's response describing next steps based on your speculated other side's perspective.

## 3. Methods

### 3.1 Data Collection

The study was conducted at a public university located on the east coast of the United States with an undergraduate engineering student population of about 500 students during the 2017-2018 school year. During August 2017, four engineering faculty engaged in a three-day university-promoted faculty professional development training. The training was limited to engineering faculty with the purpose of training faculty on the new structured approach to engineering online discussions. The faculty trainees learned the nuances of the three core elements (interdisciplinary viewpoints, real world and authentic experiences, and information literacy), spent a considerable amount of time drafting discussion prompts, and received qualitative feedback from their peers and the training facilitators. At the end of the three-day training, the engineering faculty were prepared to implement a series of eight discussions prompts in their engineering class during the Fall 2017 semester. A summary of the student survey instrument questions are provided in Table 2. The following courses were impacted:

- Engineering Opportunities (required First-Year engineering course)
- Engineering Design 1 (required Sophomore engineering course)
- Engineering Design 3 (required Junior engineering course)
- Hacking for Diplomacy (elective Senior engineering course)

In addition to completing regular coursework, all student participants were asked to complete a pre-class survey, participate in eight different online discussion sessions throughout the semester, and complete a post-class survey upon completion of the semester. IRB was approved with the caveat of required anonymity and de-identification of specific classes. As such, individual collective data collection instruments were used for all four engineering courses mentioned about. A total of 331 students completed the pre-class survey. At the end of the semester, a post-class survey was completed. In an effort to compare treatment group (e.g., those students who participated in a course with the online discussions) to a control group (e.g., any engineering student not enrolled in a class using online discussions), a total of 285 students completed the post-treatment survey and 24 students completed the post-control survey.

Table 2: Summary of Survey Instrument Questions

| | |
|---|---|
| **Pre- and Post-Survey** | |
| **Blended and Self-Regulated Learning** | Q1. Identify the top three factors that are most important for student learning and success. |
| | Q2. Blended learning occurs when a student learns at least in part through digital and online engagement with some element of student control over time, place, path, or pace. What is your perception of blended learning in comparison to face-to-face learning? |
| **Post-Survey Only** | |
| **Information Literacy Applications** | In comparison to other courses that do not include online discussions, how much has your coursework in this course emphasized the following? (1 = Not at All, 5 = Very Much) |
| | Q3. [Understand the motivations and perspectives of others] |
| | Q4. [Explore a contrarian view of accepted solutions] |
| | Q5. [Identify unexpected opportunities to create extraordinary value] |
| | Q6. [Persist through and learn from failure] |
| | Q7. [Demonstrate constant curiosity about our changing world] |
| | Q8. [Integrate information from many sources to gain insight] |
| **Real-World and Authentic Experiences** | In comparison to other courses that do not include online discussions, how much has your coursework in this course emphasized the following? (1 = Not at All, 5 = Very Much) |
| | Q9. [Discovery and exploration of real-world examples related to class topics] |
| | Q10. [Evaluation and assessment of real-world examples related to class topics] |
| | Q11. [Exploitation and design of real-world examples related to class topics] |
| **Interdisciplinary Viewpoints** | In comparison to other courses that do not include online discussions, how much has your coursework in this course emphasized the following concepts? (1 = Not at All, 5 = Very Much) |
| | Q12. [Customer Desirability, taking into consideration customer wants and needs required to validate a new product or service] |
| | Q13. [Technology Feasibility, taking into consideration resources and capabilities required to produce a product or service] |
| | Q14. [Business Viability, taking into consideration revenue and cost structures required to offer a new product or service] |
| **Student Satisfaction** | To what extent do you agree/disagree with the following statements about engaging in online discussions during this course? (1 = Strongly Disagree, 5 = Strongly Agree) |
| | Q15. [Engaging in online discussions was an enjoyable experience] |
| | Q16. [Engaging in online discussions was an effective learning method] |

### 3.2 Data Analysis

A mixed methods approach was used to analyze the data. Both the pre- and post-surveys each included a combination of open-ended questions and numerically scaled questions. The NVivo 11 qualitative analysis software was used to analyze the qualitative open-ended questions. All data documents were imported into NVivo and the researchers read through the documents several times. Two researchers individually coded and highlighted the documents with the purpose of identifying themes related to the research questions and picture taking prompts. Upon completion of the independent analysis, the researchers compared their results, read through the documents again, and came to a consensus for developing themes and a coding framework. Analysis of the documents led the researchers to identify major themes related to the research question, which are identified in the next session. The Statistics Package for Social Sciences (SPSS) was used to analyze the quantitative numerically scaled questions. Descriptive statistics, graphical techniques, and hypothesis testing using the Student’s t-test for a difference in means was used to quantitatively analyze the data.

## 4. Results

The mixed methods analysis of data was conducted in three key areas. First, quantitative analysis was performed to determine to what extent the student participants acknowledged existence of the three core elements of interdisciplinary viewpoints (Q3-Q8), real world and authentic experiences (Q9-Q11), and information literacy applications (Q12-Q14). The treatment group (participants who received the intervention of online discussions) were compared to the control group (students in classes that did not have online discussions. The results are shown in

Table *3*. The findings suggest that there is a statistically significant difference (at p=0.05) for four of the questions. With respect to Information Literacy Applications, students reported that online discussions allowed them to (1) persist through and learn from failure, (2) demonstrate contact curiosity about our changing world, and (3) integrated information from many sources to gain insight. With respect to Real-World and Authentic Experiences, students reported that online discussions allowed them to (1) evaluate and assess real-world examples related to class topics. Although only four of the twelve questions were statistical significant in comparing the treatment group to the control group, the findings are positive in that students were able to recognize the intentional inclusion of Information Literacy Applications and Real-World and Authentic Experiences within the discussion prompts.

Second, quantitative analysis was performed to determine to what extent the students found participating in the online discussions enjoyable and effective. Q15 and Q16, respectively, asks participants to consider if engaging in online discussions was an enjoyable experience and an effective learning method. The results are shown in Figure 2 and Figure 3. The results are similar for students responding to online discussions being an enjoyable experience and an effective learning. method Although the far majority of students (about 1/3 of the participants) “”Disagreed” that participating in online discussion was an enjoyable experience and “Disagreed” that participating in online discussions was an effective learning method, over 25% of the participants “Agreed” or “Strongly Agreed” that participating in online discussions was an enjoyable experience and “Agreed” or “Strongly Agreed” that participating in online discussions was an effective learning method. Many teachers would view this information as a success.

Table 3: T-Test Results Related to Student Learning

| Survey Question | | Control Group (n = 24) | | | Treatment Group (n = 285) | | | Independent Samples Test (t-test for Equality of Means) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Std. Error Mean | Mean | Std. Dev. | Std. Error Mean | t | df | Sig. (2-tailed) |
| **Information Literacy Applications** | Q4 | 4.21 | 0.799 | 0.047 | 4.13 | 1.424 | 0.291 | 0.467 | 307 | 0.641 |
| | Q5 | 3.85 | 0.861 | 0.051 | 4.17 | 1.204 | 0.246 | -1.265 | 25.020 | 0.217 |
| | Q6 | 3.94 | 0.886 | 0.053 | 4.25 | 1.073 | 0.219 | -1.359 | 25.710 | 0.186 |
| | Q7 | 4.08 | 0.925 | 0.055 | 4.46 | 0.658 | 0.134 | -2.603 | 31.227 | **0.014 |
| | Q8 | 3.85 | 0.890 | 0.053 | 4.50 | 0.722 | 0.147 | -3.503 | 307 | **0.001 |
| | Q9 | 4.07 | 0.804 | 0.048 | 4.54 | 0.658 | 0.134 | -3.333 | 29.115 | **0.002 |
| **Real-World and Authentic Experiences** | Q10 | 4.21 | 0.786 | 0.047 | 4.54 | 0.884 | 0.180 | -1.778 | 26.156 | 0.087 |
| | Q11 | 4.14 | 0.793 | 0.047 | 4.75 | 0.442 | 0.090 | -3.716 | 307 | **0.000 |
| | Q12 | 4.15 | 0.772 | 0.046 | 4.46 | 0.884 | 0.180 | -1.633 | 26.042 | 0.114 |
| **Interdisciplinary Viewpoints** | Q13 | 4.40 | 0.718 | 0.043 | 4.17 | 1.090 | 0.223 | 1.030 | 24.708 | 0.313 |
| | Q14 | 4.06 | 0.898 | 0.053 | 4.29 | 0.999 | 0.204 | -1.084 | 26.224 | 0.288 |
| | Q15 | 3.67 | 1.050 | 0.062 | 3.88 | 1.154 | 0.236 | -0.855 | 26.311 | 0.400 |

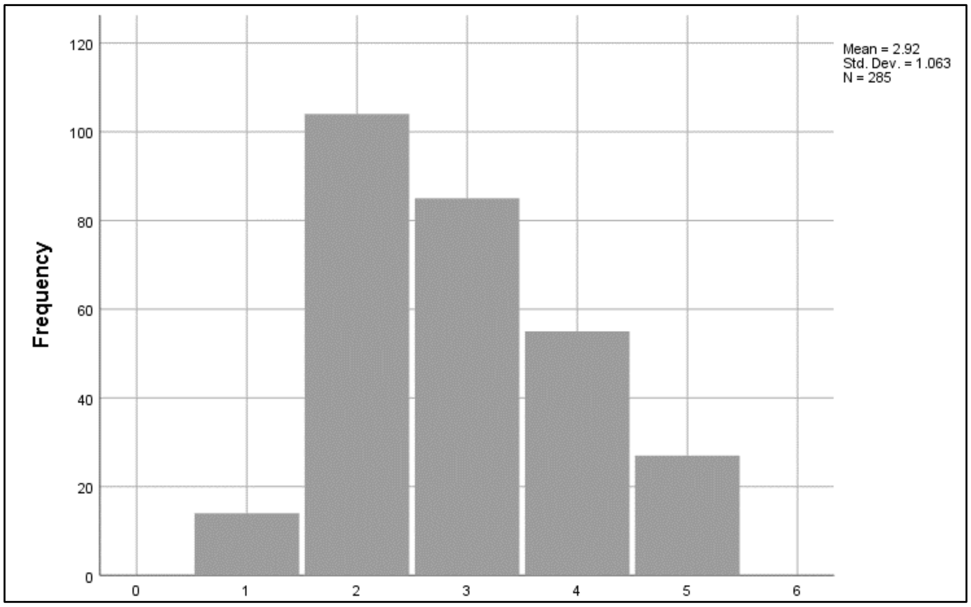

Figure 2: Histogram Results Showing Student Satisfaction – Enjoyable Experience

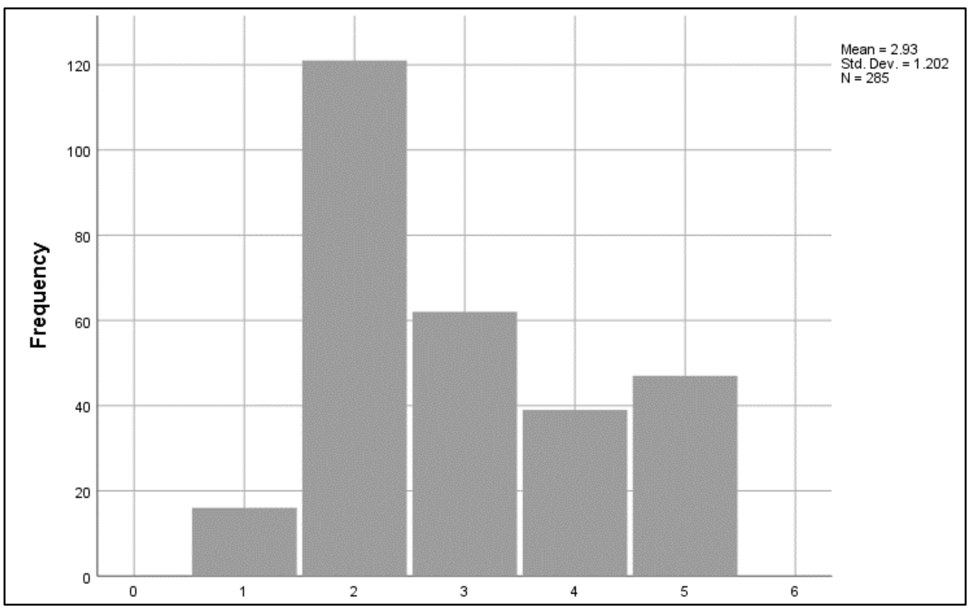

Figure 3: Histogram Results Showing Student Satisfaction – Effective Learning

Third, qualitative analysis was performed to understand changes in student perceptions, if any, related to blended learning and self-regulated learning. This analysis required comparing responses from the pre-survey to the post survey. Q1 asked students to "Identify the top three factors that are most important for student learning and success." In comparing the pre-survey to the post-survey, the open-ended responses were coded as (a) In Student's Control, (b) Both In Student's Control and Out of Student's Control, and (c) Out of Student's Control. Example responses are shown here:

a. In Student's Control: "Paying attention in lecture, Studying the material, Practicing on their own"
b. Out of Student's Control: "Professor's willingness to have open hours, Curriculum, Pace"

The results, shown in Table 4, suggest a shift from pre- to post-responses for things that are In Student's Control. Although the results are not statistically significant, this suggests that the intervention of online discussions may leans towards a potential shift of students viewing learning and success within their control rather than being depending upon the instructor and other outside factors.

Table 4: Results - Top 3 Factors Most Important for Student Learning

| Q1: Top 3 Factors Most Important for Student Learning | Pre | Post |
|---|---|---|
| In Student's Control | 55% | 59% |
| Both | 35% | 31% |
| Out of Student's Control | 10% | 10% |

Q2 was as follows: "Blended learning occurs when a student learns at least in part through digital and online engagement with some element of student control over time, place, path, or pace. What is your perception of blended learning in comparison to face-to-face learning?" In comparing the pre-survey to the post-survey, the open-ended responses were coded as (a) Positive or (b) Negative. Example responses are shown here:

a. Positive:
    - "Blended learning is a lot easier to be receptive towards, especially with our generation. Our generation grew up with technology, so a lot of times it can be easier for students now to learn through digital engagement."
    - "Blended learning is sometimes easier and more efficient for individuals and the class as a whole. This allows for students to read material online and take quizzes online (both at their own pace), so in class they can participate in more hands on or discussion based activities instead of wasting time reading or taking quizzes."
    - "I believe mixing the two elements greatly increases retention of information because it allows the student to encounter the information in different mediums and thereby interact with the information differently each time."

b. Negative:
    - "I am terrible at motivating myself to do work for any sort of unstructured schedule."
    - "I would rather learn the material from a professor than read it online."
    - "I love face on face learning because I am able to listen to the teacher talk, watch them do the problems/write on the board, and finally I also write down my notes so I get to use many different parts of my brain. Also when I do not understand something I get to ask a question on how they got something or why something worked the way it did."

The results, shown below, suggest a shift from pre- to post-responses for positive perceptions. Although the results are not statistically significant, this suggests that the intervention of online discussions may lean towards a potential shift of students perceiving blended learning as a positive experience.

Table 5: Results - Perceptions of Blended Learning

| Q2: Perceptions of Blended Learning | Pre | Post |
|---|---|---|
| Positive | 41% | 43% |
| Negative | 59% | 57% |

**5. Discussion**

The guiding research question was as follows: *What factors influence engineering student perceptions and learning outcomes associated with the structured approach to online discussions?*

The findings suggest the structured approach to online discussions can be beneficial for improving student learning outcomes and satisfaction.

First, the findings suggest that there is a statistically significant difference (at p=0.05) related to students' ability to (1) persist through and learn from failure, (2) demonstrate contact curiosity about our changing world, (3) integrate information from many sources to gain insight, and (4) evaluate and assess real-world examples related to class topics. These findings are positive in that students were able to recognize the intentional inclusion of information literacy applications and real-world and authentic experiences within the discussion prompts. This findings are consistent with the literature, in particular (and respectively) related to the growth mindset [44], inquiry-based learning [45], information literacy [46], and entrepreneurial mindset [47]

Second, students reported participation in the online discussion sessions to be an enjoyable experience and an effective learning method. In addition, the findings suggest a shift from pre- to post-responses for positive perceptions for blended learning These findings are positive in that student perceptions can influence student motivation to learn. These findings are consistent with other studies which aim to integrate the authentic learning into engineering online discussions via entrepreneurially minded learning [48-51]. From a practical perspective, the structured approach to online discussions can assist engineering faculty who struggle to fit the desired amount of content within a lecture. Specifically, using the structured approach to online discussions is not only effective for student learning, but also requires a limited amount of faculty time in the classroom, while promoting active learning and student engagement outside the normal classroom environment.

Third, the findings suggest a shift from pre- to post-responses for things that are "In Student's Control". Although the results are not statistically significant, this suggests that the intervention of online discussions may lean towards a potential shift of students viewing learning and success within their control rather than being depending upon the instructor and other outside factors. This is consistent with the literature which focuses on the relationship between online discussions and participant empowerment in civic participation [52], self-management of chronic diseases [53], and online support groups [54]. From a practical perspective, student empowerment and self-regulation [55] is important for learning in that it encourages students to continually assess their own abilities towards taking action and making change happen.

Finally, although the focus of this paper was on designing a framework for developing online discussion prompts for engineering classes using the interdisciplinary topic of entrepreneurial mindset, the researchers are confident the framework would likely be successful outside of engineering, applicable to most any other discipline.

As with any study, this research has limitations which should be taking into consideration. First, although the sample size was reasonably large (pre sample size = 331, post sample size = 285), a control group was used, and courses were selected at each level of the undergraduate experience (freshman, sophomore, junior, and senior), the study was limited to one university within the United States. In addition, as with any experimental design there is the potential of error. Thus, there may be some uncontrollable factors (i.e. instructor likeability, topic area) which may have played an influential role within the statistical analysis. Because of these limitations, generalizability to all engineering programs throughout the world should be applied with caution. Second, some of the survey instrument questions (from Table 2) were grounded in the KEEN philosophy. Although this philosophy is trending and rising in popularity among engineering program administrators and educators, alike, it is limited with respect to theoretical grounding.

## 6. Conclusion

In conclusion, the researchers found that using a structured approach to develop online discussion prompts aimed to prepare engineering students for entering the workforce is an effective way to integrate (1) interdisciplinary viewpoints, (2) real-world and authentic experiences, and (3) information literacy applications into engineering courses. As compared to a control group, participants who experienced the structured discussions reported a statistically significant (at p=.05) increase in student learning. Additionally, the researchers conclude that structured approaches to online discussions may result in increased student satisfaction of blended learning.

Future research should be performed with attention to increasing the generalizability of the findings. This could be done applying the structure approach to online discussions with a greater quantity of engineering students, with additional engineering programs at other higher education institutions throughout the world, with a more diverse set of engineering courses, and extending out to non-engineering courses (e.g., Calculus, Technical Writing) which include high engineering student enrollment. In addition, future research should be performed with attention to further validate the repeatability and reliability of the survey instrument and/or consider different assessment and evaluation approaches.

## Biographies

Dr. Lisa Bosman, PhD in Industrial Engineering, is an Assistant Professor within the Purdue Polytechnic Institute (formerly, the College of Technology) at Purdue University. Dr. Bosman's education research interests include the entrepreneurial mindset, energy education, interdisciplinary education, and faculty professional development. In addition, her engineering research focuses on the development of information systems to enable the integration of grid optimization, solar energy performance modeling, and decision making. Prior to joining higher education, Dr. Bosman spent several years working in industry as a manufacturing engineer with well-known companies including Harley-Davidson Motor Company, John Deere, and Oshkosh Truck. Dr. Bosman's desire to increase STEM (science, technology, engineering, mathematics) education accessibility and attainment has resulted in her founding of the Purdue University iAGREE Labs (www.iagree.org). Dr. Bosman has authored over 50 publications, and has recently co-authored the book, "Teaching the entrepreneurial mindset to engineers" (Springer-Verlag GmbH, 2018). In addition, she has obtained over $1M USD in research funding from agencies including the National Science Foundation (NSF), Environmental Protection Agency (EPA), and the National Aeronautics and Space Administration (NASA). She has been an invited speaker and workshop facilitator for over 20 engagements. She is active in the American Society for Engineering Education (ASEE) and currently serves as an officer for the Industrial Engineering Division. She can be reached at lbosman@purdue.edu.

Dr. Kurt Paterson is the department head and professor for James Madison University's engineering program. The Madison Engineering program launched in fall 2008 and has quickly surpassed early objectives for student enrollment, curricular innovation, and alumni success. Madison Engineering is an interdisciplinary, project-based, undergraduate program focused on sustainable design. Prior to serving James Madison University, Dr. Paterson was on the faculty at Michigan Tech, where he created numerous programs in innovation, international development, and community service. He received a baccalaureate degree in Mechanical Engineering, master's in Environmental Engineering, and doctorate in Civil and Environmental Engineering, all from the University of Iowa.

Margaret Phillips is an assistant professor of library science in the physical science, engineering, and technology division of the Purdue University Libraries & School of Information Studies. Additionally, she holds a courtesy faculty appointment in the School of Engineering Technology in the Purdue Polytechnic Institute and is an adjunct professor of mechanical engineering at Pusan National University in Busan, South Korea. As a Libraries faculty member, Margaret is a co-instructor in the Purdue University School of Engineering Technology capstone course, and has developed and taught several other Purdue courses. She is the 2020 recipient of the Purdue University Libraries & School of Information Studies Excellence in Teaching award. Her current research interests include standards education, standards collections in academic libraries, and preparing engineering and technology students for the information literacy needs of transitioning from college to the workplace.

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