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# Preparing Instructors to Encourage an Entrepreneurial Mindset

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# Preparing Instructors to Encourage an Entrepreneurial Mindset


## 1 Abstract

In this full paper we analyze the results and feedback from two years of interactive training modules on the Entrepreneurial Mindset (EM) for instructional teams in an engineering education department. The second year's training module was modified based on feedback and updated goals from the previous year's training. Modifications included a greater emphasis on creating social, environmental, and economic value, the inclusion of specific examples of EM in curriculum, and language adjustments. One specific change was an emphasis on inclusivity and accessibility rather than the more general concept of user needs. Both iterations of the training also included open-ended questions about encouraging an Entrepreneurial Mindset.

The outcomes of this paper include an analysis of trainee responses to case scenario questions and open-ended prompts. A comparative analysis of responses from prompts shared across the two iterations of training is also presented. Results show a significant change in how UTAs respond to open-ended prompts between the two training iterations with a substantial increase in responses related to environmental, economic, and social value as well as accessibility and inclusion. Additionally, an analysis of feedback indicates a positive shift towards perceptions of EM. This paper begins to outline evidence-based guidelines for training instructors to develop their own EM and encourage their students' EM.


## 2 Introduction

Changes in the field of engineering have led to its redefinition to be more than just the mathematical and scientific resolution of problems. Instead, engineering aims to embrace innovation and concern for human welfare [1]. Similarly, higher education must shape engineering solutions to match social, economic, political, and cultural landscapes [2]. This shift toward social, environmental, and economic responsibility in engineering must be reflected in engineering education to match the changing field. Therefore, we must train engineers to be able to think through and solve complex, global, and constantly changing problems. We believe one way to do this is through the development of an EM that fosters an appreciation for curiosity, making connections, and creating value.

Instilling a mindset in students to think entrepreneurially has been gaining popularity, especially in engineering [3]. Faculty and administrators have been supportive of increasing entrepreneurship education in engineering classes [4]. It has been commonly thought that entrepreneurial spirit is something that people are born with [5]. However, research has shown that these skills can be developed through education [6]. An EM encourages students to seek new information, make connections between topics, and constantly think about how the product or service they are creating as an engineer is useful and valuable to a customer or society. This entrepreneurial thinking is more than just focusing on starting a business venture and is more applicable for the typical engineer since most will have jobs in established companies [7]. The Kern Entrepreneurial Engineering Network (KEEN) [8], a consortium of thousands of engineering faculty, has been central to integrating an EM into the engineering classroom. KEEN refers to this Entrepreneurial Minded Learning (EML) as the 3Cs: Curiosity, Connections, and Creating Value. As such, at The Ohio State University (OSU), we have infused EML into the standard and honors sequences of our First-Year Engineering Program (FYP) as well as into Capstone courses to help prepare our students to help solve the complex problems of an ever-changing world.

## 3 Background

### 3.1 History of EM at OSU

OSU joined KEEN in 2017. At the time, we had already been using EML approaches across our FYP and Capstone courses; however, we did not have a unified or structured approach to guide our work. Joining KEEN gave us a

framework on which to base our EML instruction with a focus on the 3Cs (curiosity, connections, and creating value). It also allowed us to gain valuable knowledge from other institutions using the same framework.

Our first EML-focused efforts included re-structuring the design-build project in our standard sequence of the FYP to more formally include EML concepts. We started that work by visiting other KEEN institutions to learn about their first-year engineering initiatives related to EML [9, 10]. We also worked through a backwards design process supported by our teaching and learning center to establish a set of new learning objectives that could guide our curriculum developments moving forward within the first-year and beyond [11, 12]. Following our institutional visits and the creation of our new learning objectives, the FYP curriculum in our standard sequence was modified to include EML more explicitly. For example, we added activities related to identifying user needs through interviews. Adjustments such as these helped to strengthen the EML experiences in our courses.

Following our EML curricular efforts in the FYP standard sequence, we embarked on new efforts to bring EML to the FYP honors sequence, to formalize the work in our Capstone courses, and to further enhance and streamline the changes we made to the FYP across both standard and honors sequences. As part of these initiatives, we also developed a series of direct and indirect assessments related to the 3Cs [13]. We revised the learning objectives to better align with our goals of EML in the college which included developing a set of complimentary rubrics [14]. Finally, in parallel with curricular and assessment efforts, we began facilitating Professional Learning Communities (PLCs) with cohorts predominantly made up of FYP and Capstone faculty and staff instructors. The goal of these PLCs was to provide support for the instructional development of EM, to disseminate and infuse EM across undergraduate engineering, and to create a shared definition of EML for OSU 's College of Engineering.

### 3.2 Need for instructional EM training

While we believed our curriculum changes were strong and had research supporting their efficacy [15], we realized that we needed a better way to onboard members of our teaching team to this new approach of engineering instruction. Given that KEEN provides many training opportunities for faculty, instructors were able to engage in professional development through the network. However, our undergraduate teaching assistants (UTAs) and graduate teaching associates (GTAs), who are crucial to our teaching teams, did not have access to the same external resources. Furthermore, engagement with faculty development through the KEEN network is optional and as such, not all instructors received the same education on the foundational ideas of EML nor consistent instruction on how to encourage the mindset with their students. Due to the similar nature of our internal PLCs as optional, PLC participants articulated a need for consistent training and shareable content with their colleagues and TAs. Anecdotes and discussions from our PLCs have also led to a shift in how we define and approach EML. For these reasons, we aimed to create EM training that would be accessible to *all* members of the instructional team from the faculty to the TA level. Our goal was that this training would communicate the OSU College of Engineering's unique vision of EM and better prepare instructional teams to encourage EM attributes with their students.

The FYP at OSU has a strong history of employing TAs and training them through a robust multi-step program that starts with an orientation and continues with content knowledge checks throughout the first few weeks of every semester [16]. As an example, in the past we have developed detailed grading training to support TAs grading of technical writing [17]. The FYP employs around 200 total GTAs and UTAs during any given semester and has a high turnover rate of instructional staff on all levels. This high turnover rate and large population further motivates the need for annual orientation and content training. While our past training efforts served us well, they did not align with our new EML focus.

In order to fill this EML training gap, we created an asynchronous EM training module that was implemented into our Learning Management System. Training modules were deployed completely online and completed by the user (trainees) on their own within a designated time frame. Our first pilot of this training module occurred in Spring 2021 and was released as optional training only to UTAs in the FYP honors sequence. Since this pilot deployment was optional, it was available for UTAs to take for the entirety of the semester. We used responses from this pilot to improve upon the training module and released the revised EML module in Autumn 2021 as part of required orientation departmental training for all members of the Department of Engineering Education, where the FYP, as well as Multidisciplinary Capstone courses, are housed. Required orientation departmental trainings were deployed completely online and trainees were required to complete modules on their own time within the first few weeks of the semester.

In this paper, we present responses from both the Spring 2021 and Autumn 2021 training modules, as well as a synopsis of the modifications we made between the two module iterations. Further, we expand on the differences in respondent answers to module quizzes using thematic coding of respondent answers for trainee populations and module quiz questions that were shared across module iterations.

## 4 Methods

### 4.1 Training Module Overview and Development

The asynchronous EM training module was first piloted in Spring 2021 and iterated for Autumn 2021 (Table 1). A total of 39 UTAs and 188 instructional team members participated in completing the training module in the Spring and Autumn of 2021, respectively (Table 1). University IRB approval (Study ID:2021E1166) was obtained to collect the module responses for this study.

The first iteration (Spring 2021) of the module videos was developed based primarily on the KEEN Framework [18]. Learning objectives focused on the Entrepreneurial Mindset as well as on the 3Cs (curiosity, connection, creating value) (Table 1). More information on that iteration of the module can be found in our short paper on the subject [19]. Modifications to the second iteration of the module (Autumn 2021) were motivated by results from the first Spring 2021 iteration and the ongoing cultural shift we observed around EM in our internal work and PLC discussions. In the second iteration, we adapted the content to better align with the language and goals of our Department of Engineering Education. Changes included a language shift and a stronger focus on impact recognition and multidisciplinary work. We also increased the emphasis on inclusion and social and environmental value creation in the module's video content. Concepts such as user needs, product marketability, and economic value were still present in the module but emphasized to a lesser extent. In revising the videos included in the module, we added a video on how different populations (e.g., instructors and TAs) may interface with EM in their teaching roles (Table 1). We also added three case scenario questions influenced partially by the KEEN framework [18] as well as a prompt soliciting feedback (Table 1). Finally, three open-ended prompts were custom-generated but created directly from each of the 3Cs of the framework - curiosity, connections, and creating value. These three open-ended prompts were the same for both Spring 2021 and Autumn 2021 iterations (Table 1).

**Table 1: Modifications to pilot modules between iterations.**

| | **Spring 2021** | **Autumn 2021** |
|---|---|---|
| Trainee Population | UTAs in the First-Year Engineering Program honors sequence | Everyone with a teaching role in the Department of Engineering (faculty, staff, GTAs, UTAs) |
| Learning Objectives | 1. Understand EM<br>2. Identify how the 3Cs can be encouraged in the classroom | 1. Understand EM<br>2. Identify how an EM can be encouraged in the classroom<br>3. Recognize elements of EM learning (EML) in the classroom and, more broadly, in your professional career |
| Training Content | • Written description of EM<br>• Video (optional): case study of an engineering student demonstrating an EM<br>• Video: Curiosity<br>• Video: Connections<br>• Video: Creating Value | • Video and written script: What is EM?<br>• Video and written script: What is OSU doing with EM?<br>• Video and written script: How might you interface with EM in the College of Engineering? |
| Assessment | • 3 open-ended prompts | • 3 case scenario questions<br>• 3 open-ended prompts<br>• Prompt soliciting feedback |

### 4.2 Module Description

Here we describe the most recent iteration of the training module in its Autumn 2021 form. This module consists of three videos (Section 4.2.1), three case scenario questions (Section 4.2.2), three open-ended prompts (Section 4.2.3), and a prompt soliciting feedback (Section 4.2.4). After watching the videos, participants were required to answer the case scenario questions and open-ended prompts. Finally, participants were encouraged to provide feedback on the module.

### 4.2.1 Training Videos

The three videos prepared for this training module were developed to describe EM in general, the context for EM at the university level, and the ways different populations might see and interact with EM. The titles for these videos are the following:

1. What is EM?
2. What is OSU doing with EM?
3. How might you interface with EM in the College of Engineering?

Each of these videos was 3.5 to 5 minutes in length. They were generated in PowerPoint with graphics and a voice-over. The video scripts were also made available as an alternative to watching the videos.

### 4.2.2 Case scenario questions

In the following multiple-select questions, the correct answers are shown in bold. Upon submission of the full quiz, text boxes describing the rationale for the correct answers for the multiple-select case scenarios were displayed.

1. Imagine you are helping a group of students working on a software design project. Which of the following questions do you think would best spark curiosity? You may select multiple answers.
    - **What if you added some code to let the user personalize their graphic interface?**
    - What syntax would you use to display text?
    - **What if you created software versions to be used by toddlers and senior citizens?**
    - **Why do some video games target specific user populations over others?**
    - How do you modify 10 lines of code into a 3-line loop?
2. Consider ways that students may make connections using EM attributes. Which of the following scenarios exemplify the ability to make connections? You may select multiple answers.
    - A student collects business cards from peers at a professional conference during a speed-networking event.
    - **While biking, a student realizes the turbulence felt on poor road surfaces causes a vibration feeling that is reminiscent of a load cell signal collected during a lab.**
    - **A student considers how her new facemask design may have unintended consequences on individuals with hearing difficulties that rely on reading lips to communicate.**
    - **A student applies their research on neural networks in the brain to understand social interactions between K-12 students.**
    - A student leader delegates out tasks to her three teammates to meet a project deadline.
3. Imagine design projects that are driven by the following motivations. Which of the following do you feel are motivated by creating widespread value? You may select multiple answers.
    - Technological advancement
    - Personal interest in innovation
    - **Authentic market demand**
    - **Unmet societal needs**
    - **Global warming and rising sea levels**

#### 4.2.3 Open-ended prompts

The following open-ended questions were given to participants in the post-module quiz.

1. Imagine guiding engineering students through a final design and/or project. Write one question you can ask student groups to spark curiosity. Think about designing your question so that students: challenge their assumptions, consider multiple points of view, consider the constantly changing world, explore a contrarian view of an "accepted" solution.
2. Consider a teaching role you have had in the past or one you have upcoming. What is one source that is NOT explicitly connected to the content that you could suggest your students draw on for information that they could integrate into a design project? Name at least one specific source (for example, a non-technical undergraduate course, an expert in a non-engineering discipline, a media source, a personal experience).
3. Think back to an earlier time in your training as an engineer or professional in a different field. What is one assignment, project, or experience that you associate strongly with EML? Why?

#### 4.2.4 Feedback

The following three questions were presented to the participants to solicit feedback on the module.

1. What feedback do you have about this training module?
2. What suggestions do you have for improving this module, or for the role of EM in the EED more broadly?
3. What questions remain about EM and EML?

### 4.3 Data coding

Quiz responses from all questions were taken directly from the Learning Management System and analyzed depending on the type of question. Case scenario questions were converted to the percentage correct and incorrect for every one of the "multiple select" responses (five per case scenario). Results of the open-ended prompts were coded thematically by two researchers, independently. Codes for the open-ended prompts were based on common themes in the first iteration of the module [19]. The same codes were used for the second iteration of the module, although a few new themes emerged and were added. The original data set from the first iteration was then re-coded using the new set of themes. Any discrepancies in the coding of the results were discussed individually until a consensus was reached; discrepancies were tracked to assess inter-rater reliability. Feedback responses collected in the Autumn 2021 module were synthesized and categorized based on the type of feedback.

### 4.4 Statistical analysis

In order to assess whether responses differed between the two module iterations (Spring 2021 and Autumn 2021), contingency tables were generated with the frequency of code response by semester for the three open-ended prompts. In order to compare alike teaching roles between the two semesters, the UTA responses were separated from the total responses in the Autumn 2021 cohort for comparison to the Spring 2021 UTA responses. Only the open-ended prompts were assessed statistically since they were shared prompts across both modules (Table 1). With the code as the response (dependent) variable, the semester as the factor (independent) variable, the null hypothesis that the code frequency and semesters are independent was tested with a Pearson correlation test. Responses that were not coded were omitted from this analysis. Tests were conducted in JMP Pro 15.2.0 (SAS Institute Inc.) with $\alpha$=0.05.

## 5 Results

The changes made to the Autumn 2021 module to incorporate it into required departmental training resulted in an expected and substantial increase in responses. While a total of 39 UTAs completed the Spring 2021 training module, 188 individuals completed the Autumn 2021 iteration. Of those responses, 17 were faculty instructors, 2 were staff member instructors, 14 were GTAs, and 155 were UTAs.

### 5.1 Case scenario questions

Overall, a majority (>50 %) of respondents correctly selected or correctly omitted the five possible responses for each of the three case scenario questions (Figures 1-3). Several of the selections across the three questions, however, had nearly $\frac{1}{4}$ of incorrect responses: selection 5 in scenario (1) (Figure 1), selection 1 in scenario (2) (Figure 2), and selections 1, 2, and 3 in scenario (3) (Figure 3). Of these, the highest incidence of incorrect responses was the first selection of scenario (3) (Figure 3), which had over $\frac{3}{4}$ of respondents incorrectly selecting "*Technological advancement*". This high percentage of incorrect responses could indicate a misunderstanding of what is meant by EM and/or indicate a need to revise certain aspects of the case scenario questions.

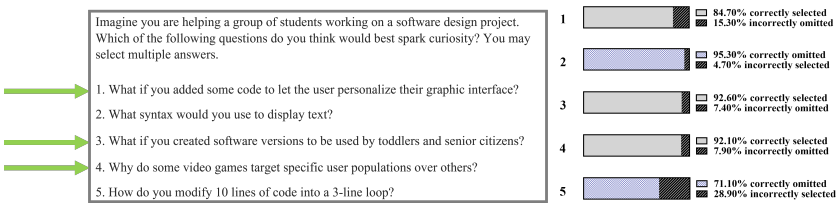



**Figure 1: Compiled results from the multiple select Case Scenario 1 question. Green arrows indicate correct selections. Solid gray indicates the percentage of respondents that correctly selected the choice; grid blue indicates the percentage of respondents that correctly omitted the choice. Hashed black indicates the percentage incorrect. n=188 total responses.**

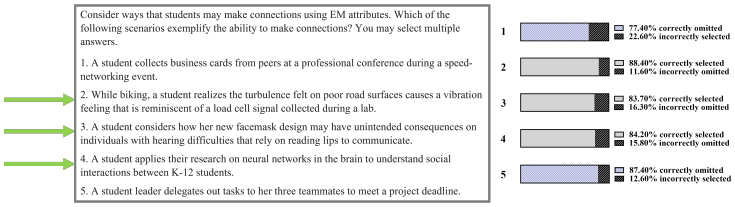



**Figure 2: Compiled results from the multiple select Case Scenario 2 question. Green arrows indicate correct selections. Solid gray indicates the percentage of respondents that correctly selected the choice; grid blue indicates the percentage of respondents that correctly omitted the choice. Hashed black indicates the percentage incorrect. n=188 total responses.**

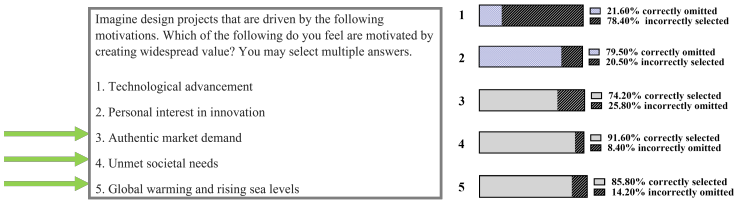



**Figure 3: Compiled results from the multiple select Case Scenario 3 question. Green arrows indicate correct selections. Solid gray indicates the percentage of respondents that correctly selected the choice; grid blue indicates the percentage of respondents that correctly omitted the choice. Hashed black indicates the percentage incorrect. n=188 total responses.**

### 5.2 Open-ended prompts

During thematic coding of Autumn 2021 responses to the open-ended prompts, seven to eight categories per question emerged that were in alignment with themes from our original Spring 2021 pilot (Figures 4-6 and Tables 2-4) [19]. Respondent answers consisting of "*N/A*" or that were left blank were not coded. Following independent coding by

two researchers of the Autumn 2021 data set, there were discrepancies in 29/188, 48/188, and 4/188 responses for open-ended prompts on curiosity, connections, and EML-aligned experiences, respectively. The largest discrepancies in the curiosity and connections open-ended prompts were due to thematic codes being non-mutually exclusive. For example, questions like "*How will people of different ages handle this design? What are some ways you could accommodate those that may struggle with it?*" could fall into the *accessibility/inclusion* or the *end-users and user needs* categories (Figure 4 and Table 2). Resolutions to these discrepancies were documented for future research studies.

### 5.2.1 Curiosity prompt

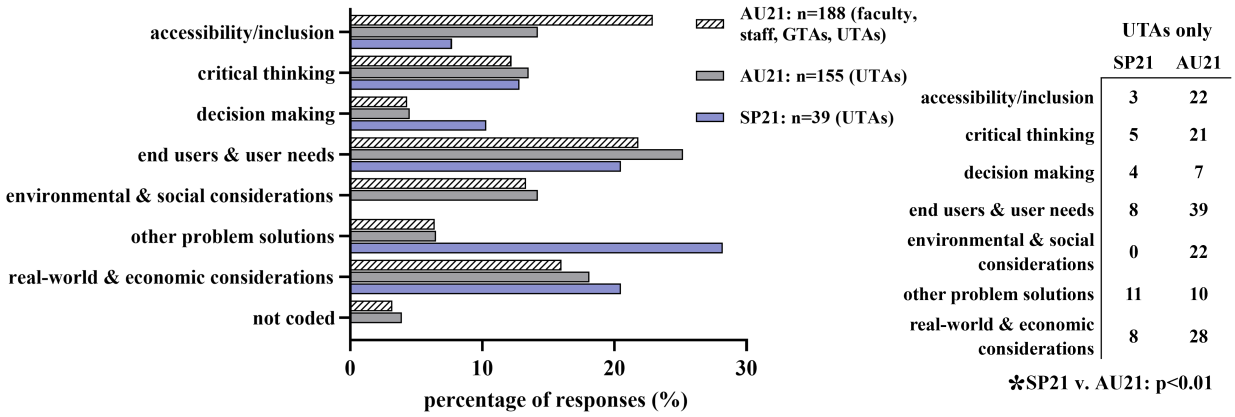
Thematic codes that emerged from responses to the open-ended prompt on curiosity spanned seven categories that exhibited a significant shift in UTA response between the two semesters (Table 2 and Figure 4). The total Autumn 2021 responses saw a substantial increase in questions coded as *accessibility and inclusion* and a simultaneous decrease in questions coded as *real-world and economic considerations* (Figure 4). The *environmental and social considerations* category emerged as a new code for the Autumn 2021 responses, with 13.3% of total responses and 22/155 of total UTA responses (Figure 4). Indeed, these differences between the semesters likely underlie the finding that thematic code and semester are not independent for the UTA responses (p=0.0013) (Figure 4). In other words, the manner in which UTAs responded significantly changed between the Spring 2021 and Autumn 2021 training modules.

**Table 2: Open-Ended Prompt 1: thematic codes and exemplar responses for generating questions to spark curiosity.**

| Code | Response Example |
|---|---|
| accessibility/inclusion | Can this solution to this problem also be applied to other social classes and personal abilities? |
| critical thinking | Think about products you use every day. What aspects of those products would you like to improve upon, or what aspects of those products make you love using them all the time? |
| decision making | At every step in design, you've chosen what you then thought to be the best option. With the benefit of hindsight, which of those initial design choices was your worst? |
| end users/user needs | Why do you think your end-users selected the needs that they did - can you think of other ways to address them? |
| environmental /social considerations | How does this address sustainability? Have you thought of environmental implications of your design? |
| other problem solutions | Can you think of any other solutions to the problem you are trying to solve? |
| real-world /economic considerations | In order to keep your design/solution feasible what features do you except to become outdated in 10 to 15 years and could you "age proof" those features and if so what are some ideas? |

### 5.2.2 Connections prompt

Similar to the open-ended prompt on curiosity, thematic codes that emerged from responses to the open-ended prompt on connections also exhibited a significant shift in UTA response between the two semesters and in total spanned eight categories (Table 3 and Figure 5). The *market research* code was developed to capture semester-specific suggestions that were largely submitted by UTAs (Figure 5). For example, the FYP includes an end-of-the-semester software design project that likely influences suggestions for students to explore video game resources, as shown by the examples for *market research* in Table 3. The frequency of codes for UTA responses was significantly different between semesters ($p<0.0001$) with substantial increases in most categories accompanied by a decrease in the prevalence of *market research* resources from 35.9% in Spring 2021 to 3.9% in Autumn 2021 (Figure 5).



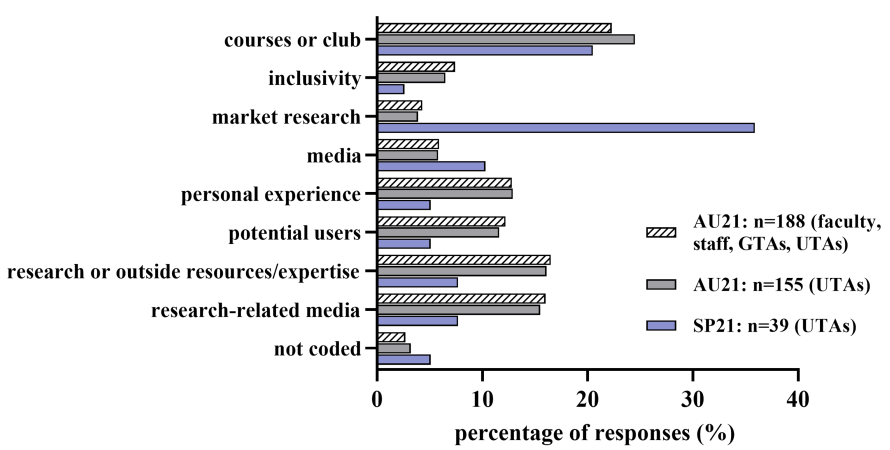

| | UTAs only | |
|---|---|---|
| | SP21 | AU21 |
| accessibility/inclusion | 3 | 22 |
| critical thinking | 5 | 21 |
| decision making | 4 | 7 |
| end users & user needs | 8 | 39 |
| environmental & social considerations | 0 | 22 |
| other problem solutions | 11 | 10 |
| real-world & economic considerations | 8 | 28 |

✻SP21 v. AU21: $p<0.01$

**Figure 4: Responses by thematic code for the open-ended prompt on generating questions to spark curiosity. The bar plot on the left depicts the relative percentage by group for all Autumn 2021 (AU21) responses (hashed black bar), UTA only responses for AU21 (solid gray bar), and all responses for Spring 2021 (SP21) which only consisted of UTA respondents (solid blue bar). Pearson correlation tests show that the frequency of responses by thematic code (table on right) between SP21 UTAs and AU21 UTAs are significantly different ($p<0.01$). GTA = graduate teaching associate; UTA = undergraduate teaching assistant.**

**Table 3: Open-Ended Prompt 2: thematic codes and exemplar responses for suggesting non-curricular links resources. Semi-colons separate distinct responses.**

| Code | Response Example |
|---|---|
| courses or clubs | Khan Academy; A source could be a business class because engineering and business are very intertwined; Student organizations on campus - particularly competition-based engineering teams. |
| inclusivity | invisiblepeople.tv; I would suggest an experience where they, or someone they know, were hindered by an inaccessible system; Students could directly ask the Office of Diversity and Inclusion how to make their product more accessible to the underserved population. |
| market research | Video games that they have played; The tutorials in the video games I enjoy playing, and the type of language used in them to help provide guidance, but also not explicitly state solutions for newcoming players. |
| media | I would suggest students read look at articles/blogs written by enthusiasts in the area (e.g. medium.com); YouTube, Shark Tank, social media. |
| personal experience | Personal experience doing the task that they're looking to improve to start developing their pains/gains. Mapping their improvement to other personal experiences; I would suggest students draw on a personal difficulty / experience they have observed a parent/ family member/ friend having regarding a product or a service. |
| potential users | Students could interview community members who are affected by the problem they are trying to solve and get more insight and empathy; They could draw from forms/polls on social media to understand their target audience better. |
| research or outside resources/expertise | Samuel Florman's books, The Existential Pleasures of Engineering and The Introspective Engineer;<br>Speak with business experts on the feasibility of the design in market to ensure its reasonable to pursue; Published research in topics unrelated to engineering. |
| research related media | TED talks; Smarter Every Day and Stuff Made Here are good examples of youtube channels that give good engineering creativity examples. |




| | UTAs only | |
|---|---|---|
| | SP21 | AU21 |
| courses or clubs | 8 | 38 |
| inclusivity | 1 | 10 |
| market research | 14 | 6 |
| media | 4 | 9 |
| personal experience | 2 | 20 |
| potential users | 2 | 18 |
| research or outside resources/expertise | 3 | 25 |
| research related media | 3 | 24 |

✲ SP21 v. AU21: $p<0.01$

**Figure 5: Responses by thematic code for the open-ended prompt on non-curricular linked resources/connections to suggest to students. The bar plot on the left depicts the relative percentage by group for all Autumn 2021 (AU21) responses (hashed black bar), UTA only responses for AU21 (solid gray bar), and all responses for Spring 2021 (SP21) which only consisted of UTA respondents (solid blue bar). Pearson correlation tests show that the frequency of responses by thematic code (table on right) between SP21 UTAs and AU21 UTAs are significantly different ($p<0.01$). GTA = graduate teaching associate; UTA = undergraduate teaching assistant.**

### 5.2.3 EML-aligned experience prompt

Responses to the open-ended prompt asking for an EML-aligned experience exhibited a wide range of experiences that were both related to and unrelated to the academic experience (Table 4). There was a substantial decrease in responses falling in the *market research* category from Spring 2021 to Autumn 2021 (Figure 6), similar to the decrease in the frequency of the *market research* code seen between the two semesters in the open-ended prompt on connections (Figure 5). New thematic codes that emerged with the Autumn 2021 responses included *other courses*, *outside resources*, and *research* (Figure 6). These differences underlie the significant difference between how UTAs responded between Spring 2021 and Autumn 2021 ($p<0.0001$), consistent with the difference between module responses by semester observed with the other two open-ended prompts (Figures 4-6).

## 5.3 Feedback

Respondent entries for module feedback were collected only for the Autumn 2021 iteration and contained many useful suggestions for future iterations. Of the total 188 responses, 32.4% were positive (e.g. "*It was nice, it made me think about EM and where it's applicable to other places besides being a TA- which is nice because it allows me to synthesize the content well.*") and 17% were negative (e.g. "*I feel that this training module should be a bit more interactive. It was not very engaging to sit through.*"). Further, 47.9% contained a suggestion and 60.6% were reviewed more in-depth due to longer and more complex responses. Unlike the thematic coding for the open-ended prompts, feedback responses were given more than one category, if applicable, so the total percentage exceeds 100%. Of the responses reviewed more in-depth and/or containing a suggestion, responses were additionally placed in categories (Table 5) and will be used for future improvement of the module.

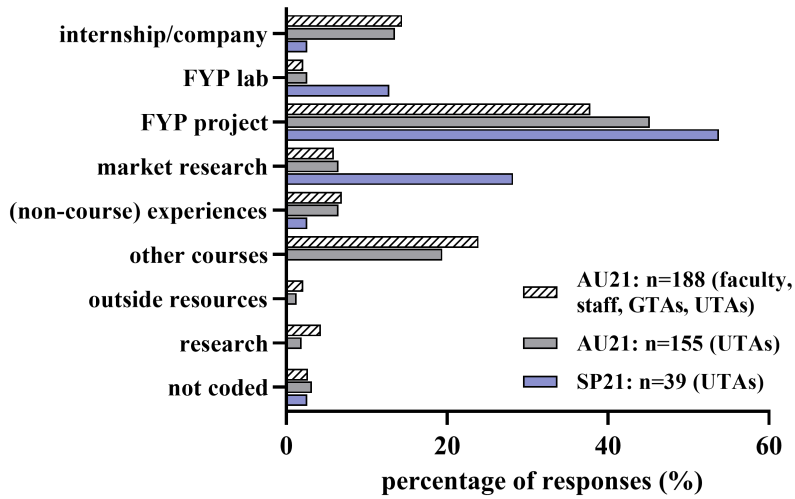
**Table 4: Open-Ended Prompt 3: thematic codes and exemplar responses for providing an EML-aligned past experience. Semi-colons separate distinct responses.**

| Code | Response Example |
|---|---|
| internship/company | I interned last summer as a Chemist working on a project aimed at breaking down plastic waste. This project helped develop my curiosity about different possible procedures: "What about this compound?" "How would this work?". It also helped me to make connections with my physics and chemical engineering classes as I could use that information to make more efficient systems. Finally, I was working to create value by removing pollutants from the environment. |
| FYP[1] lab | The FEH[2] toy adaptation lab was closely related to the EM. Curiosity played a role in investigating how each toy worked and figuring out how to wire in additional buttons, and the underlying motivation for the project was to create value in the lives of children and families. |
| FYP[1] project | 1182 project because it dealt with more than just building. We had to keep track of finances, marketing, environmental impact and building all in one; The robot project in FEH[2]. It challenged our creativity and helped us get a picture of how real life problems are solved. |
| market research | The Software Design Project was the pinnacle of EM because it was group work that involved many facets of creativity and teamwork. |
| (non-course) experiences | I worked on a water project with a group of engineers from around the world, and I associate that project with EM because we looked at user needs and conducted interviews with community members and professionals to both make connections and get more information on the problem. |
| other courses | My senior capstone because it was really open ended and we had to define the problem; My architecture project was similar to the EM. We had to walk around outside ... to analyze the city and just be out of the traditional classroom. We had to work in a group and figure out a way in order to make it better. This is similar because we are thinking about ways that will make society better in a group setting, there are different opinions being tossed around but we have to work as a team to make it better. |
| outside resources | Places like the SimCenter, Center for Automotive Research, ElectroScience Lab, Ohio Supercomputer Center. Especially the OSC and programming the nodes via shell scripts and Python with CUDA or OPENCL enabled Python libraries. |
| research | I associate my entire dissertation research in bioengineering as heavily EM aligned. The value creation inherently required for successful funding and publication, the necessity to connect disciplines and experimental techniques to conduct research, and the need to be curious to identify an unmet need/ ask the "why" of how physiology works. |

[1] First-Year Engineering Program
[2] First-Year Engineering Program Honors sequence

**Table 5: Feedback: categorization and magnitude of responses.**

| Feedback Category | Number of Responses |
|---|---|
| Add more examples/applications/graphics; make more interactive/engaging | 51 |
| Add information on how to implement as a teacher/ how to use in course work for themselves | 45 |
| Extend access to students | 5 |
| Broad/confusing wording | 19 |
| Complete this training in person and/or in groups | 7 |
| Explore a different formatting | 2 |
| The training helped bring more clarity and understanding/ trainees were able to connect their own experiences to EM | 13 |
| Material was helpful and useful to better understand EM | 28 |




| | UTAs only | |
|---|---|---|
| | SP21 | AU21 |
| internship/company | 1 | 21 |
| FYP lab | 5 | 4 |
| FYP project | 21 | 70 |
| market research | 11 | 10 |
| (non-course) experiences | 1 | 10 |
| other courses | 0 | 30 |
| outside resources | 0 | 2 |
| research | 0 | 3 |

✲SP21 v. AU21: $p<0.01$

**Figure 6: Responses by thematic code for the open-ended prompt asking for an experience that is EML-aligned. The bar plot on the left depicts the relative percentage by group for all Autumn 2021 (AU21) responses (hashed black bar), UTA only responses for AU21 (solid gray bar), and all responses for Spring 2021 (SP21) which only consisted of UTA respondents (solid blue bar). Pearson correlation tests show that the frequency of responses by thematic code (table on right) between SP21 UTAs and AU21 UTAs are significantly different ($p<0.01$). GTA = graduate teaching associate; UTA = undergraduate teaching assistant.**

## 6 Discussion

Collectively, the significant shift in UTA responses, trends in total responses for the Autumn 2021 respondent cohort (Figures 4-6), and the occurrence of positive feedback with myriad suggestions for improvement (Table 5) indicate a positive shift toward the adoption of EM. We posit that the significant shift in UTA responses across thematic codes is at least partially attributed to the content modifications to the second iteration of the module. This notion is supported by respective increases in the occurrences of thematic codes (e.g. *accessibility and inclusion* in the curiosity open-ended prompt and *research or outside resources/expertise* in the connections open-ended prompt) that track with verbiage used in the training videos and the examples embedded in those videos. The training modules presented in this work were completely asynchronous and completed by trainees individually and occurred in parallel with curricular, assessment, and PLC efforts that were ongoing in the Department of Engineering Education and College of Engineering. As such, respondents in this study were likely influenced by these parallel EM efforts in addition to the training module itself. Nonetheless, our results suggest that trainees comprehended the updated content and that the emphasis on attributes of an EM such as social and environmental considerations was effective.

### 6.1 Case scenario questions

Feedback responses regarding the case scenarios provide context that assists our interpretation of the results (correct vs. incorrect entries) (Figures 1-3) and provide guidance on future module iterations. For example, many participants articulated that case scenario questions (1) and (3) were more open to interpretation than the multiple-select format allowed, a notion that is further supported by the higher number of incorrect responses recorded for some of the selections in those questions (Figures 1 and 3). For question (1) that asked participants to consider how to spark curiosity, we did not consider the answers *What syntax would you use to display text?* and *How do you modify 10 lines of code into a 3-line loop?* as correct (Figure 1). However, there are situations where students may have to complete their own research and think critically to solve these problems. Although these scenarios were defined by the KEEN framework [18] as not sparking curiosity, limiting the definition of curiosity in this way may not be a productive way of teaching the concept, especially in an asynchronous mode. Additionally, it seems that the case scenario question format may not be the best way to test this type of knowledge.

The other case scenario question that received the most negative feedback and the highest incidence of incorrect responses was case scenario question (3), which asked which motivations create the most value (Figure 3). We considered *Technological advancement* and *Personal interest in innovation* to be incorrect answers. These answers were considered incorrect because the primary outcome of these motivations is not value creation and these motivations alone may not consider the user experience. Although text boxes displaying the rationale behind the correct answers were displayed upon quiz submission, it is clear that the incorrect motivations are still likely to create value with certain contexts, yet this context and the intention behind displaying the rationale may be lost in the present format. This is another example where the case scenario format may not be conducive to teaching EM. Case scenario question (2), however, effectively provided results on whether participants learned what the word *connections* means in the context of EM. Although this word means many things in standard English, including networking with peers, this is not the definition of the term in EM. Instead, it is about connecting material from many sources and is closely related to multidisciplinary work. Participants who answered this question wrong indicate a training gap that should be addressed, which made it an effective quiz question.

### 6.2 Feedback on content videos

Respondent feedback regarding the module videos inform our next iteration of this training module and collectively provide ideas on different formats, highlight where the wording is unclear, and inform where training gaps on EM remain for the training population. For example, a total of 51 respondents suggested adding more examples and interactive components (Table 5), such as quiz questions integrated within the videos and easily-digestible infographics to demonstrate examples of EM curriculum. One respondent suggested the addition of a discussion board to provide engagement that could still be asynchronous, "*One thing that I might suggest is to have some sort of discussion board that trainees can share their answers from the response questions on this quiz or other related questions. This would allow some discussion that I think can really supplement the videos.*"

The feedback regarding a desire for interactive components highlights the strength in including synchronous/collaborative training initiatives in parallel with asynchronous modules. The PLCs we facilitate provide that synchronous component and were in fact an original motivation for the development of the asynchronous modules. Moreover, the PLCs are a platform to discuss results of the training modules and feedback from respondents. While the asynchronous modules are invaluable for their ability to provide foundational information to a large department efficiently, the PLCs are necessary for the deeper inquiry and discussions that help create a shared definition of EM.

### 6.3 Future work

Effective training on EM for instructors and teaching assistants is a long-term goal for our department, and continuous improvement of the training is necessary to retain relevance and encourage buy-in. Feedback from the most recent module is already being incorporated into the training for the upcoming year. One of the most substantial changes being implemented is an overhaul of the case scenario questions. In addition to providing insight into how to improve the module, the collection of responses to the open-ended prompts provides over 200 unique questions intended to spark curiosity and a wide breadth of resources students can draw upon for inspiration. Collectively, these responses provide a database that can be disseminated to instructional teams as resources to assist in encouraging the development of an EM in students, particularly for those new to teaching roles.

Moreover, although the breakdown of UTA responses from Autumn 2021 was analyzed as a matched group to the pilot module, we did not further break down responses for the total Autumn 2021 cohort by role. Preliminary analyses suggest that the frequency of thematic codes may further differ by role (e.g. faculty vs. UTAs). For example, 14 out of 17 total faculty responses to the open-ended prompt on curiosity were coded as *accessibility and inclusion*, a larger relative percentage for the faculty group than for the other roles. Finally, although our results support a positive training effect with respect to quiz responses, this study does not assess the *direct* efficacy of the training module as it translates to the trainees' teaching practice. Further studies will explore the ability to capture direct measures of instructional teams members' ability to teach and understand EM in parallel with our training initiatives.

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