2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #37455

Evaluating Students' Entrepreneurial Mindset Attributes in First-Year Design Projects

Nicholas H. Cheong
Dr. Meagan Eleanor Ita, The Ohio State University

Dr. Meagan Ita is a Research Scientist at Arvinas working to develop disease modifying therapies for neurodegenerative diseases. Her career passion is to develop novel biotechnologies and therapeutics to better understand human physiology with the goal of equitably extending healthspan, ideally at the intersection of healthcare and STEM education. Meagan has experience as a Postdoctoral Scholar in Engineering Education from The Ohio State University (OSU), earned a Ph.D. in Bioengineering from the University of Pennsylvania and an M.S. and B.S. in Biomedical Engineering from OSU.

Dr. Rachel Louis Kajfez, The Ohio State University

Dr. Rachel Louis Kajfez is an Associate Professor in the Department of Engineering Education at The Ohio State University. She earned her B.S. and M.S. degrees in Civil Engineering from Ohio State and earned her Ph.D. in Engineering Education from Virginia Tech. Her research interests focus on the intersection between motivation and identity, first-year engineering programs, mixed methods research, and innovative approaches to teaching. She is the principal investigator for the Research on Identity and Motivation in Engineering (RIME) Collaborative.

Dr. Krista M. Kecskemety, The Ohio State University

Krista Kecskemety is an Associate Professor of Practice in the Department of Engineering Education at The Ohio State University and the Director of the Fundamentals of Engineering for Honors Program. Krista received her B.S. in Aerospace Engineering at The Ohio State University in 2006 and received her M.S. from Ohio State in 2007. In 2012, Krista completed her Ph.D. in Aerospace Engineering at Ohio State. Her engineering education research interests include investigating first-year engineering student experiences, faculty experiences, and the research to practice cycle within first-year engineering.

Mr. Ethan Cartwright, The Ohio State University
Miss Amanda Marie Singer, The Ohio State University

Amanda Singer is a second-year Ph.D. student in the Department of Engineering Education at The Ohio State University. She graduated in 2021 from Michigan Tech with a Bachelor's and Master's of Science in Environmental Engineering. Her current research interests include engineering identity formation, community college engineering education, and mixed methods research.

Evaluating Students' Entrepreneurial Mindset Attributes in First-Year Design Projects

Abstract

Engineering education has been focusing on incorporating the Entrepreneurial Mindset (EM) into First-Year Engineering Programs (FYEPs) due to evolving employer expectations and the benefits that develop from engineers equipped with an EM. The Ohio State University honors FYEP includes a semester-long design project to help students synthesize engineering concepts, create a coherent product, and further their EM development. Two of these first-year design projects are a robot design project and a nanotechnology research project. For the robot design project, students develop autonomous robots that complete a series of tasks within a two-minute period. For the nanotechnology research project, students design a lab-on-a-chip and explore nanotechnology applications in medicine. Both projects provide a vast number of experiences that support the development of an EM.

The goal of this complete research study was to evaluate the efficacy of how these projects further an EM in the honors FYEP. We focused on one specific attribute of EM which was making connections. Our primary research question was: *Are there differences in students' ability to make connections between different first-year engineering design projects?* The purpose of the comparison was to determine whether both projects provided equal value to the first-year students regarding their ability to learn to make connections. To answer our research question, we used concept maps developed during the 2021-2022 academic year. We scored a subset of 22 maps (n = 11 from the robot design project, n = 11 from the nanotechnology research project) with an adapted traditional scoring method to assess the concept map structure, and we used inductive coding to assess concept map content.

Although there was no difference in the adapted traditional scoring method scores between the robot and nanotechnology projects, the coding exhibited a clear distinction in how robot and nanotechnology students differed when identifying content in the concept map activity. The most common code was Engineering Design Process, while the least common code was Exploration. Our findings suggest that both projects generally cultivate equal amounts of connection-making ability from students. Future work should investigate how our inductive coding findings translate to established categorical scoring methods for concept maps, particularly in the space of EM.

Introduction

Entrepreneurship education has been regarded as an important component of undergraduate training programs in the last decade [1], including in engineering education [2]. For example, 94% or above of faculty and academic administrators believe that students should have access to innovation and entrepreneurship opportunities via electives and/or extracurricular activities, despite their personal engagement level in those opportunities [2]. Most respondents in the study, however, identify challenges to making entrepreneurship a core component of curriculum, with a "lack of room in curriculum" reported as the most common challenge [2].

The author(s) acknowledge The Kern Family Foundation's support and collaboration through the Kern Entrepreneurial Engineering Network (KEEN) for contributing to this work.

One way that educators have eased the infusion of aspects of entrepreneurship education into undergraduate engineering curriculum is through Entrepreneurial Minded Learning (EML). For this work, we use KEEN's approach that focuses on attributes of the "Entrepreneurial Mindset" (EM) [3]. Broadly speaking, we define EM as a collection of mental habits that empower one to question, adapt, and make positive change that engineers possess and leverage in their professional work. This mindset is applicable for engineers broadly, not only in the context of entrepreneurial ventures and starting new companies.

The increased integration of EM has pushed universities to evaluate its impact. While others have developed holistic assessments of an EM [4], these holistic assessments may lead to an oversimplification of more refined EM attributes. One of these attributes is the ability to make connections. To make connections is to find relationships between diverse sources including, but not limited to, engineering courses, non-technical courses, media sources, and personal experience. A tool that has been used to measure students' ability to make connections in the context of measuring EM attributes is concept mapping [5]–[9]. Concept maps are visual representations of one's ability to connect various sources to a central theme and are commonly used as tools for formative assessments [10]. Their use across STEM domains and in medicine mirrors the notion that the habitual practice of making connections is critical in a broad context [11]–[13].

The First-Year Engineering Program (FYEP) at our university provides honors students with the option to undertake two projects. The first option is a robot design-build course which has a focus on mechanical engineering and computer programming [14]. The other is a research and development design project with a focus on lab-on-a-chip (LOC) and nanotechnology applications [15]. Differences in these two courses are intended to serve the varying interests of the different students, but they may also have differences in cultivating EM attributes which have yet to be explored.

This study evaluated concept maps completed by students in the FYEP's honors sequence using two approaches, the adapted traditional scoring method and coding, to assess how students demonstrate connection-making ability in the two types of FYEP courses. The primary goal of this study was to assess the differences in students' ability to make connections between the robot design project and the nanotechnology research project. We anticipate that the outcome of this work will contribute to curricular improvements for the FYEP and minimize any unintentional discrepancy in fostering students' ability to make connections from the different projects.

Background

The Ohio State University has partnered with KEEN to incorporate EML into the standard and honors sequences of our FYEP [16], [17]. This work has incorporated concept maps into the FYEP as an activity and as a direct assessment of students' ability to make connections [5]. The work presented here is part of a larger initiative to assess the 3C's of KEEN's EML (Curiosity, Connections, and Creating Value) using separate direct and indirect assessments for each "C" [18]–[21].

Concept Map and Map Scoring
Concept maps can be evaluated through different methods of scoring that consider various aspects of the maps, such as content, size, and structure [8], [22], [23]. There are benefits and drawbacks to the different scoring methods depending on the educational context in which the concept maps are being applied, and these considerations have been thoroughly analyzed elsewhere [8], [22], [23].

In this study, we chose to use an adapted traditional scoring method that builds off Novak's traditional scoring method [10] due to its objective nature and because it assesses the breadth and complexity of the map more in-depth than Novak and Gowin's method alone [5], [24]. To evaluate the maps' content and determine the common themes to which students in each design project made connections, we also used an inductive (or open) coding approach to assess the content of the concept maps [25].

Adapted Traditional Scoring
The traditional scoring method consists of objective scoring and combines three sub-scores that result in a total score [10]. The three sub-scores evaluate the breadth, depth, and connectedness of a concept map, respectively. Breadth is measured through the total number of concepts (or "nodes"), depth through the map's hierarchies (amount and length), and connectedness through the number of interconnections, or crosslinks, between and within hierarchies.

Equation 1 details how the three sub-scores are calculated for the adapted traditional scoring method. The equation for this method includes a set of weights for Number of Concepts (NC), Highest Hierarchy (HH), and Number of Cross-links (NCL) as part of the original scoring method: NC represents the number of concepts in the map excluding the central topic. HH indicates the depth of the map's longest hierarchy, from the central topic to an end node. NCL is the Number of Cross-Links that connect different concepts from different hierarchies together. The adapted traditional scoring method also includes Intra-hierarchy Cross-Links (ICL), the cross-links within a given hierarchy, and Number of Hierarchies (NH), the number of hierarchies stemming from the central topic [27]. In this study, we refer to $(NC * 1)$ as Breadth, $((HH + NH) * 5)$ as Depth, and $((NCL + ICL) * 10)$ as Connections.

$$Total\ Score = NC * 1 + (HH + NH) * 5 + (NCL + ICL) * 10 \tag{1}$$

Figure 1 shows an example concept map created to outline the adapted traditional scoring method. This concept map has 8 nodes (NC) excluding the central topic of "Engineering Mindset". Two nodes branch from the central topic to form 2 hierarchies (NH), outlined by blue dotted lines in Figure 1. The Highest Hierarchy (HH) is traced in red dashed lines and totals 3 nodes "deep", excluding the central topic. There are 4 cross-links *between* the two hierarchies (NCL), denoted by the purple crosses. Finally, there are 3 cross-links (ICL) *within* the hierarchies, as shown by the green stars (Figure 1). These values result in a total score of 103, detailed in Equation 2. This example shows a scenario where a map with few nodes (8) can result in a relatively high score given the number of cross-links.

$$103 = 8 * 1 + (3 + 2) * 5 + (4 + 3) * 10 \tag{2}$$

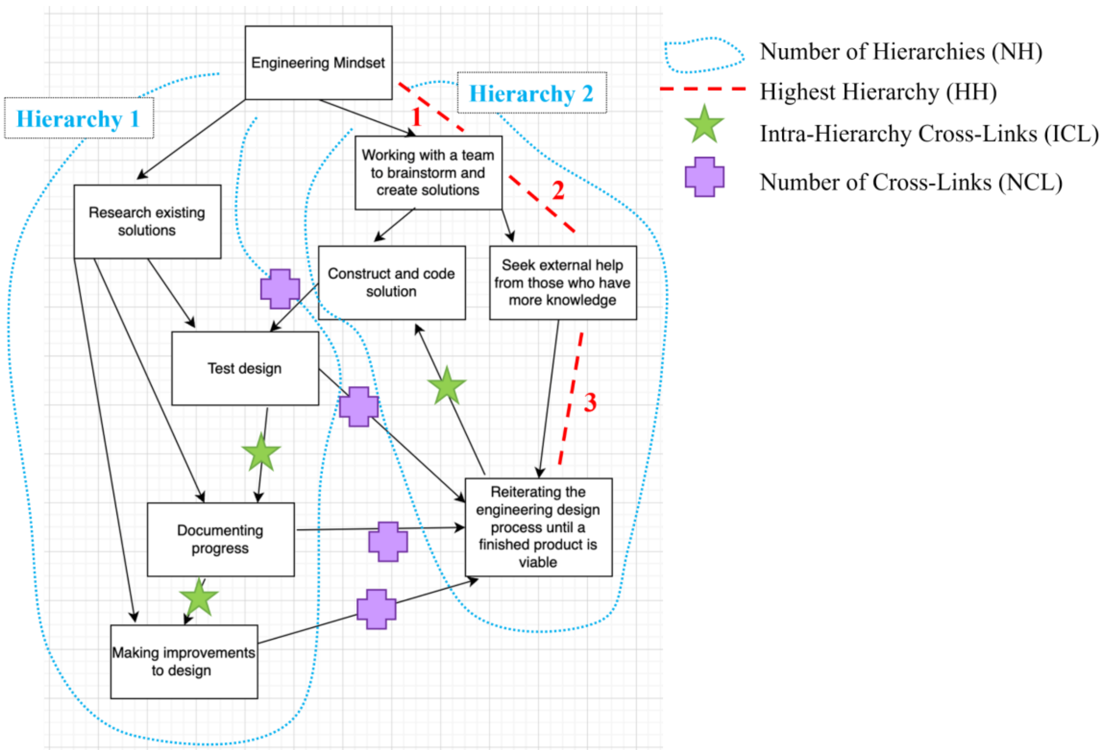

Figure 1: Example of concept map scoring for the adapted traditional scoring method.

Evaluated First Year Projects

Our university's FYEP honors sequence engages students in two different projects in the second course of its two-course sequence. We compared the two to evaluate the efficacy of EM in supporting students' ability to create connections from each project experience. The first project is a design-build robotics project [14] and the other is a nanotechnology research project focused on implementing a lab-on-a-chip (LOC) device [15].

The robot project provides students a realistic and hands-on experience with a mechanical, electrical, and programming emphasis [14]. The project is conducted in groups of four where teams design, build, and program an autonomous robot to complete tasks on a competition course. The project requires teamwork, budgeting, project planning, oral and written communication, documentation, microcontroller programming, prototype construction, and electrical wiring.

In the nanotechnology research project, students work in teams of four to complete the project. While the nanotechnology project includes some design elements, it is more focused on research and medical applications relative to the robot design project [15]. The project focuses on the development, manufacturing, and testing of a LOC device and culminates with a judged poster forum and technical slideshow presentation of the students' research and results. The project requires project planning, oral and written communication, and documentation where there is an emphasis on the research process as well as hands-on experimentation.

Purpose and Research Question
Through this research, we aimed to answer the research question: *Are there differences in students' ability to make connections between two different first-year engineering design projects?* In answering this question, we intended to determine whether curricular changes are necessary to standardize students' ability to make connections within the two projects.

Methods

Data Collection
Concept maps were collected in the 14th week of the second semester, following the culminating event for the project teams (e.g., the robot competition or the research poster presentation). In the activity, students were directed to a Qualtrics link that described the definition of a concept map, provided a link to an example concept map, and instructed students to create a concept map about "the mindset that is required in the design/research process you used this semester." Students were explicitly instructed to have "Engineering Mindset as the central topic that all other topics and concepts branch from." Note that "Engineering Mindset," versus "Entrepreneurial Mindset" was used at this time because we were presenting EML as an "Engineering Mindset" in our first-year sequences to increase accessibility. Despite the difference, the concepts used by KEEN related to EML, particularly the 3C's, remained the same. The language in the prompt specified "design" or "research" for the robot and nanotechnology sections, respectively. Although students completed their concept maps individually, the following class day consisted of an "EM workshop" that included a discussion about the concept maps. During this discussion, students compared their concept maps and generated a new, group concept map based on the ones generated individually.

This study was approved as exempt by our university's Institutional Review Board. There was a total of 7 sections for the robot design project and a total of 2 sections for the nanotechnology research project. A total of 244 participants across all sections provided informed consent for this study as part of our larger initiative to assess all 3C's in the FYEP (Figure 2). We selected a subset from each assessment for analysis, also as part of our larger initiative; this subset resulted in 53 participants from the robot and nanotechnology course sections. For the analysis presented in this work, we pulled from the subset and selected 11 concept maps at random to analyze. This number (n=11 for project) was chosen to represent the robot design project and nanotechnology research project equally (Figure 2).

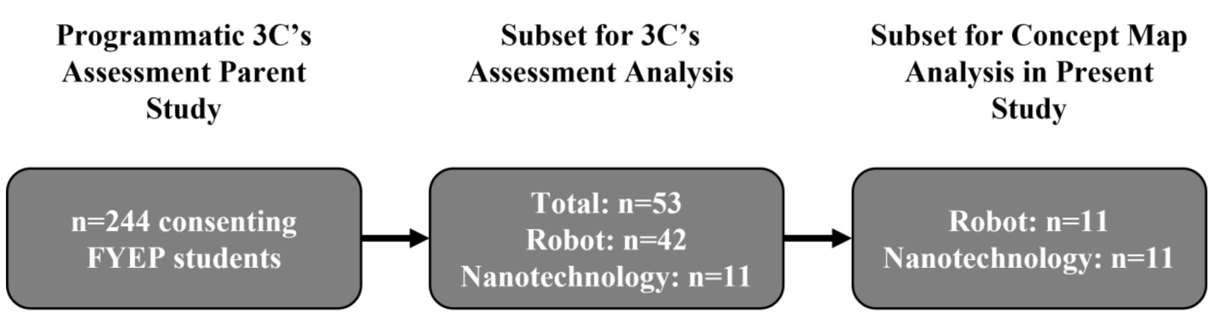

Figure 2: Population size for this study in the context of our larger work.

Adapted Traditional Scoring Method
Three researchers scored the selected concept maps using the adapted traditional scoring method. Prior to final scoring, all three researchers completed three pilot rounds of scoring to ensure consistency across scoring, with 5 concept maps chosen at random for the pilot rounds. Although the adapted traditional scoring method is beneficial due to its objective nature [5], subjectivity is introduced depending on how the scorer separates hierarchies stemming from the central topic. Therefore, inter-rater reliability was determined for the team from the sum of the NCL and ICL sub-scores since these two sub-scores were determined to be the most direct measurement of students' ability to make connections [26]. The inter-rater reliability reached after the final pilot round for the sum of the NCL and ICL was 80%, which was deemed adequate given a minimum reliability of 70% [26]. Note that this process was done with the subset (n=53) pulled for the full 3C's assessment analysis (Figure 2).

For this study, we compared 4 different metrics from the adapted traditional scoring method in the subset of 22 concept maps (n=11 per project) to test whether there was a significant difference between the scores in robot and nanotechnology projects. The 4 metrics we analyzed were (1) Total Score, as detailed above in Equation 1, (2) Connections, represented by the sum of the NCL and ICL, (3) Breadth, represented by the NH, and (4) Depth, represented by the HH. For each of these 4 metrics, we computed the average and standard deviations for the maps in each project, and then performed a Wilcoxon rank sum test to test the statistical significance for each metric, separately. A Wilcoxon rank sum test was used since the data were non-normal. Tests were conducted in JMP Pro 15.2.0 (SAS Institute Inc.) with $\alpha=0.05$.

Inductive Coding
In order to further analyze the content of the selected maps, we used an inductive coding approach that allowed the data within the concept maps to drive emergent themes. To generate the codebook, we first had three researchers independently review 6 maps chosen at random from the subset of 22, with 3 from each project. We used the established KEEN EML framework [3], our university's EM learning objectives [27], and categorical EM themes being developed by KEEN faculty (Module 3, slide 18 in Barrella et al. [9]) to guide our code identification. During this independent review, each researcher identified "themes" from the 6 concept maps' content and grouped similarly themed concept map nodes into different codes. The three researchers then discussed their observations and identified common conceptual codes across their three independent reviews. The finalized thematic codes that resulted from this process are shown in Table 1 below. During this coding process, a node could only be coded with one code, not duplicate codes.

Table 1: Final codebook for the inductive coding with examples from student responses to the concept map assessment.

Code	Definition	Examples	Notes	EM Learning Objectives
Growth Mindset	Nodes related to learning from failure and next steps one can take after failing	*Failure, Optimism, Importance of Setbacks,*	Specific to talking about failure, where Engineering Design Process	6. Learn From Failure

		Making Improvements	talks about design process as a whole	
Engineering Design Process	Nodes related to the steps of the FYEP Engineering Design Process (DRPIE).	*Performing Experiments, Documentation, Making changes to design, Coming up with new solutions*	Emphasizes problem solving and critical thinking	7. Define Problem 8. Define User Needs 9. Develop Concepts and Visual Representations 10. Analyze Solutions and Develop Design Requirements 12. Test and Validate Solutions
Attributes	Nodes related to the traits of an engineer	*Determination, Patience, Curiosity, Efficiency*	Characteristics rather than actionable items, which is Behavior	6. Learn From Failure
Behavior	Nodes related to the actions that an engineer may take or the behaviors they may exhibit. Nodes also relate to how engineers think	*Optimal organization, thinking*	Something that is actionable	1. Demonstrate curiosity 6. Learn from Failure
Technical Skills	Nodes related to the usage of tools or certain technical skills that an engineer may possess	*Coding, Materials, Building a robot, designing a presentation*	Can reference anything related to robot or nanotechnology design projects	11. Perform Detailed Design
Teamwork	Nodes related to working in a team and the collaboration with other peers	*Distribution of work, cooperation, listening to team members*	Specific to working with other peers	6. Learn From Failure
Exploration	Nodes related to seeking external information	*Research, seeking TAs for help, asking question*	Specific to seeking information	1. Demonstrate Curiosity

			from external sources	

Following the finalization of this codebook, the three researchers returned to the set of 22 concept maps to assign each node to a code. To complete this final coding process, at least two researchers independently assessed every map. Differences in codes were discussed between the two researchers responsible for each given map to reach an agreement. In a few instances, "No Code" was assigned to a node if the node contained text that could not be interpreted, such as uninterpretable misspellings, or was left blank.

To assess whether the frequency of codes differed between the two projects, contingency tables were generated with the frequency of code response by project. With the code as the response (dependent) variable, the project as the factor (independent) variable, the null hypothesis that the code frequency and project were independent was tested with a Pearson correlation test. Responses designated as "No Code" were omitted from this analysis. Tests were conducted in JMP Pro 15.2.0 (SAS Institute Inc.) with $\alpha=0.05$.

Results

Adapted Traditional Scoring Results

To compare the adapted traditional scoring metrics for the subset chosen for this study (n=11 for each project), we tested the statistical difference between the robot and nanotechnology maps. The robot project had a greater average Total Score compared to the nanotechnology project, at 107 compared to a lower 75, respectively (Figure 3). However, each metric (Total Score, Connections, Breadth, and Depth) had similar scores between the two projects (Figure 3).

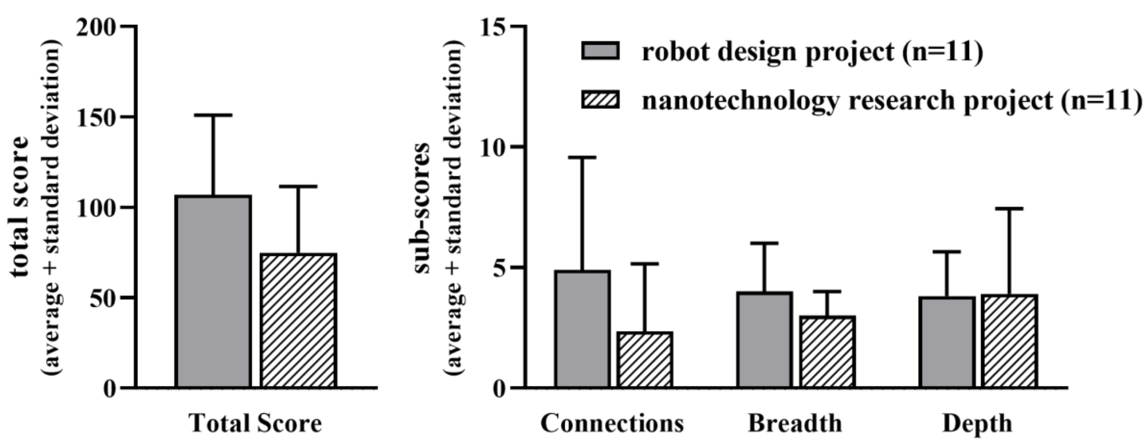

Figure 3: Adapted traditional scoring metric comparison between students' concept maps, shown as average + standard deviation, from the robot design project and nanotechnology research project.

Wilcoxon rank-sum tests indicated no statistically significant difference between robot and nanotechnology for any of the metrics compared, with calculated p-values of $p= 0.082$ (Total Score), $p=0.188$ (Connections), $p= 0.664$ (Breadth), and $p=0.523$ (Depth).

Coding Results

Although we found no statistical difference in the metrics of the adapted traditional scoring method between the two projects, the researchers observed differences in the topics of the nodes with the inductive coding approach. The counts for the coding are shown in Table 2; the first number in the columns of "Robot" and "Nano" represents the magnitude of nodes designated for a given code, and the second percentage in parentheses provides the relative percentage of nodes categorized for that code within the project. Nodes marked as "No Code" are shown here for completeness but were not included in the statistical comparison between robot and nano.

Table 2: Code counts for the two projects.

Code	Robot (# nodes, relative %)	Nano (# nodes, relative %)
Growth Mindset	13 (7%)	17 (12%)
Engineering Design Project	38 (19%)	37 (25%)
Attribute	35 (18%)	27 (18%)
Behavior	32 (16%)	14 (10%)
Technical Skills	24 (12%)	19 (13%)
Teamwork	40 (21%)	16 (11%)
Exploration	6 (3%)	12 (8%)
No Code	7 (4%)	4 (3%)
Total Nodes	195 (100%)	146 (100%)

A Pearson correlation test revealed that the distribution of codes between the robot and nanotechnology projects was significantly different ($p < 0.030$). The code with the highest percentage in the robot section was Teamwork (21%) compared to the most prominent code, Engineering Design Process (25%), from the nanotechnology project. Engineering Design Process (19%) also appeared the second most in the robot concept maps, indicating that Engineering Design Process had the greatest shared presence between the two projects. Furthermore, Exploration was the lowest category in respect to other categories between each project. However, Exploration was slightly higher in the nanotechnology section (8%) compared to the robot section (3%).

Discussion

We began this study by asking the question: *Are there differences in students' ability to make connections between first-year engineering design projects?* Ultimately, we wanted to know if students completing different design projects conceptualized EM differently. First, we used the adapted traditional scoring method to calculate an objective score for the concept maps. Our adapted traditional scoring findings showed no statistical significance between robot and nanotechnology. This was true for the Total Score and for the different metrics of Connections, Breadth, and Depth, indicating that students were able to make connections at a similar level between the different projects. However, a known limitation of the adapted traditional scoring method is that it does not quantify content but rather assesses structural aspects of the maps [8], [9], [23]. Because of this, the adapted traditional scoring method only assessed students' ability to make connections from one aspect of the concept maps: the structure. Thus, to analyze the maps more fully, we added an inductive coding approach to assess the content of the concept maps.

Ultimately, the coding showed a clear distinction in how students in the robot and nanotechnology projects differed when identifying content during the concept map activity. For example, students from the robot sections exhibited substantially greater frequency in the categories of Teamwork and Behavior than students in nanotechnology sections. Teamwork was the most abundant theme in the robot related maps at 21%, nearly twice the percentage of Teamwork occurrences in the nanotechnology maps (11%). and Behavior was 6% higher than nanotechnology related maps. The high frequency of Teamwork in the robot concept maps may be due to elements of teamwork in the course structure. For example, students in robot typically work in teams of four. It is common in a robot team to have each student specialize in a specific area (e.g., coding, building); therefore, it is possible that this lends to students thinking more about the teamwork required in the course. In the nanotechnology research project, students also work in teams of four; however, their roles may be less specialized, and they often work together to solve the same tasks. Since they are less specialized in their roles than robot students, it may not be as apparent to them how important teamwork was for them to complete their tasks. That said, in the curriculum, teamwork is just as important and emphasized equally across both projects. It is possible that the differences in Teamwork in the coding also help explain the differences in Behavior scores as many of the behaviors may stem from working in a team and how roles are managed.

Our finding that the Engineering Design Process was found to be the most applied code across the datasets supports that the FYEP honors sequence curriculum emphasizes the EDP in both first-year projects. This is consistent with the FYEP curriculum strongly emphasizing the EDP in the first and second sequences of the curriculum. Moreover, because the central topic of the concept mapping assignment was “EM,” this finding suggests that students connect the concept of the EDP to the foundational ideas of an Entrepreneurial Mindset. Relative to the EDP, EM is a newer addition to the FYEP curriculum, so we posit that an EM-to-EDP connection may indicate that students are beginning to see an EM as integral to the design process. Although we hesitate to draw strong conclusions given our sample size, future work should explore how students conceptualize the relationship between moving through the EDP and doing so with an EM as their guide.

On the other hand, Exploration was the least applied code across datasets. Our finding that students mentioned Exploration the least may indicate an area where the design project curriculum can be improved. For example, we could have students reflect on how external experiences, resources, and/or other courses may relate to their projects, or we could require students to conduct research that might be tangential to their project. Given the research focus in the nanotechnology project, Exploration is higher in nanotechnology (8%) compared to robot (3%) given the course has a significant research component and includes reading journal articles and presenting on others’ research.

Although concept maps are a formative pedagogical tool, they may have a limited ability to assess the complexity of students’ ability to make connections. A known limitation of the adapted traditional scoring method is its inability to assess the content of a concept map [5], [8], thus we used a coding approach. Another way we could have addressed this would be to use Categorical Scoring [28] using the codes that were developed in this work. Scoring concept maps using Categorical Scoring considers the number of categories used and the links between categories to develop another standardized metric. Additionally, other work with EM concept maps have identified other sets of categories that are similar to our codes and that build off of years of concept mapping and EM expertise [6], [29]. Future work could compare the sets of categories to gain further insights into the use of concept maps in our courses.

In addition to the scoring of the concept maps, instructor pedagogy and student understanding of the assignment may have impacted the results. EM understanding and classroom infusion by instructors are not fully standardized across the robot and nanotechnology sections. This may have caused different levels of EM understanding by students, separate from the standardized course curriculum. Our use of the verbiage "Engineering Mindset" in the assignment prompt also presents a limitation in that it differs from the verbiage that is explicitly used in KEEN's EML framework, thus limiting this work's direct integration with other EM concept map studies in the literature.

Assessing EM depends on more facets than those of just the classroom. Students who attend our university have diverse backgrounds, coming from different races, genders, socioeconomic backgrounds, and different levels of high school preparation. As a result, a generalized plan for developing an EM could result in certain groups missing out on some of the proposed benefits, if the diversity of our student body is not considered. As such further work needs to account for these differences to isolate variables and identify any trends from the data. Analysis of these different variables could generate curricular improvements by placing a greater emphasis on EM on underrepresented groups, for example, rather than a generalized approach to developing EM. Finally, we could also include better instruction for instructors and students on creating concept maps to standardize the concept maps. A concept map toolkit exists with instructor resources that could be used for this purpose [9].

Conclusion

The importance of EM has become more prevalent and has led our university to incorporate EML into our undergraduate engineering curriculum. The second course in our FYEP for honors students includes two design projects: robot and nanotechnology. To evaluate students' ability to make connections, we used an adapted traditional scoring method and coding to analyze concept maps. The adapted traditional scoring did not result in a statistical difference related to students' ability to make connections across the two projects whereas the coding measured a statistical difference between common codes across the projects. The advantage of using both an adapted traditional scoring and a coding analysis was that it gave different insights into the concept maps.

References

[1] M. T. Azim and A. H. Al-Kahtani, "Entrepreneurship Education and Training: A Survey of Literature," *Life Sci. J.*, vol. 11, no. 1s, pp. 127–135, 2014.

[2] A. R. Peterfreund, E. Costache, H. L. Chen, S. K. Gilmartin, and S. Sheppard, "Infusing innovation and entrepreneurship into engineering education: Looking for change as seen

by ASEE Members, 2012 to 2015," in *American Society of Engineering Education Annual Conference & Exposition*, 2016, vol. 2016-June.

[3] KEEN, "The Framework for Entrepreneurially Minded Learning," *Engineering Unleashed*, 2022. [Online]. Available: https://engineeringunleashed.com/framework.

[4] C. Q. Li, R. S. Harichandran, M. I. Carnasciali, N. O. Erdil, and J. Nocito-Gobel, "Development of an instrument to measure the entrepreneurial mindset of engineering students," in *American Society of Engineering Education Annual Conference & Exposition*, 2016, vol. 2016-June.

[5] M. E. West, M. E. Ita, L. E. Rumreich, R. L. Kajfez, and K. M. Kecskemety, "Development of a Direct Assessment for Measuring Students' Ability to Make Connections," in *127th American Society for Engineering Education Annual Conference and Exposition*, 2021.

[6] C. A. Bodnar and C. Hixson, "Capturing Students' Perception of Entrepreneurial Mindset: Tools for What and Why," *Adv. Eng. Educ.*, vol. 7, no. 1, pp. 1–12, 2018.

[7] C. A. Bodnar, S. Jadeja, and E. Barrella, "Creating a master entrepreneurial mindset concept map," *American Society of Engineering Education Annual Conference & Exposition*, vol. 2020-June, 2020.

[8] K. M. Kecskemety, M. E. Ita, L. Rumreich, E. Cartwright, and C. M. Staniak, "Using Concept Maps for Assessment in an Aerospace Structures Course: A Comparison of Scoring Techniques," in *AIAA Science and Technology Forum and Exposition, AIAA SciTech Forum 2022*, 2022.

[9] E. Barrella *et al.*, "EM Concept Map Toolkit," *Licensed under Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License*, 2023. [Online]. Available: https://sites.google.com/dforxconsulting.com/emcmaptoolkit/home. [Accessed: 14-Feb-2023].

[10] J. D. Novak and D. B. Gowin, *Learning How to Learn*. New York, New York: Cambridge University Press, 1984.

[11] B. J. Daley and D. M. Torre, "Concept maps in medical education: an analytical literature review," *Med. Educ.*, vol. 44, no. 5, pp. 440–448, May 2010.

[12] B. J. Daley, C. R. Shaw, T. Balistrieri, K. Glasenapp, and L. Piacentine, "Concept maps: a strategy to teach and evaluate critical thinking," *J. Nurs. Educ.*, vol. 38, no. 1, pp. 42–47, Jan. 1999.

[13] T. Holme and K. Murphy, "The ACS exams institute undergraduate chemistry anchoring concepts content map I: General chemistry," *J. Chem. Educ.*, vol. 89, no. 6, pp. 721–723, May 2012.

[14] D. J. Frank *et al.*, "Developing and Improving a Multi-Element First-Year Engineering Cornerstone Autonomous Robotics Design Project American Society for Engineering Education," in *American Society of Engineering Education Annual Conference & Exposition*, 2017.

[15] M. T. Spang, A. S. Strickland, and D. M. Grzybowski, "Works in progress: Impact of First-Year Micro-/Nano-Technology Research Project Course on Future Research and Graduate/Professional School Involvement," in *American Society of Engineering Education Annual Conference & Exposition*, 2014.

[16] R. M. Desing, R. L. Kajfez, K. M. Kecskemety, and D. M. Grzybowski, "Intersections Between Entrepreneurial Minded Learning, Identity, and Motivation in Engineering," *Int. J. Eng. Educ.*, vol. 38, no. 5(A), pp. 1389–1407, 2022.

[17] R. Desing, K. M. Kecskemety, R. L. Kajfez, D. M. Grzybowski, and M. F. Cox, "A Multi-Institution Investigation into Faculty Approaches for Incorporating the Entrepreneurial Mindset in First-Year Engineering Classrooms," in *American Society of Engineering Education Annual Conference & Exposition*, 2019.

[18] A. M. Singer, M. E. Ita, and R. L. Kajfez, "A Multi-Method Analysis of Engineering Student Curiosity," in *American Society of Engineering Education Annual Conference & Exposition*, 2023.

[19] S. Youssef, M. E. Ita, and R. L. Kajfez, "Student Comprehension of and Growth in Creating Value with an Entrepreneurial Mindset," in *American Society of Engineering Education Annual Conference & Exposition*, 2023.

[20] D. M. Grzybowski, X. Tan, E. Park, A. Leonard, J. Delano, and K. Zhao, "Integration of Entrepreneurial Minded Learning," in *American Society for Engineering Education Annual Conference and Exposition*, 2020.

[21] M. E. Ita, M. E. West, and R. L. Kajfez, "Development of Two Instruments to Measure Ability to Make Connections and Create Value in Engineering," *Int. J. Eng. Educ.*, 2023.

[22] E. Cartwright, M. E. Ita, and K. M. Kecskemety, "Analyzing Various Scoring Methods for Fill-In Concept Maps," in *American Society of Engineering Education Annual Conference & Exposition, Conference Proceedings*, 2022.

[23] M. K. Watson, J. Pelkey, C. R. Noyes, and M. O. Rodgers, "Assessing Conceptual Knowledge Using Three Concept Map Scoring Methods," *J. Eng. Educ.*, vol. 105, no. 1, pp. 118–146, 2016.

[24] M. E. Ita, M. E. West, L. Rumreich, R. L. Kajfez, and K. M. Kecskemety, "Concept Maps as a Direct Assessment for Measuring Students' Ability to Make Connections," *Engineering Unleashed*, 2022. [Online]. Available: https://engineeringunleashed.com/card/2784. [Accessed: 13-Feb-2023].

[25] M. Q. Patton, *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publishing, 2014.

[26] R. Hays and D. A. Revicki, *Assessing quality of life in clinical trials: Methods and practice "Reliability and validity (including responsiveness)"*, 2nd ed. New York, New York: Oxford University Press, 2005.

[27] L. Rumreich, M. E. West, K. M. Kecskemety, R. L. Kajfez, R. Desing, and C. Wallwey, "EM Learning Outcomes and Direct Assessment Rubrics," *Engineering Unleashed*, 14-Oct-2022. [Online]. Available: https://engineeringunleashed.com/card/2441. [Accessed: 28-Nov-2022].

[28] J. Segalas, D. Ferrer-Balas, and K. F. Mulder, "Conceptual maps: measuring learning processes of engineering students concerning sustainable development," *Eur. J. Eng. Educ.*, vol. 33, no. 3, pp. 297–306, Jun. 2008.

[29] A. Jackson *et al.*, "Refining an Entrepreneurial Mindset Master Concept Map through Multi-Institutional Collaboration," in *9th Research in Engineering Education Symposium & 32nd Australasian Association for Engineering Education Conference*, 2022.