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Refining an Entrepreneurial Mindset Master Concept Map through Multi-Institutional Collaboration

Alexandra Jackson[a], Elise Barrella[b], Cheryl Bodnar[a], Maria-Isabel Carnascali[c], Juan Cruz[a], Heather Dillon[d], Krista Kecskemety[e], Elif Miskioglu[f]
Rowan University[a], DfX Consulting LLC[b], University of New Haven[c], University of Washington-Tacoma[d], Ohio State University[e], Bucknell University[f]
Corresponding Author's Email: elise@dforxconsulting.com

ABSTRACT

CONTEXT

Over the past decade, there has been a substantial increase in the demand for the integration of entrepreneurial mindset (EM) into training of undergraduate engineering students. Although the engineering education field recognizes the importance of training related to this mindset, the assessment of EM development has lagged behind its implementation. Concept maps (cmaps) offer potential for direct EM assessment as they can provide a snapshot of students' conceptual understanding at a specific time point. A cmap uses nodes (concepts) and links (connections between concepts) as visual representation of an individual's perception of a topic.

PURPOSE OR GOAL

This study supports a larger project and focuses on applying a master/criterion EM cmap as a benchmark for scoring engineering students' cmaps. The research questions we will address are: What differences exist between students' cmap representation of EM concepts and the categories of a master EM cmap? How do student cmaps completed in different contexts compare in regard to their EM concept integration?

APPROACH OR METHODOLOGY/METHODS

This research study involved collecting EM-related cmaps from five distinct classes at different institutions representing a variety of institutional types and contexts, although only data from three institutions was analysed as part of this study. All cmaps were de-identified prior to analysis. A total of 65 cmaps were included in this analysis. Starting with a previously developed draft master EM cmap, we used the categories (or branches) from that cmap for categorically scoring students' cmaps. As part of the analysis process, training and calibration was completed for the two main researchers to ensure that the scoring process was reproducible. After which, cmaps were scored separately by both main researchers and inter-rater reliability was monitored for their scores.

ACTUAL OR ANTICIPATED OUTCOMES

This preliminary work benefits the engineering education community by demonstrating a reliable scoring approach that can be applied to evaluate cmaps generated for complex topics such as EM. This study provides insight into the challenges associated with using a master cmap approach to assess cmaps generated from multiple institutional contexts and different assignment prompts. Results are guiding changes to the draft master EM cmap to clarify categories and ultimately streamline the qualitative scoring process.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Through this study, we demonstrated how a master EM cmap can be used in the scoring of EM focused cmaps generated through multiple implementation methods. The results help us to address gaps in the literature on EM and operationalize a "definition" of EM that can be applied for direct assessment of the construct. After additional scoring, we will offer best practices that will assist faculty members with assessing EM development in their courses.

KEYWORDS

Concept maps (cmaps), entrepreneurial mindset (EM), undergraduate students

Introduction

Entrepreneurship (or intrapreneurship) has become an important aspect to integrate within the engineering curriculum due to its focus on the development of collaborative skills, technical and analytical skills, and personal attributes like flexibility, resiliency, creativity, empathy and opportunity recognition (Byers et al., 2013; Sheppard et al., 2009). Entrepreneurial-minded engineers are expected to demonstrate both traditional technical expertise and organizational level leadership to meet the needs of changing markets (Kriewall & Mekemson, 2010). Accordingly, Entrepreneurial Mindset (EM) has been integrated into various engineering educational settings through projects, courses, and degree programs (Huang-Saad, Morton, & Libarkin, 2018). It has become accepted that EM is vital to instill in students as more industries seek well rounded individuals with an abundance of technical and professional skills (Byers et. al 2013; Dabbagh & Menasce, 2006). Further, engineering program accreditors such as ABET and Engineers Australia require assessment of student competencies that align with EM dimensions, particularly related to applying engineering knowledge through design processes and developing professional skills (Bosman & Ferhaber, 2018).

Although there has been a considerable increase in entrepreneurially-minded learning (EML) within engineering (Huang-Saad, Morton, & Libarkin, 2018), measurement of EM development has proven difficult (Zappe et. al, 2013). The use of tools such as surveys and rubrics for assessment have been successful, though the results of the studies have often been inconsistent with each other, making it difficult to draw any definitive conclusions about EM development (Huang-Saad, Morton, & Libarkin, 2018).

One direct assessment method that has been applied widely in educational research, yet not used very often within EM research, is the use of concept maps (cmaps) (Watson et. al, 2016). Cmaps involve creating an organized, graphical depiction of knowledge surrounding a specific topic and have been shown to be useful for assessment and training of students' understanding in various areas (Turns, Atman, & Adams, 2000; Watson et. al, 2016). The purpose of this paper is to introduce a reliable approach to assess EM development using cmaps. To achieve this purpose, we seek to address the research questions: *(1) What differences exist between students' cmap representation of EM concepts and the categories of a master EM cmap? (2) How do student EM cmaps completed in different contexts compare in regard to their EM concept integration?* Our approach involves scoring cmaps from different institutional and course contexts and comparing results to a published master EM cmap. This paper describes both our findings related to the research questions and our efforts to refine the assessment method based on those findings.

History and Applications of Concept Maps

Assessment of conceptual knowledge in students has been a widely approached topic within all forms of education (Rittle-Johnson, 2006). Studies have sought possible ways to understand this knowledge, as it has become accepted that true conceptual knowledge requires organization and the ability to draw from prior knowledge to make connections between concepts (Rittle-Johnson, 2006; Watson et. al, 2016). In the 1980s, Novak & Gowin (1984) built upon these ideas to create a tool that could be used to assess students' true understanding of a topic. They referred to their tool as a "concept map", (cmap) in which various ideas relating to a certain theme (concepts) are connected using linking phrases (propositions) (Novak & Gowin, 1984; Novak & Canas, 2008). Over time, cmaps have been used across disciplines for a vast range of topics, leading to a variety of interpretations of the tool throughout curricular practice. The most common method for organization of cmaps uses multiple hierarchies that branch from the main topic (Watson et. al, 2016). Hierarchies that are tied together using a linking phrase, known as a "cross-link", show increased understanding of the topic (Novak & Canas, 2008).

Cmaps have been implemented to encourage learning at all educational levels and have been associated with positive outcomes such as increase in critical thinking skills and ability to retain knowledge (Walker & King, 2002; Watson et. al, 2016). At the university level, cmaps are used for classroom activities, homework assignments (Patel, 2018), curriculum development, and lecture material (Turns, Atman, & Adams, 2000). There are several methods for scoring cmaps that give educators options for assessing their students' learning. We will briefly describe the four most frequently used methods, which include both quantitative and qualitative approaches. Often, more than one scoring method will be used to capture the breadth, depth, and connectedness of students' conceptual understanding.

Traditional scoring. Introduced by Novak & Gowin (1984), traditional scoring is the most used approach, which analyses maps based on the number of concepts, hierarchy levels, and cross-links. These results are inserted into a formula to produce the final map score (Novak & Gowin, 1984; Novak & Canas, 2008).

Holistic scoring. Besterfield-Sacre et. al (2004) found that Traditional Scoring was somewhat restrictive and failed to encompass the full depth of students' knowledge, so they developed a more qualitative approach to scoring. This method involves assigning scores to an entire cmap based on Comprehensiveness, Organization, and Correctness, and then adding the three scores together.

Categorical scoring. This is a common mixed methods scoring approach which involves assigning concepts to certain categories decided by the scorer. The number of links between the various categories are then assessed and applied to a formula for complexity analysis to obtain the final map score (Watson et. al, 2016).

Expert map comparison scoring. This method uses an "expert" designed cmap to compare to the student maps and ultimately determine their level of conceptual understanding of a topic (Turns, Atman, & Adams, 2000). This method can provide insight into possible disconnects between student and expert understanding, and also serve as a basis for analysing future maps on the same topic (Bodnar, Jadeja, & Barrella, 2020).

Methods

Study Design

This study is part of a larger project involving five institutions in the United States that are developing cmap activities related to entrepreneurial mindset. We will present methods and results from three institutions, which are classified as a small, teaching-focused, liberal arts university (Bucknell University); a small, private, research university (University of New Haven); and a large, public, research-intensive university (The Ohio State University). Concept mapping assignments were integrated into existing engineering courses and varied across institutions based on the course topic and learning objectives, as shown in Table 1. Each assignment used a prompt related to EM in general (for lower-level courses) or EM in the context of the disciplinary course content (upper level courses). Student participants were first asked to complete a survey as part of the consent process. This survey gathered data regarding each participant's experiences with EM and cmaps, as well as demographic information such as gender, race, institution, and current curricular semester. For example, if students answered "Yes" to the question "Do you have any prior experience or knowledge of entrepreneurial mindset or entrepreneurship?", they would also be prompted with the question "Was this prior experience or knowledge of entrepreneurial mindset or entrepreneurship from: Coursework, Co-Curricular Activities, Work Experience, Other?"

Two out of the three institutions from which data was analysed, opted to assign "Construct-a-map" activities, while the other institution chose "Fill-in-a-map". "Construct- a-map" asks students to create a cmap from scratch based on a prompt. The "Fill-in-a-map" activity involved providing students with a central topic, a predetermined cmap structure, and list of 22 EM related terms. Of the 22 related terms, 5 were pre-filled in and 17 were listed alphabetically in a concept word bank. Appropriate human subjects' approval was obtained prior to data collection.

Table 1: Concept Mapping Assignments at Each Participating Institution

Institution	Course(s)	Cmap Type	Prompt	Sample Size
Bucknell University	Technical communications (upper level)	Construct-a-map	Value proposition for an engineering business proposal	13
Ohio State University	Engineering Fundamentals (first year)	Fill-in-a-map	Entrepreneurial Mindset	38
University of New Haven	Thermo Fluids Lab (senior)	Construct-a-map	Value created by their Thermo-Fluid projects	14

Notes: The sample size refers to the number of students who completed a cmap.

Concept Map Scoring

Categorical scoring was applied to cmaps based on categories generated from a published expert map (Bodnar et al., 2020). The categories from the EM master cmap were used to code each concept in each student-generated cmap. There were a total of seven main categories and five subcategories identified, as shown below in Figure 1. Each category included numerous terms.

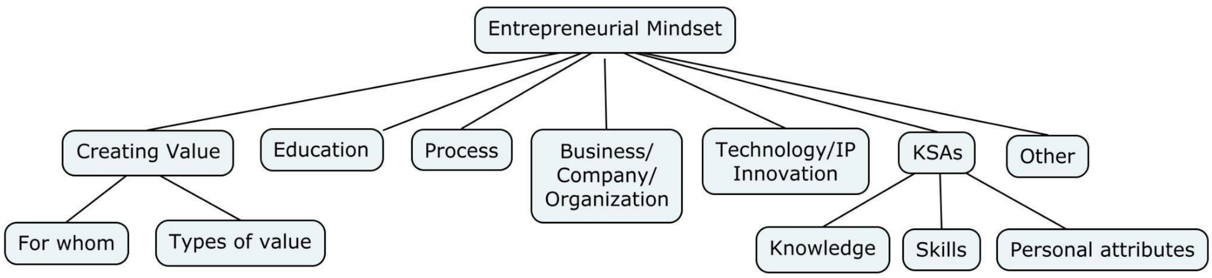

Figure 1: EM Categories for Coding

Cmaps were initially reviewed to correct spelling errors and identify prepositions that were meant to be concepts. Then, two researchers calibrated by categorically scoring one randomly selected cmap from each institution. Once the training was completed, the two researchers independently scored the remaining cmaps from one institution at a time. The researchers then met to reconcile any discrepancies, before proceeding to code maps from the next institution. In this manner, the researchers could learn from their coding process to help assist with better agreement on the subsequent institution's maps. An overall inter-rater reliability calculation using Cohen's Kappa alongside percent agreement (refer to Table 2) was used to check for coding inconsistency across the two researchers.

Table 2: Reliability Analysis for Concept Map (Cmap) Scoring Process

Institution (Sample Size for Reliability Analysis)	Inter-rater Reliability (as measured by Cohen's Kappa)	Percent Agreement (%)
Ohio State University (n=37)	0.877	83.79
Bucknell University (12)	0.627	66.35
University of New Haven (13)	0.764	80.79

The results obtained for inter-rater reliability showed fair (0.4 to 0.75) to strong agreement above chance (>0.75) (Fleiss, 1986). Overall, percent agreement was seen as reasonable with values across two out of the three institutions above 75% and the final institution above 65%. It was also observed that the two measures employed for reliability analysis were in alignment with one another. The reliability measures are similar to those from other cmap categorical scoring studies (Barrella et. al, 2021; Cassol & Verrett, 2020). Both Bucknell and University of New Haven used similar cmap prompts, which allowed for the reconciliation discussion after scoring Bucknell maps to assist with improving overall agreement on University of New Haven maps. Disagreement tended to center on specific terms in each dataset or entire hierarchies that were categorized differently from the root concept. Other studies have described similar challenges with scoring judgments when the central topic is a complex, multidimensional construct (Watson et al., 2016; Svanstrom et al., 2018).

Results and Discussion

In the initial review of the categorical scoring across institutions (see Table 3), we observed that all the categories derived from the EM master map were used in student generated cmaps. We also found that there was very infrequent application of the category "other". This implies that the initial EM master map was comprehensive in terms of its ability to capture the concepts relevant to EM and that there were no significant gaps between student perception of entrepreneurial mindset and the categories of the master EM cmap.

To address the first research question "*(1) What differences exist between students' cmap representation of EM concepts and the categories of a master EM cmap*?", we compared the categorization of student cmaps across the three different institutions. Through this analysis, we found a range in the application of Entrepreneurial Mindset (EM) categories (refer to Table 3). We expected that the "Education" category would be used infrequently based on the assignment prompts and the student perspective as compared to the faculty perspective used to develop the initial EM master map. In fact, that category was not assigned to any of the Ohio State University cmaps and only to a few concepts in the Bucknell University and University of New Haven samples. The results may suggest "gaps" in student perceptions, such as business/company/organization functions for Ohio State University and University of New Haven students or engineering competencies/personal attributes (KSAs) for Bucknell University students. However, exploring our second research question suggests that student responses were sensitive to the assignment context and prompt such that the cmaps may not fully reflect students' perceptions of EM.

To address the second research question, "*How do student EM cmaps completed in different contexts compare in regard to their EM concept integration?*", we examined in more detail differences in the approaches taken to implement the cmaps at the three institutions and the selection of the assignment prompts. The variability in application of EM categories seems to be at least partially related to the initial prompt that was provided to students for constructing their cmap and the course context.

Table 3: Use of Entrepreneurial Mindset Categories within Student Concept Maps

Category	Ohio State University	Bucknell University	University of New Haven
Creating Value	12.5%	20.2%	4.1%
Process	32.5%	22.2%	12.5%
Business/Company/ Organization	1.1%	15.2%	1.7%
Technology/ Intellectual Property	20.7%	36.4%	15.2%
Knowledge, Skills, & Attributes	32.7%	2.6%	65.3%
Education	0%	3.4%	1.2%
Other	0.6%	0%	0%

Ohio State University's cmaps had a broad focus on EM and due to the use of a Fill-in-a-Map structure, also provided students with concepts that covered a breadth of topics relevant to an EM. Despite providing students with the concepts to include in their map, we still observed that some students would interpret these concepts differently in their completion of the map. Examples included 3D printing, adapting, new ideas, time, and cost efficiency. For instance, adapting would sometimes be listed as a knowledge, skill, or attribute when referencing characteristics of the individual that was building their knowledge of an EM but in other occasions would fall under the category of technology/intellectual property when referencing innovation or new development. Another concept that was categorized differently across student maps was time. Students may have placed this under a type of resource where it would have been categorized as *Process*. In other situations, students would place time as a type of value that would be created by the technology. However, it was also quite common for students to randomly place time on the map, which led to difficulty in interpreting how to score this concept, leading it to fall under the "other" category.

The cmaps that were collected from both Bucknell University and University of New Haven were not explicitly focused upon the term "entrepreneurial mindset" but rather provided students with a prompt focused upon creating value through a student technical proposal (Bucknell) or lab project (New Haven). The students were also provided with less guidance in terms of map structure and concepts to be included through the application of the construct-a-map activity. In both cases, students were upper level and should have been exposed to EM in prior courses, which makes the less direct prompts appropriate for assessing students' understanding of EM. As such, we observed that these maps had a higher number of concepts that were relevant to either *Technology/intellectual property* or *Knowledge, skills, and attributes* than was observed in the Ohio State University cmaps. Understanding how to assign technical information and determining whether it pertained to new or existing technology was one of the main challenges we experienced throughout the scoring process of these two institutions' maps. For this reason, we proposed splitting apart Category 7 into the two sub-categories of traditional and novel technology to distinguish between these constructs moving forward. There is also the need in future implementations to encourage students to apply better linking words in their cmaps to aid with this classification.

For Bucknell University, students also completed a business model canvas as part of their technical proposal, which resulted in greater emphasis on the category

Business/Company/Organization. In categorizing the concepts, we had difficulties distinguishing between process and business and/or business and creating value. It was determined at the end of our reconciliation process with this set of maps that a sub-category should be added to the *Business/Company/Organization* heading that has *Channels* (how do you pursue marketing, supply chain, etc.) to help capture concepts that were relevant to the business model canvas that did not exist in the initial expert cmap. This may also help address a challenge we faced with differentiating between the steps taken when creating a product from the work done once the product has been created (business related functions).

There were a few scoring disagreements that were common across maps from all three institutions. These disagreements included how to distinguish between process and technology/intellectual property, process and knowledge, skills, and attributes, and technology/intellectual property and knowledge, skills, and attributes. To assist with better application of these categories, we need to clarify the distinction between process and technology/intellectual property, making it clear where concepts such as product specifications should be located. A potential reasoning could be that *Process* is how we create the “thing” and then *Technology/intellectual property* is used as a category to define the “thing" and what it does. Throughout our scoring process we recognized just how important the linking words can be in interpretation of student cmaps, particularly when a concept could be placed under two different categories. For this reason, we recommend encouraging instructors to emphasize labelling links between concepts when students are completing cmap activities in classes.

Conclusion

Applying the codes from the EM master map worked well across different assignment types and prompts; all categories were used, and concepts were rarely assigned to the “other” category. Further, the coding revealed differences in student responses based on the assignment type, context, and prompt. Main challenges with the categorical scoring involved assigning specific terms that were not included in the original expert map dictionary or assigning the same term to different categories depending on the context in an individual student map. As a result of the initial round of categorical scoring, changes are being made to the codebook and coding process. Ultimately, the master EM cmap will be revised in order to better distinguish between categorical codes like business and process or existing technology/knowledge and new technology/innovation. The coding process is also being simplified to make scoring easier and account for predictable differences in interpretation such as critical thinking being viewed as a personal attribute and a skill, and thus belonging in the larger KSAs category. Final revisions to the coding process will be made after scoring cmaps from the other two institutions included in the larger study, which both used similarly straightforward prompts about EM and we expect will match well with the current categorical scoring process.

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