Using Micromoments and Concept Maps to Enhance Entrepreneurially Minded Learning of Indoor Air Pollution Control

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Abstract

Micromoments targeted toward indoor air quality were introduced to students in an Air Quality Engineering course to enhance their entrepreneurial mindset. Three micromoment activities, i.e., “Question Frenzy”, “Make It Relevant”, and “How Do We Make It Better?” that are linked, respectively, to the curiosity, connections, and creating value elements of EM were deployed in the class in the context of the use of a Corsi Rosenthal cube (a do-it-yourself structure that has recently become popular as an inexpensive way to reduce indoor particle pollution). Students generated concept maps pre-and post- micromoment intervention using the freely available CMap Tools software. The digital concept maps were scored using the traditional scoring approach, and the scores were used to provide a quantitative assessment of whether EM-oriented micromoments enhanced students’ entrepreneurial mindset. The concept map scoring (16 maps were scored for 8 students) indicated a significant increase in average concept map scores from the baseline average score of 30 to the after-intervention maps average score of 99 was noticed, with much of the scoring increase attributed to an increase in the number of concepts, i.e., the parameter that correlates to the breadth of understanding. Overall, this study shows the value of using micromoments in an air quality engineering class and provides a quantitative framework that may be broadly applied across different engineering fields for enhancing and assessing students’ understanding of EM.

Introduction

Numerous papers have been published to discuss why an entrepreneurial mindset (EM) enables added learning in engineering as a whole, and several papers have been published to suggest why or how EM may be encouraged in environmentally-enabled theme areas[1–5]. However, more examples are needed of ways in which EM-based learning may be facilitated, and specifically in using environmentally-based themes that students may easily relate to their real-world experiences. Moreover, additional ways to assess students’ EM learning are needed.

This work serves as a seminal paper for environmental engineering and engineering faculty as a whole to reinforce the basic EM concepts of curiosity, connections, and creating value (i.e., the 3 Cs) since it provides a unique combination of activities with a quantitative assessment method- micromoments combined with scored concept maps. Numerous laboratory and project-based experiences[2,3,6] have been developed to encourage an entrepreneurial mindset. The use of micromoments[7–9], i.e. short, applied scenarios, help students to develop their curiosity about a subject, make connections between concepts, and ultimately create value. In short, the implementation of micromoments may facilitate the development of an entrepreneurial mindset[10] while simultaneously improving students’ ability to connect classroom knowledge to real-world experiences. Concept maps have previously been used as tools in engineering education, specifically in evaluating entrepreneurial mindset (EM) themes[11,12]. Still, no published work exists to implement or evaluate micromoments in environmental engineering courses-specifically air quality engineering courses- with concept maps used to assess students’ learning. Thus, this work provides a unique basis from which other faculty may not only develop in-class activities, but also assess the effectiveness of those activities. The process that is described herein is one that could be easily adapted to large classes, given the digital nature of the outputs that are produced.

Research Question and Goals

The study sought to address the following research question: Does using EM – oriented micromoments enhance students' entrepreneurial mindset? The specific goals were to:

(1) use the "entrepreneurial mindset" framework to discuss indoor air pollution control,

(2) employ three micromoment activities to expand on ideas related to indoor air pollution control, and

(3) assess student learning through the use of concept maps.

Methods

A brief refresher on the 3 Cs of the EM framework was provided to students to address goal #1. Students at Arizona State University are traditionally introduced to EM throughout the entire curriculum from the undergraduate to graduate level[1]. Thus, all students in the class had previous interactions (even briefly) with the 3Cs.

A do-it-yourself portable air cleaner, specifically a Corsi-Rosenthal (CR) cube[13] was brought to class, and scientific study results were shared with the students regarding the use of CR cubes in indoor air pollution control[14,15]. No discussion of the CR cube, apart from what was shared in the publications that students were provided, was initiated in the classroom setting. Students were instructed to download the freely available Cmap Tools program[16,17], were given a starting concept map (see Figure 1), and were told to try to expand on the concept map by thinking of the CR cube as an example and thinking of the terms "curiosity", "connections", and "creating value" based on their own starting knowledge of these terms and the brief refresher that was provided to students about these terms. The purpose of providing the starting concept map was to make sure that the starting node ("Indoor air pollution control") was the same in all concept maps, and to give students initial guidance in thinking about the topic in terms of the EM framework of developing curiosity, making connections, and creating value. The only pieces of advice that students were provided with were to make sure that each added node(s) and linking word(s) were unique and made sense by showing how the nodes and linking words could combine to form a phrase. The concept map created in this first phase was denoted as the "baseline" concept map and labelled as "student#_1", where the # was replaced with an actual number.

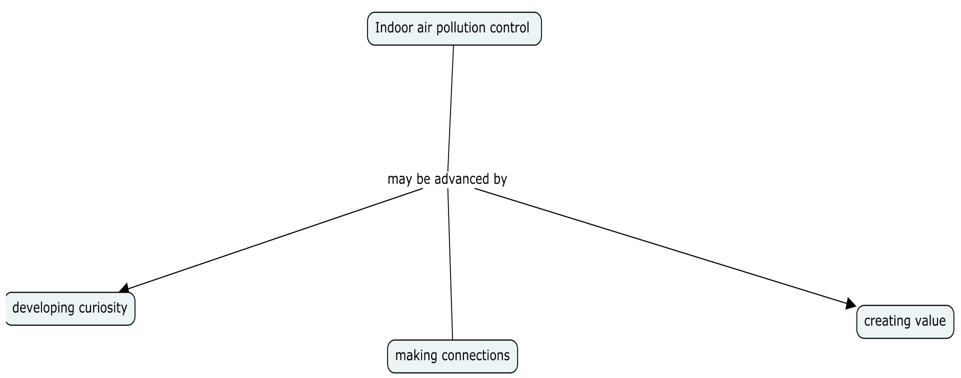

Figure 1: Starting concept map (created in Cmap Tools) that was provided to students.

To address goal #2 of the study, the authors of this paper selected three specific micromoment activities using the general framework of the EM-themed micromoments of "*Question Frenzy"*, "*Make It Relevant"*, and "*How Do We Make It Better"* [9] for, respectively, the EM themes of curiosity, connections, and creating value. For the specified air quality engineering course, the *Question Frenzy* and *Make It Relevant* micromoment activities were carried out on a single day, and the *How Do We Make It Better* micromoment was carried out one week later.

Students were advised that the *Question Frenzy* micromoment activity was meant to expand their curiosity about indoor air pollution control and was carried out in a 5-minute period in class in teams of two. The teams were instructed to look at the CR cube and ask themselves what questions they had about the cube. They had a 5-minute period to quickly write down every question that the team came up with, without stopping to discuss the questions or the answers, and without making any judgments about the questions.

Students were advised that the *Make It Relevant* micromoment was meant to expand their thinking about the connections to indoor air pollution control and the CR cubes. Assembled in their groups of 2, students were given 15 minutes to ask and respond to the following questions: (1) What themes and specific topics did we cover this semester that relate to the Corsi Rosenthal (CR) cube? (2) What other technologies or methods exist that are similar to/have the same function as the CR cube? Students were prompted to quickly write down as many short responses to the two questions as they could and were encouraged to use their class notes and the internet to address the questions.

The *How Do We Make It Better* micromoment was carried out one week later, given the added time required for this portion of the module. Students were advised that the *How Do We Make It Better* micromoment was related to the creating value portion of the EM framework. They were encouraged to think about what elements of the CR cube they were curious about and how the cube related to class topics to make the cube better and create added value. Teams of 2 were encouraged but not required, and students had 30 mins to discuss ideas. After the 30-minute period, additional discussion regarding the information assembled for all three micromoments was undertaken for another 20-25 minutes. During this time, students were also encouraged to update their baseline concept maps by thinking of all three micromoment activities that they engaged in.

Theoretically, teams could have finished their concept mapping activity in class. However, some students wished to think more about the activities and completed the activities over an additional up to 7-day period. Students were encouraged to continue to work on updating their baseline concept maps to create an expanded concept map (labeled as student#_2). They were given a small amount of extra credit to hand in their original and updated concept maps and the results of each of their micromoment activities. Moreover, students were encouraged to develop a more expanded design for how they could create value. In the interest of time and since this was the first implementation of this activity, only a short (2-page) document was required for this extra credit opportunity. Students were encouraged to provide a clear description of the design change and the potential added value, a schematic, a potential parts/cost list, and the proposed steps for use (if they were substantially different from the original CR cube).

To address goal #3, the baseline and final concepts maps were scored. Scoring of the maps was done automatically using the automated scoring tool, version 1.2.1[18] which is freely available through GitHub and requires .cxl files that may be easily created using the CMAP Tools program. The traditional scoring method[11,19] for concept maps of counting the number of concepts (NC), the highest hierarchy (HH), and the number of crosslinks between levels (NCL) and developing a score based on a weighted combination of these numbers (as seen in Equation 1) was used within the automated scoring tool :

$$\text{Score} = NC + (5*HH) + (10*NCL) \qquad (1).$$

The traditional scoring method of Equation 1 was chosen to enable a direct and easy comparison between the baseline and updated concept maps for each student, similar to previously published data on the use of concept maps to assess EM learning[11,12,20]. The data were output to a CSV file from the automated scoring tool, and further analyzed in Excel. Excel was used to obtain the average baseline and updated concept map scores, and a one tail paired t-test was performed to assess- using statistics- the significance of the difference between the average baseline and updated concept map scores. A one tail test was performed given that there was an expectation that the scores would increase in going from the baseline to the updated concept map.

In addition to handing in the concept maps and designs, students were asked to complete a survey that specifically related to the use of micromoments and concept maps. Students were asked to respond on a Likert scale ranging from Strongly Disagree (1 point) to Strongly Agree (5 points) for the following six statements:

(1) Before this air quality engineering class, you had previously heard of or used the Entrepreneurial Mindset framework, i.e., the 3 Cs of developing curiosity, making connections, and creating value <u>in a class.</u>
(2) Creating the concept maps was an easy process.
(3) The "Question Frenzy" micromoment activity was effective in helping to expand curiosity about Corsi-Rosenthal cubes and their use in improving air quality.
(4) The "Make it Relevant" micromoment activity was effective in helping to make connections between the design or use of the Corsi-Rosenthal cubes and topics that were covered in our air quality engineering class.
(5) The "How to make it better?" micromoment activity was effective in encouraging broader thinking of how the Corsi-Rosenthal cubes might be re-designed or upgraded to create added value.
(6) The three micromoment activities made it easier to update/expand the original concept map that was created in activity #1.

In addition to these six prompts, students were asked to provide a free response to the following question/request: "*How might the concept mapping and micromoment exercises related to the Corsi-Rosenthal cubes be improved upon? Please provide suggestions.*"

Results and Discussion

Table 1 provides scoring data for the baseline and updated concept maps obtained from the class, and Figure 2 provides examples of baseline and updated concept maps. The submission of the two concept maps and supporting material was for extra credit, so only eight students out of the twenty-two in the class submitted their work for credit. (The lower submission rate was due simply to the timing closer to the end of the semester.) It is important to note that two students (students #2 and #7) worked together throughout the entire process, including in creating the concept maps and all three micromoments, since their work was entirely done in class. No restrictions were placed on students in terms of handing in their concept maps, except that they were required to indicate who they might have worked with in creating the concept maps so that duplicate scores could be accounted for. All other students worked independently in creating their final concept maps, even if they worked together to carry out the micromoments.

Table 1: Scores for the baseline (Student #_1) and final (Student #_2) concept maps listed by student.

Name	Number of Concepts (NC)- Baseline Map	Number of Concepts (NC)- Final Map	% change in NC	Highest Hierarchy (HH)- Baseline Map	Highest Hierarchy (HH)-Final Map	% change in HH	Number of Crosslinks (NCL)- Baseline Map	Number of Crosslinks (NCL)- Final Map	Score - Baseline Map	Score - Final Map	% change in the score
Student1_1	58			4			0		78		
Student1_2		74	27.6		4	0.0		0		94	20.5
Student2_1	8			3			0		23		
Student2_2		25	212.5		4	33.3		17		215	834.8
Student 3_1	9			2			0		19		
Student3_2		21	133.3		3	50.0		1		46	142.1
Student4_1	13			2			0		23		
Student4_2		85	553.8		5	150.0		0		110	378.3
Student5_1	13			3			0		28		
Student5_2		19	46.2		3	0.0		1		44	57.1
Student6_1	12			3			0		27		
Student6_2		21	75.0		3	0.0		0		36	33.3
Student7_1	8			3			0		23		
Student7_2		25	212.5		4	33.3		17		215	834.8
Student8_1	10			2			0		20		
Student8_2		21	110.0		2	0.0		0		31	55.0
Averages	**16**	**36**		**3**	**4**		**0**	**5**	**30**	**99**	

As noted in the methods section, Excel was used to analyze the data of Table 1. The average score in going from the baseline to the updated concept map increased from 30 to 99. A t-test to assess the hypothesis of whether the baseline and final concept maps' average scores were identical resulted in a p value of 0.022, suggesting significant differences between the two average scores. This statistically significant difference in concept map scores suggests that students' knowledge was indeed expanded after implementation of the micromoments (i.e. goals #2 and #3). Additional information can be gained by examining the differences between the individual categories of the baseline and updated concept maps. Past work has shown that the number of concepts, highest hierarchy, and number of crosslinks are, respectively associated with knowledge breath, knowledge depth, and connectedness between concepts.[11,12] The data of Table 1 show that after implementation of the micromoments, students' breath, depth, and connectedness of knowledge in the indoor air pollution area are, in general, expanded significantly, with the largest increases consistently occurring in the breadth of knowledge, as measured by a consistent expansion in the number of concepts (NC) reported in the updated concept maps. The number of concepts increased from a baseline concept map average of 16 to a final concept map average of 36, i.e. a 125% increase. The data provide a quantitative way to assess the areas where learning was expanded, as well as areas where additional work is needed. The zero initial values for the number of crosslinks (NCL) suggests that students may not be connecting concepts as easily as may be desired, especially in an upper division course that the micromoments were implemented in.

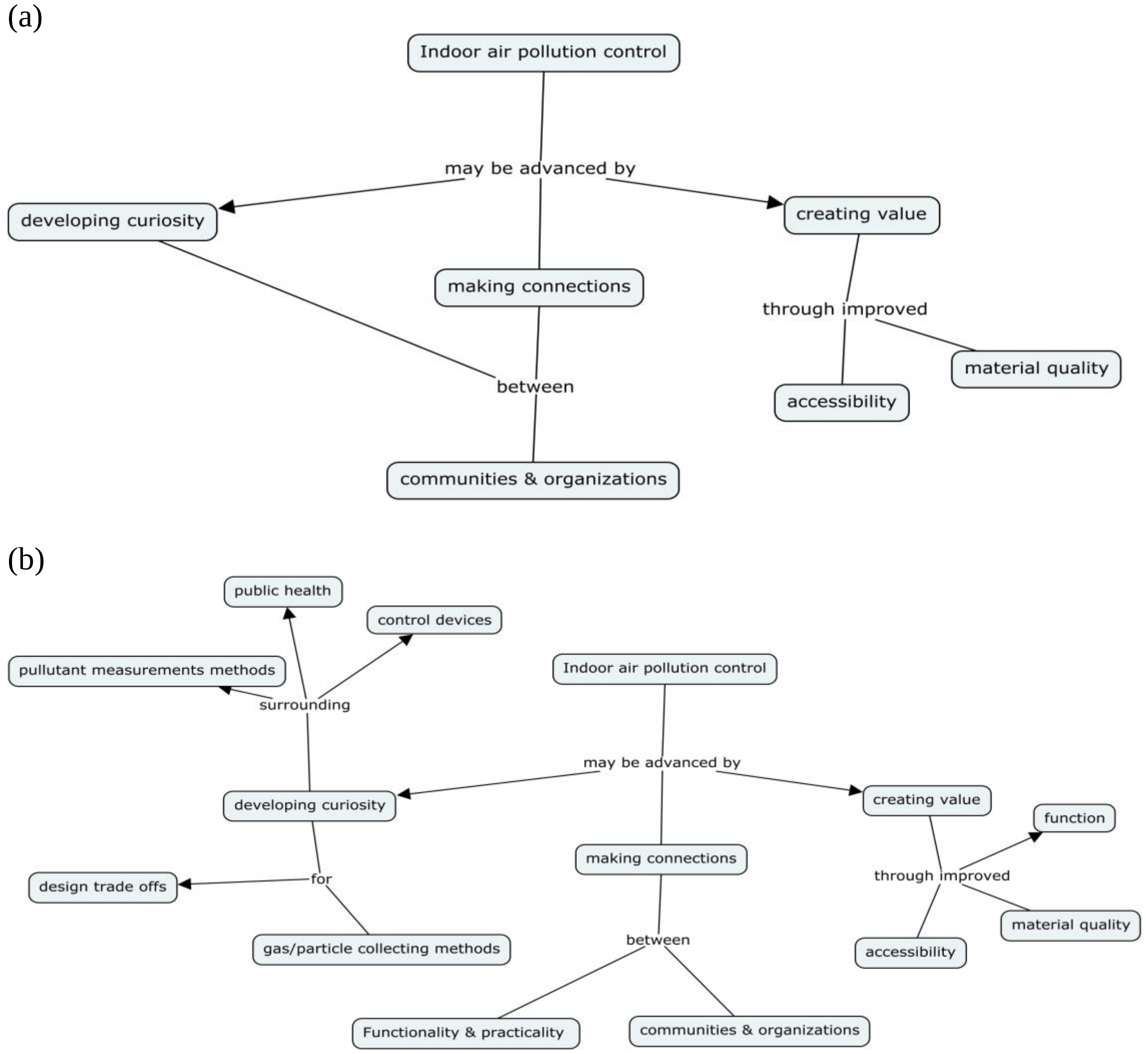

Figure 2: Examples of (a) baseline and (b) updated concept maps created in Cmap tools.

It is also important to note that the students who worked together not only with the micromoments but also in creating the concept maps were able to significantly increase the number of crosslinks in their concept maps. Students #2 and #7 went from having no crosslinked terms to having 17 crosslinked terms. This is a significant result, especially given that the number of concepts (NC) and the length of the highest hierarchy (HH), representing, respectively, the breadth and depth of knowledge, for students #2 and #7 were in the same range as other students. This result suggests that consistent teamwork may enable students to identify more connections between concepts. The connections that students form between subjects are essential for fostering innovation and enhancing the impacts of new designs since multiple factors are considered.

Twelve students responded to the survey, four more than those who turned in the concept maps. All twelve students participated in the classroom activities, but four students decided not to hand in the supplemental material for extra credit due to timing constraints. Table 2 provides aggregate results for the survey, presenting the averages and standard deviations associated with each of the questions, and suggests the following main conclusions:

(1) Even though it was known that the students had been exposed to EM previously, students were just slightly above neutral in remembering that they had been previously exposed to the 3 Cs of EM in a class.
(2) Students tended to agree that creating and updating the concept maps was easy.
(3) The use of the micromoments helped expand students' curiosity, ability to make connections, and thinking regarding the creation of value.

Table 2: Results of the survey, questions 1-6 for twelve (12) respondents for each question. A score of 1 corresponds to "strongly disagree" and a score of 5 corresponds to "strongly agree".

Question	Average	Standard Deviation
(1) Before this air quality engineering class, you had previously heard of or used the Entrepreneurial Mindset framework, i.e. the 3 Cs of developing curiousity, making connections, and creating value in a class.	3.8	0.8
(2) Creating the concept maps was an easy process.	4.2	0.7
(3) The "Question Frenzy" micromoment activity was effective in helping to expand curiosity about Corsi-Rosenthal cubes and their use in improving air quality.	4.6	0.6
(4) The "Make It Relevant" micromoment activity was effective in helping to make connections between the design or use of the Corsi-Rosenthal cubes and topics that were covered in our air quality engineering class.	4.3	0.9
(5) The "How to make it better?" micromoment activity was effective in encouraging broader thinking of how the Corsi-Rosenthal cubes might be re-designed or upgraded to create added value.	4.4	0.8
(6) The three micromoment activities made it easier to update/expand the original concept map that was created in activity #1.	4.3	0.9

The free-response section of the survey resulted in several repeated themes and suggestions for improvement:

- Students suggested that the timing for introducing the 3Cs of EM could have been enhanced. Students wished to see the 3 Cs introduced and reinforced throughout the semester rather than just at the end of the semester when the concept mapping and the three micromoment activities were introduced.
- Students wanted more time to discuss answers and responses to the questions and themes that arose with each micromoment activity. They particularly commented on the desire to discuss the results of the *Question Frenzy* activity that was meant to

enhance students' curiosity right after that micromoment, rather than after the second micromoment.

- Students were eager to provide answers and do some hands-on experimenting with the device that was brought into class. While some of this experimenting did occur (students turned on the cube, made observations about the flow direction and speed of the air, openly pondered the question of whether the speed of the fan impacted the collection efficiency of particles onto the surface, etc.), it was clear that more time to discuss and experiment was desired.

Comments provided by students directly to the instructor during the activities also remarked on the novelty and fun nature of the activities.

Impacts and Future Opportunities

This is a seminal paper showing how micromoments may be used to enhance students' knowledge of the 3 Cs of the entrepreneurial mindset framework in environmentally-related subjects (goals #1,2). Previous studies have focused on different engineering subject areas , and no previously published work combines micromoment activites with concept mapping as an assessment tool. Using concept maps provides a way to quantitatively assess the extent of knowledge enhancement (goal #3). Moreover, framing the micromoments with a hands-on, real-world example (in this case the CR cube) that students may connect to their everyday lives enables students to think more about the 3 Cs. This approach of coupling micromoments and concept mapping may be applied to any field.

Although the students appeared to value and learn from the micromoment activities, the concept maps still show a lack of specific information related to the object that was brought into the class (i.e., the CR cube). This discrepancy in including more specific information in the concept maps regarding the CR cube may have been related to the need to encourage students to provide more specific examples within the concept map. Nevertheless, the presented data suggest that students' abilities to more clearly articulate elements that they were curious about, to make connections to lecture material, and to spark innovation and additional creation of value (i.e., the 3Cs of EM learning) were increased. Although the number of concepts that students include in their maps and the highest hierarchies may be more directly related to the lectures that are provided to students (and hence may be influenced by the instructors), the connections that students make between concepts (as evidenced by the number of crosslinks) may be enhanced through consistent small group teamwork activities. This result is supported in this work by the results of only one team, and therefore needs additional testing.

Future implementations are suggested to include gathering intermediate concept maps. Specifically, it is recommended to request updates to students' concept maps after each micromoment activity, rather than just having a starting and ending concept map. Scoring the intermediate concept maps would provide added data to potentially show (a) the value of having multiple micromoments that can build off each other and (b) the importance of one type of micromoment activity over another in terms of improving students' technical knowledge and their ability to apply that knowledge. Follow up mini projects that enable students to engage in hands-on design and/or testing would (a) enable students to make additional connections between the micromoment activities, concept mapping exercises, and, ultimately, the EM framework, and (b) further extend this work from a lecture-only class to a laboratory course or a capstone design course, depending on the activities undertaken following each micromoment and intermediate concept map activity.

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