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Enhancing Entrepreneurial Minded Learning of Process Control and Heat Transfer Concepts Using Micromoments and Concept Maps

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Abstract

The Entrepreneurially Minded Learning (EML) Framework seeks to infuse an Entrepreneurial Mindset in engineering students. The EML framework is founded on the 3 C's principles of curiosity, connections, and creating value. Assessing EML efforts, however, is a well-known challenge for many engineering courses that do not have a design component. Through concept maps and micromoment activities, this work seeks to answer the following questions: Does implementing micromoment activities enhance students' EML in two core areas of chemical engineering, i.e., heat transfer and process controls? A secondary research question is whether introducing a physical device in lectures enhances students' EML. The micromoments were introduced at two Universities in the USA and Mexico.

Using Cmap Tools, a freely available software, students were asked to create a digital concept map connecting their learning to the concepts explained using a 3 C's model: curiosity, connections, and creating value. Then three micromoment activities, including process control and/or heat transfer scenarios, were presented to the students to reinforce 1) heat exchanger control concepts, feedback control schemes, and advanced control schemes concepts in a Process Control course and 2) heat transfer concepts, processes, and applications after using and answering questions related to a "hands-on" double pipe heat exchanger module in a Heat Transfer Processes course. Subsequently, students were asked to update their original concept map and to adjust their maps considering the three micromoment activities. The digital concept maps were scored using the traditional scoring approach, and the total score was used to provide a quantitative assessment of whether EM-oriented micromoments enhanced students' EML. A 10 – 20 point difference in concept map total score increase was observed at both universities after introducing the micromoment activities. In summary, we developed technical micromoment activities and demonstrated their effectiveness using concept maps as EML assessment tools for core chemical engineering courses.

1. Introduction

The Entrepreneurial Mindset (EM) is defined as an "inclination to discover, evaluate, and exploit opportunities.[1]" With more than 50 engineering school partners, the Kern Entrepreneurial Engineering Network (KEEN) has adopted and disseminated an Entrepreneurially Minded Learning (EML) Framework to infuse EM in engineering students. The EML framework is founded on the 3 C's principles of curiosity, connections, and creating value.[2], [3] Numerous resources exist for faculty to implement EML principles in their courses, including the Engineering Unleashed platform,[4] which provides multiple activities readily available for faculty to deploy in the classroom. The Engineering Unleashed platform has more than 2500 resources shown in the form of cards and is continuously updated by participating faculty through peer-collaboration. Additionally, KEEN hosts an annual meeting and various workshops to infuse EM learning and teaching-related activities for faculty members.

In chemical engineering, a recent study by Liberatore et al. [5] highlighted numerous aspects of EML implementations. Examples include using a makerspace to design and produce 3D-printed impellers and study the pump's efficiency, creating value for students [6], and the design of a winning Chem-E-car at the 2021 AIChE annual competition by constantly applying the 3 Cs [5]. EML has also been incorporated in the Unit Operations laboratory through online student interactions with a non-profit company [7], using the 3 Cs where students try to help a customer solve a heat transfer problem. In a materials course, students can redesign and propose new construction materials for a tank that failed during a molasses disaster in 1919 [8].

These activities, however, are sometimes challenging to implement due to significant course modifications, including multi-week implementations and time allotted during a traditional semester.[7], [8] As a potential alternative, EML micromoments[9], [10], [11] provide a rapid alternative for faculty to engage students in EML activities. EML micromoments are short and rapid implementations of in-class activities deployed to students in 2 – 30 minute intervals during regular class times. These activities are shown under resources in the Engineering Unleashed platform[4]. The micromoments are student-centered learning activities, where students solve a given task for a short time, promoting students' curiosity, connections, and value creation. The micromoment initiative lists at least 25 potential micromoment activities[10] that instructors and faculty members can use at any university. However, the micromoment list does not provide particular examples related to engineering or chemical engineering concepts, implementation guidelines for core engineering courses, or micromoment activity assessment tools. In fact, assessing Entrepreneurially Minded Learning (EML) efforts is a well-known challenge for many engineering courses that do not have a design component[12].

In this study, we developed technical micromoments for Process Control and Heat Transfer Processes courses using the related micromoments of "Question Frenzy," "Make It Relevant," and "How Do We Make It Better?." These micromoments are linked to curiosity, connections, and creating value elements of EML. Traditional chemical engineering concepts were introduced to students in heat transfer and process control courses. Using Cmap Tools[13], a freely available software, students were asked to create an initial digital concept map connecting their learning to the concepts explained using a 3 C's model: curiosity, connections, and creating value. Students were provided with the start of the concept map. This included the initial node and three branches from the node related to curiosity, connections, and creating value.

Two course sections were analyzed for the process control course. One section used micromoment activities (intervention group), and the other section (control group) did not. A comparison between the two groups is provided in this study. For the heat transfer course, only one course section was analyzed. Initially, students were asked to complete the initial concept map using the 3 C's with just the information they had gathered from the primary class lectures or in-class activities—including a "hands-on" activity using a low-cost desktop learning module (LC-DLM) for a double pipe heat exchanger—and their own experiences such as co-ops, internships, or previous courses. Following the implementation of the micromoment activity, students were asked to modify their initial concept map, and the total concept map scores were assessed pre- and post-micromoment intervention.

This study provides a seminal contribution to using micromoment activities for chemical engineering faculty or engineering faculty teaching Process Control or Heat Transfer Processes. Current implementations involve two universities in the USA and Mexico, respectively.

2. Research Questions and Goals

The study's primary research question is: Does using EML micromoment activities enhance student learning related to heat exchangers in two Chemical Engineering courses through the use of concept maps? A secondary research question examines whether introducing a physical device enhances students' EM assessment through the development of concept maps.

The specific goals of this study are:

a) To incorporate EML micromoment activities in Process Control and Heat Transfer courses,
b) to deliver and assess EML micromoment activities to students in Chemical Engineering at two separate institutions,
c) to contrast the micromoment interventions with a "hands-on" experimental module and
d) to provide recommendations for future technical EML micromoment implementations.

3. Methods

3a. EML and Selected Micromoment Activities

Although one institution is a KEEN member, EML is not explicitly included in the curricula of the two universities' programs. However, some courses where EML approaches are implemented provide guidelines for using the 3C's as part of their learning objectives. Students at both institutions typically relate the entrepreneurial mindset (EM) to only business ideation and creation or senior design projects. For the two courses used in this study, the authors provided resources to the senior students taking the two courses (outlined next), including handouts or videos. Hence, a brief explanation of EM and the 3 C's was provided to senior engineering students during the second week of the semester to dispel misconceptions.

Three micromoment activities were deployed at the two institutions: "Question Frenzy," "Make It Relevant," and "How do we make this better." General descriptions of the three micromoments are provided in different published formats.[9], [10]

It is important to note that the two interventions and participants are different since these took place at two different universities and in different countries. However, the focus of using two courses at two universities is to compare the total scores obtained from concept maps for the following scenarios: 1) comparing micromoment interventions (EM intervention) with no micromoment interventions (control group) for a process control course and 2) using pre- and post-implementation assessment of micromoment activities with the same students for a heat transfer course. The specific goals, micromoment activities, and differences in implementations for each scenario are described in sections 3b and 3c, respectively.

3b. EML micromoment implementation at Universidad Autónoma de Nuevo León – Process Control

Participants. Two sections of the Process Control course were recruited for the study. Section 1, from now on referred to as the EM intervention group, had 40 students participate in the intervention, while Section 2, referred to as the control group, had 27 students. It is worth mentioning that although Universidad Autónoma de Nuevo León is located in Mexico, its Chemical Engineering program is ABET accredited.

Entrepreneurial Mindset and Micromoments Introduction. Students from both sections were given an introductory talk about EM, which consisted of describing the 3 C's and how these help engineers tackle problems. This activity took approximately 10 minutes during class time. Then, the EM intervention group did three micromoments of "Question Frenzy," "Make It Relevant," and "How Do We Make It Better?" with each micromoment linked to one of the 3 C's of EM. The intervention took place throughout the semester, using the control of a heat exchanger (HX) as the base problem to consider.

Chemical Engineering Micromoment Activities: Process Control. During the third week of the semester, as part of the course content on process modeling, students were presented with the first micromoment, "Question Frenzy." The lecturer presented a heat exchanger diagram and tasked the students to ask as many questions as needed to understand the system (**Figure 1**). This activity lasted for five minutes, after which students met in teams for 15 more minutes to develop the mass and energy balances that described the system according to the results from the discussion sparked by the micromoment. Some questions students formulated were: What fluids were involved in the process? Is there a phase change taking place in the heat exchanger? Is the heat exchanger configuration co-current or counter-current?

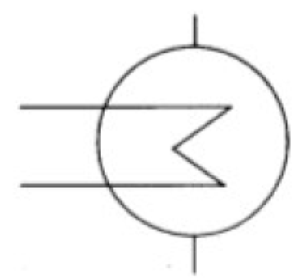

Figure 1. Heat exchanger diagram provided to the students in the Process Control course for the "Question Frenzy."

While studying the feedback control scheme for a single loop, students were presented with the previous example of the heat exchanger and tasked to "Make It Relevant" to find examples in their daily lives and analyze the control schemes of such examples. Students dedicated 10 minutes to discuss their results in teams and 5 minutes for a group discussion. Students were able to identify everyday examples, such as a water heater, air conditioner, and a refrigerator as cases of heat exchangers, and the way those systems work with a temperature sensor, a manipulator (such as a compressor, valve to regulate the flow of natural gas, etc.), and the process in itself. Thus making a connection to the content covered in class.

Finally, during the last two weeks of the semester, the topic of advanced control schemes, such as cascade control, ratio control, and feed-forward control, was discussed. Students were asked to work in teams and devise ways on "How Do We Make It Better?" taking the heat exchanger as the base problem. The instructor described a case study where problems in the steam supply and variations in the process flow and temperature were present. After 15 minutes of teamwork, each team presented their proposal and the rationale behind it. The instructor closed the intervention by explaining each control scheme and how to implement it in the heat exchanger. The total time dedicated to the activity was 45 minutes.

<u>Concept Maps:</u> After the micromoment interventions, the instructor provided a base concept map consisting of a starting node, "Control of a heat exchanger," and three branches, each about one of the 3 C's in EM. Students were instructed to download the free software Cmap Tools[14], [15], [16] and complete the concept map based on what they learned during the micromoments. Since participation in the study was optional, students who submitted the completed concept map were rewarded 5 points over their final grade.

The control group covered the same material but without doing the micromoments. The control group was asked to submit a concept map of their understanding of EM related to the control of a heat exchanger.

Approximately 95% of the chemical engineering students at Universidad Autónoma de Nuevo León, come from the high school system integrated into the university, where they are introduced to concept maps early in their high school program. Thus, only a brief explanation of how to use Cmap tools was given to account for differences with the software they had used before to develop their concept maps, mainly Microsoft PowerPoint.

An automated scoring tool[17] that handled input from Cmap Tools was used to grade the concept maps from the EM invervention and the control groups. The traditional scoring method for concept maps was chosen as it allows for a direct comparison since it considers a weighted sum of the number of concepts (NC), the highest hierarchy (HH), and the number of crosslinks between levels (NCL) to assign a score based on equation 1.

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

To probe if the average scores of each section were equivalent, a t-test was performed using the t-test function in Microsoft Excel.

3c. EML micromoment implementation at the University of Dayton – Heat Transfer Processes

Participants. One section of the Fluid Flow and Heat Transfer Processes was chosen for this study. The section had 17 senior students registered at the University of Dayton (UD), all participating in the micromoment activities. Specific technical micromoment activity examples are provided in this work. No class control group was available for a comparison study, and hence, a direct comparison with students in part 3b is limited.

Entrepreneurial Mindset and Micromoments Introduction. Students were introduced to the KEEN framework with an assignment. They had to read the KEEN framework document or had the opportunity to watch a video prepared by the UD KEEN representative (1 h video). Students were introduced to the three micromoment activites, i.e., "Question Frenzy," "Make it Relevant," "How do we make this better" in the classroom as the activities were developed. For this study, the three micromoments were implemented during a single class period.

Chemical Engineering Micromoment Activities: Heat Transfer. After covering concepts of double pipe heat exchangers, students were exposed to a well-known "hands-on" activity using the double pipe heat exchanger hands-on, low-cost desktop learning module (LC-DLM) developed and provided by Washington State University (WSU),[18], [19] as shown in **Figure 2A**. Briefly, the module consists of a double-pipe heat exchanger cartridge run with a "hot" fluid and a "cold" fluid, and the temperatures at the entrance and exit reservoirs for each stream are measured. A schematic is shown in **Fig. 2B**. Students can also vary the pump speed to adjust flow rates. Data is recorded by a team of students working collaboratively in teams of 3 – 4 students, and a worksheet with calculations and pre-, post-, and motivational surveys are completed. The team at WSU provided all of this information. Through the Unit Operations laboratory, some students also gained exposure to a pilot scale concentric tube heat exchanger (**Fig. 2C**) with a riffled inner and outer diameter for the inner tube within the double pipe system (**Figs. 2D and 2E**). After this exposure to several heat transfer concepts, the students developed an initial concept map as homework (pre-micromoment). In the following class period, the students performed the micromoment activities as listed below.

"Question Frenzy" Heat Exchanger Micromoment Activity (5 mins): Students were provided schematics of the double pipe heat exchanger and a tubular finned pipe, similar to the one shown in **Figure 2B**. The students also had access to a "real" piece of finned pipe found in our laboratories (**Fig. 2D**) and the concentric double pipe experimental kit (**Fig. 2A**). The micromoment activity consisted of listing as many questions as possible involving these two objects in a maximum allotted 3 minutes. The following 2 minutes were used to discuss some of the questions. Some example questions formulated by students include: why are etchings on the pipe?, how does the system account for friction? What metal material was used in the experiment? What if fluids are pumped co-current? Which system has more losses to the surroundings?

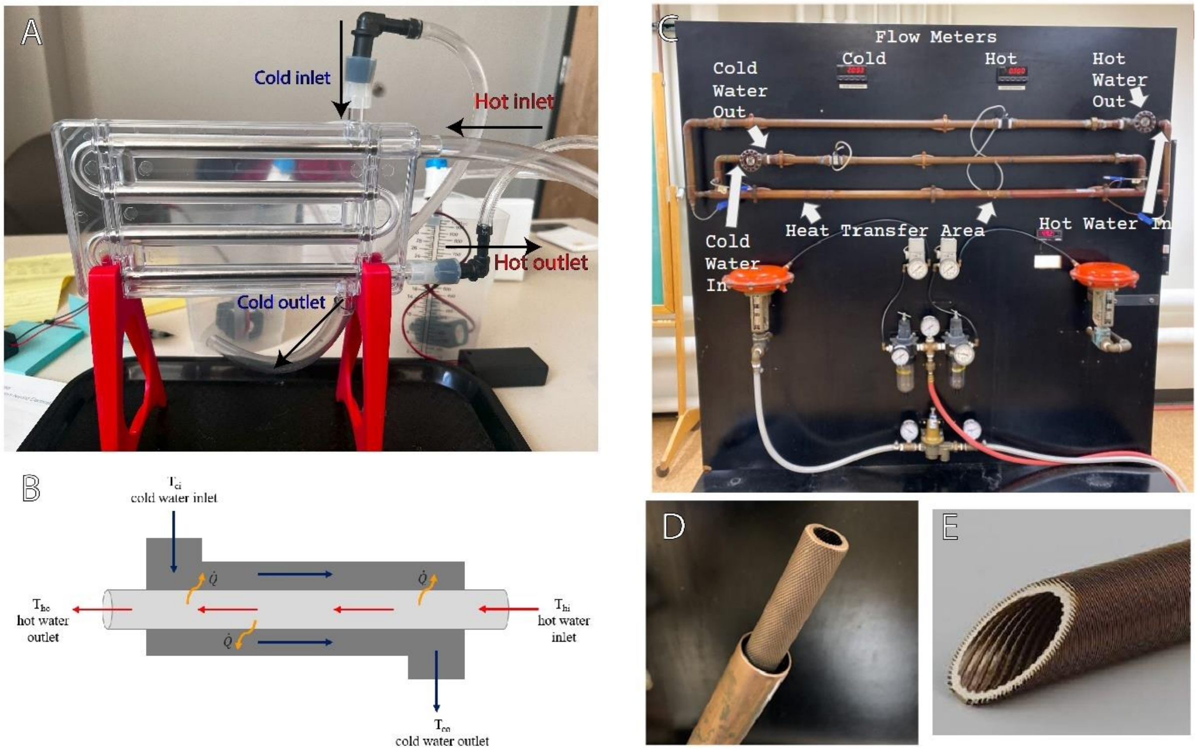

Figure 2. Chemical engineering students complete a series of "hands-on" experiments using double pipe heat exchangers at the University of Dayton. A module provided by WSU is shown in (A), (B) shows a schematic of the heat exchange process, (C) shows the pilot scale system located in the Unit Operations Laboratory with a tubular/rifled structure (D/E).

"How do we make the WSU double pipe heat exchanger better?": Students were challenged to individually list as many changes or suggestions to improve the double pipe HX (7 mins). It is important to note that the students had already worked with the experimental module, and some had already run a finned concentric tube in the Unit Operations Laboratory at the University of Dayton. The students were also allowed to use Google Patents as a search tool to find additional ideas or reinforce their thinking. Following the individual brainstorming, students worked in teams and analyzed their top suggestions (8 – 10 mins), and a few groups shared their findings with the class (5 mins). A few suggestions provided by the students include the ability to switch out the pipe material or geometry in the LC-DLM, the ability to control frictional losses through the addition/removal of pipes or bends, and the ability to use different types of small pumps.

"Make it Relevant": A series of questions were given to the students to encourage creating value from the heat exchanger micromoment activities. The specific questions provided are listed below:

- Do the double pipe heat exchanger examples remind you of anything in your life or professional experience where heat transfer is necessary? Explain
- Does the double pipe HX remind you of another concept you have learned?
- How is the double pipe HX similar to other concepts you have learned?
- How is the double pipe HX different from other concepts you have learned?

Use Google Scholar (https://scholar.google.com/) to answer the following questions:

- What industries benefit from using double-pipe heat exchangers?
- Are there any other heat exchangers that are better than double-pipe systems? How can the efficiency of a heat exchanger be determined?
- How might heat exchangers (heat transfer) relate to societal issues?

Most students connected these questions with Transport Phenomena concepts, a pre-requisite course, and professional experiences, including co-ops or internships.

Concept Maps: Students completed homework assignments to submit concept maps using Cmap Tools pre- and post- micromoment implementations. Out of the 17 students registered, only 12 responses are included in this work. Two students submitted incorrect file types, and three did not submit the homework assignment. The first concept map was prepared before the micromoment intervention—after finishing the concentric double pipe heat exchanger "hands-on" module developed by WSU. The second concept map was prepared by the students following the three micromoments. Concept map scoring was also performed using equation 1 and the t-test function in Excel was also used to analyze the data.

4. Results and Discussion

4a. EML micromoment implementations at Universidad Autónoma de Nuevo León, – Process Control

Since participation in the study was optional, and submission of the concept map was for extra credit, only 32/40 and 10/27 students from the EM intervention and control groups chose to participate, respectively. The results for each variable and final scores, along with the average, minimum, and maximum score and standard deviation for each process control group, are included in Table 1.

The concept maps that scored 16 were those where students only added one node to each branch and were the norm in the control group. Higher scores and some crosslinks are observed in the concept maps from the EM invervention group. The average score in the EM intervention group is more than 50% higher than that of the control group. The p-value for a two tailed t-test on their average scores is 0.003. Since this p-value is lower than 0.05, this suggests that the average scores are statistically different.

Table 1. Concept maps results and scores for Process Control course.

	EM INTERVENTION GROUP				CONTROL GROUP			
ID	NC	HH	NCL	Score	NC	HH	NCL	Score
1	11	2	0	21	6	2	0	16
2	10	4	0	30	7	2	0	17
3	12	2	0	22	17	0	0	17
4	13	3	0	28	6	2	0	16
5	9	2	0	19	6	2	0	16
6	14	4	0	34	17	3	0	32
7	12	2	0	22	6	2	0	16
8	20	5	1	55	9	3	0	24
9	11	2	0	21	7	2	0	17
10	17	4	0	37	11	4	0	31
11	19	2	0	29				
12	16	7	0	51				
13	15	3	0	30				
14	13	3	0	28				
15	23	3	0	38				
16	9	2	0	19				
17	10	2	0	20				
18	13	2	0	23				
19	16	3	1	41				
20	10	2	0	20				
21	16	4	0	36				
22	11	2	0	21				
23	21	3	0	36				
24	19	3	0	34				
25	14	3	0	29				
26	16	2	0	26				
27	11	3	2	46				
28	13	5	0	38				
29	14	5	0	39				
30	15	3	0	30				
31	11	2	0	21				
32	12	3	0	27				
AVERAGE	14	3	0	30	9	2	0	20
MIN	9	2	0	19	6	0	0	16
MAX	23	7	2	55	17	4	0	32
STD DEV	4	1	0	9	4	1	0	6

NC = number of concepts, HH= the highest hierarchy, and NCL = the number of crosslinks between levels (NCL). Total scores (Eqn 1) are used for analysis in this study.

Thus, the results show that the micromoments impacted changing the students' perception of what entrepreneurial mindset encompasses. The apparent lack of motivation/participation from the control group students could be attributed to the fact that the class took place late at night, on Thursdays from 6 to 9 PM, with most students showing up tired as they work full time and take classes at night. The EM intervention group sessions took place on Fridays from 9 AM to 12 PM, with students displaying consistently more energy and commitment to the class.

The concept map results were compared to the final grades to further prove if the micromoments impacted student performance. First, an F-test was performed on the student grades and concept map scores for each group, resulting in a p-value of 0.22 and 0.19 for the EM intervention and control groups, respectively. These meant that the grades and concept map scores for each group had a similar behavior in terms of their variances. The p-value for a two-tailed t-test on the average grades is 9E-20. The average grade for the EM intervention group was 75, compared to an average of 50 for the control group. Thus, the grades are statistically different, which can be attributed to the effect of the micromoments in providing students with a framework to address problems.

4b. EML micromoment implementations at the University of Dayton – Heat Transfer Processes

Concept map examples, as well as quantitative and qualitative findings and observations by the instructor, are provided in this section. An example of the assigned concept map supplied to the students and generated using Cmap tools is shown in **Figure 3**. The initial node consisted of identifying how the entrepreneurial mindset can be applied to concentric tube heat exchangers through "curiosity," "connections," and "creating value." As noted, the students were introduced to linking word(s) and nodes. Most students have done concept maps before and a quick introduction was provided. An example of a concept map generated by a student pre-intervention, which was done prior to the micromoment implementation is provided (**Fig. 4**). In this example, the student started identifying connections among the "3 C's" as well as the application in heat exchangers after using the LC-DLM "hands-on" module and after in-class lectures.

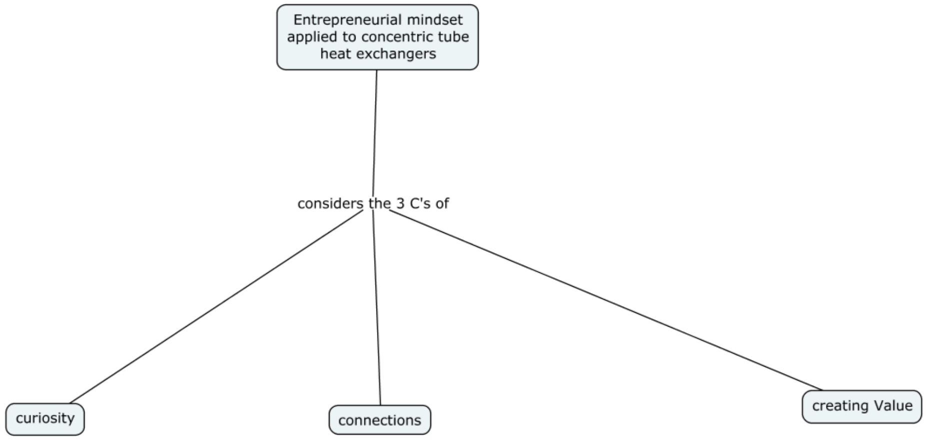

Figure 3. Initial concept map file prepared in Cmap Tool provided to the students in a Heat Transfer Processes course

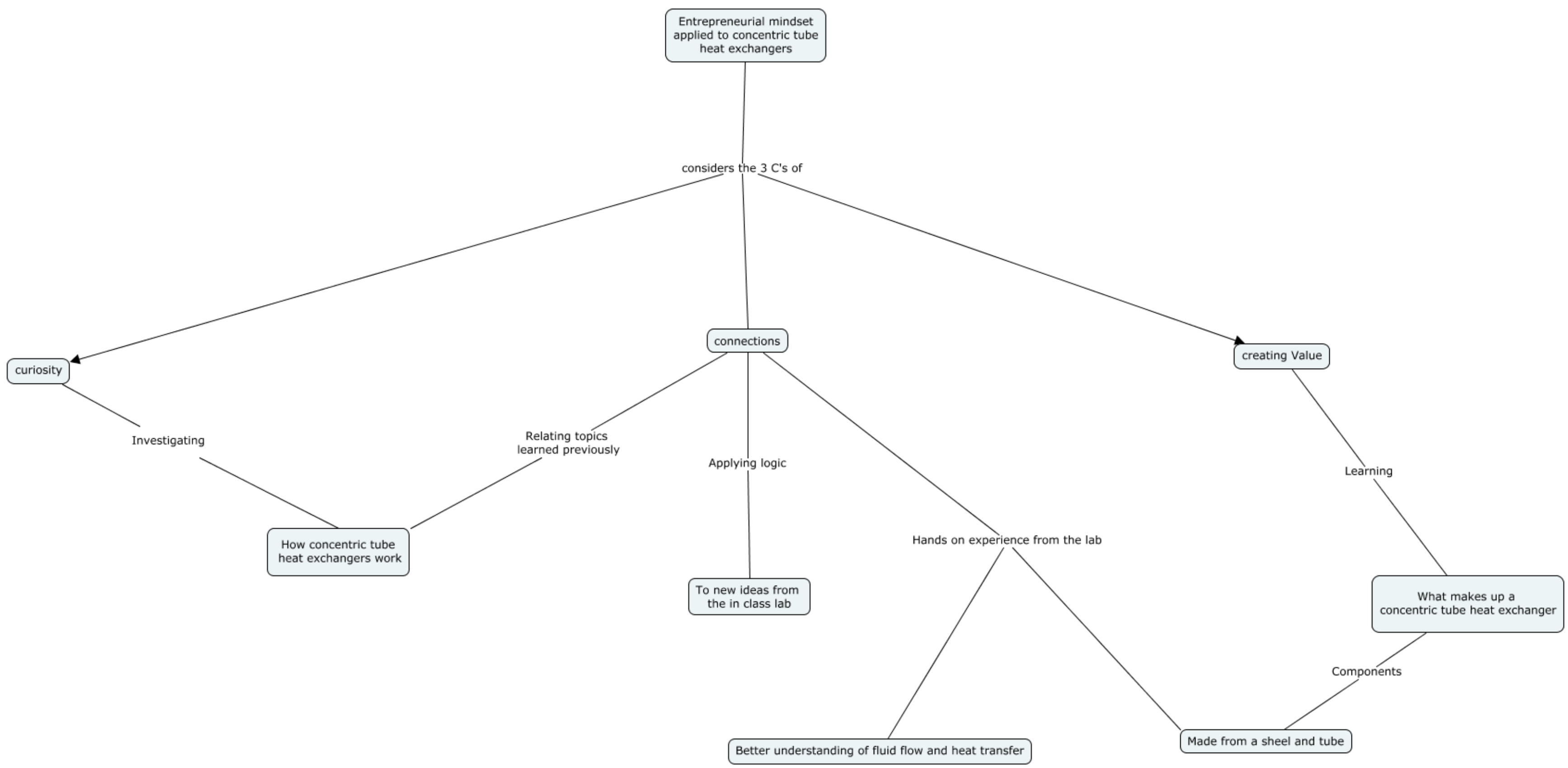

Figure 4. Concept map example of applying an entrepreneurial mindset to concentric tube heat exchangers

After implementing the micromoment activities, students had the option to update their original concept map and submit the revised concept map file in a new homework (post-intervention). Unfortunately, only 6 out of 12 students updated their initial concept map. Table 2 shows the results for each variable and the final scores (eqn. 1), along with the average, minimum, and maximum score and standard deviation for each variable.

Table 2. Concept map (Cmap Tools) results and scores for micromoment implementations in a Heat Transfer Processes course.

	PRE-INTERVENTION				**POST-INTERVENTION**			
ID	NC	HH	NCL	Score	NC	HH	NCL	Score
1	21	4	5	91	28	5	6	113
2	9	5	11	144	12	3	13	157
3	8	2	2	38	8	2	2	38
4	17	3	0	32	27	3	0	42
5	15	2	0	25	15	2	0	25
6	23	3	25	288	30	4	28	330
7	15	3	1	40	12	3	13	157
8	9	2	2	39	9	2	2	39
9	23	7	5	108	23	7	5	108
10	36	4	3	86	36	4	3	86
11	33	3	0	48	33	3	0	48
12	21	5	2	66	29	5	2	74
Average	19	4	5	84	22	4	6	101
Min	8	2	0	25	8	2	0	25
Max	36	7	25	288	36	7	28	330
Std dev	9	2	7	74	10	2	8	85

NC = number of concepts, HH= the highest hierarchy, and NCL = the number of crosslinks between levels (NCL). Total scores (Eqn 1) are used for analysis in this study.

Note that the six students had initial scores below 50 (participant ID = 3, 4, 5, 7, 8, 11). Some did not modify the concept maps (n = 4) and others only showed a modest improvement (n = 2). However, the average percent change improvement in the total score for the two participants who decided to update their concept map was significant. For example, participant ID 7 increased from a score of 40 to 157, showing a 293% improvement attributed to the micromoment activities.

The six remaining students with initial scores above 50 (participant ID = 1, 2, 6, 9, 10, 11) had four students who modified the initial concept map file, and their average score also increased. The average result for score % increase was 12.8%, with a maximum increase of 19.5% (participant ID = 1) and a minimum increase of 10.8% (Participant ID = 12). The student with the highest initial and final score (participant ID = 6), increasing from 288 to 330, had a 12.7% increase, which aligns with the average result for these students.

The p-value for a paired two-tailed t-test on the average pre- and post- micromoment implementation scores is 0.0485. Since this p-value is slightly lower than 0.05, this suggests that the average scores are statistically different even though six students did not update their initial concept map (participant ID = 3, 5, 8, 9, 10, 11). We observed that students with lower initial scores could benefit more from micromoment implementations in the classroom. However, adding assignments for completing the concept map may represent a challenge for low-performer students with multiple competing demands in other courses during their senior year, including plant design and the unit operations laboratory at the University of Dayton.

Overall, the Heat Transfer Processes course aligns with the Process Control course results, demonstrating that the micromoments impacted and changed the students' perception of applying the entrepreneurial mindset to technical concepts. However, a few differences were noted in the absolute scores between the two institutions.

Because the student profiles are similar at both institutions (i.e., all students are senior-level students), differences in overall scores for the Cmap Tools concept maps are not likely attributable to the student level. Instead, we hypothesize that the main difference in the absolute average scores (30 vs. 84) between the institutions may be due to differences in the sequence of courses taken by the students and the "hands-on" component introduced at one institution. At Universidad Autónoma de Nuevo León, students take a transport phenomena course with a brief heat and mass transport concept coverage (5th semester), an applied heat transfer course (7th semester), and the Process Control course in the 9th semester, where the micromoment interventions were applied. At the University of Dayton (UD), students take two transport phenomena courses (5th and 6th semester) that include an introduction to heat transfer concepts and principles, a transport phenomena laboratory (6th semester), followed by an applied Heat Transfer Processes course (7th semester), where the micromoment intervention took place, combined with a Unit Operations Laboratory (7th semester). Thus, students at UD are more exposed to heat transfer concepts. Additionally, students at UD had a chance to complete a "hands-on" modular experience with a low-cost module prior to developing the initial concept map.

5. Recommendations and Suggestions for Future Micromoment Implementations

We provide the following suggestions and recommendations for future implementations and deployment of micromoment activities:

- Develop and deliver short micromoment activities, such as "Question Frenzy," before engaging students in longer, complex activities. This activity will allow the instructors to recognize the students' level of interest in performing micromoments or concept maps.
- Deliver micromoment interventions at different points during the semester. Students' fatigue was noticed when interventions were delivered in a single class period. It is important to balance time for lecturing course notes and EML activities.
- Align micromoments adoption with the instructor's teaching style. While there are micromoments for each of the 3 Cs—curiosity, connections, and creating value—it is important that the instructor feels comfortable delivering this type of activity to the students

in the classroom. For example, an instructor needing to emphasize connections to different topics in a course can use activities focused on connections only.

- Use concept maps for assessing micromoment effectiveness only as needed. Some students were apprehensive about learning new software, making a concept map, and submitting homework. Moreover, multiple students complained about updating a concept map after performing a micromoment intervention.
- Investigate alternative micromoment assessment tools such as quizzes to assess students' specific knowledge or quick surveys or questionnaires to assess the effectiveness of newly prepared engineering-based micromoments.

6. Conclusions and Future Work

The primary goal of this work was to answer the question: Does implementing micromoment activities enhance students' EML in two core areas of chemical engineering, i.e., process control and heat transfer courses? The study showed that micromoments could be easily adapted to complement student activities and be directly tied to course materials rapidly and inclusively for all students who participate in micromoment activities and prepare a concept map. Additionally, the micromoments provide a powerful tool to infuse the 3 C's in student learning of a topic, as quantitatively shown by the total scores obtained from the concept maps.

A secondary research question examined whether introducing a physical device enhances students' EM learning. There was nearly a 50-point difference in the overall score in the initial concept map generated when students had access to a "hands-on" activity with a physical device compared to students who did not have access to those tools at a different university in a different country. We recognize that multiple differences exist, such as student profiles, class sizes, universities, and countries and further work is needed to answer this question.

Based on the results presented and the different interventions in two universities in two countries, we conclude that the micromoments directly impact students' entrepreneurial mindset, as shown by concept maps and three initial nodes of curiosity, connection, and creating value (3 Cs). Despite the numerous differences at both universities, results showed a 10 – 20 point increase in the total concept map score observed after introducing the micromoment activities for both courses.

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