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Fostering Entrepreneurial Mindset in Chemical Engineering Students Through an Alumni Seminar Series and Alumni-Led Jigsaw Activities

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Abstract

The development of an entrepreneurial mindset (EM) is critical for engineering students as they prepare to navigate complex, real-world challenges. This project aimed to enhance students' EM by connecting them with early-career professionals through a seminar series and in-class jigsaw activities. In the spring semester of 2024, four alumni, representing diverse career paths in consulting, water treatment, enzyme manufacturing, and data science, participated in a monthly seminar series open to all engineering students. Following each seminar, the alumni collaborated with the course instructor to design and present a jigsaw activity related to their profession in a junior-level, chemical engineering separations course. The jigsaw activities provided a hands-on, problem-solving framework to engage students in the practical application of EM concepts, aligning with the three Cs of curiosity, connections, and creating value.

To assess the impact of these activities, pre- and post-surveys based on EM were administered. Data analysis showed a statistically significant improvement in students' EM across several factors. For instance, students demonstrated greater confidence in their ability to lead teams and assess the feasibility of new products. Through alumni engagement that emphasized practical applications of engineering concepts and real-world problem-solving, students' EM was enhanced by improving their confidence in leadership, creative thinking, and problem-solving.

Introduction

As part of a Kern Entrepreneurial Education Network (KEEN) Fellowship I received in AY2023, I incorporated a semester-long project to have recent alumni engage undergraduate engineering students and lead classroom activities focused on the entrepreneurial mindset (EM) and the three Cs: curiosity, connections, and creating value.[1] "It spiked my interest in understanding how engineering students develop through their… professional experiences and how [those position them to incorporate] entrepreneurial mindset into their work. Especially the three Cs," was a student's seminar survey response. The development of an EM is important for engineering students as they prepare to navigate complex, real-world challenges. KEEN has focused on this mission in order to graduate engineers that can create personal, economic, and societal value.[2] One way to contribute to this mission is through alumni and professional speakers. Often times undergraduates do not realize the scope of career opportunities open to them once they graduate or how they can create value in society. By bringing speakers to campus that focus on the three Cs, undergraduates can begin to see the possibilities that are open to them in their future and the value of being curious, creating value, and making connections.

Interacting with industry professionals is valued by students,[3, 4] but is often lacking in engineering curriculums outside of internships and design projects. Additionally, students that are curious, can make connections, and create value are valued in industry, but students in an undergraduate program may not see the value in having those skills. Oftentimes undergraduates are unclear on what they can expect in "the real world'" not realizing the value of the three Cs.

As a faculty member that had three years of industry experience prior to going to graduate school, I do try to foster the three Cs in my students, but my industry experience was over 20 years ago and although some things stay the same, industry and the corresponding expectations evolve rapidly. The goals of this project were two-fold, 1) to allow students to get first-hand information regarding the EM from recent graduates and 2) to determine which factors of EM changed pre- and post-intervention for the students. These factors were identified previously by Li et al.[5] and are listed in Table 1.

Table 1. List of factors[5] that the EM survey[6] questions load on to.

• Intrinsic curiosity	• Value creation
• Risk management	• Ability to learn
• Problem solving/logical thinking	• Ability to anticipate technical development
• Systems thinking	• Team building
• Engaging stakeholders	• Ability to assess financial value
• Data driven decision making	• Exposure to entrepreneurship
• Career plan	• Interests in entrepreneurship

The two activities the alumni did included a seminar and an in-class jigsaw activity. The alumni gave a 1 h seminar on how the three Cs helped them throughout their careers and then presented a jigsaw activity they developed in a junior-level, chemical engineering course. The alumni were four early-career chemical engineering professionals (2-5 years post-graduation) with a variety of career paths including job changes, being fired from a job, and taking roles outside their discipline/main interests. The guest lecture/seminar series was open to the entire College of Engineering while the jigsaw activity took place in a core, junior-level chemical engineering course.

Previously, jigsaw activities have been effectively used to cultivate an EM in engineering education by promoting the three Cs. These approaches engage students in active learning by providing partial information and foster independent problem-solving, require teamwork to integrate knowledge, and provide deeper connections to real-world applications. Studies have shown that jigsaw methods, whether applied in digital communication systems,[7] biomedical engineering,[8] or online game-based learning,[9] enhance engagement, critical thinking, and creative problem-solving. Santiago and Guo[7] applied the KEEN EM framework to a digital communication systems course using jigsaw activities that were integrated into learning modules, requiring students to research emerging topics such as the Internet of Things and artificial intelligence. Then, the students had to present findings while making connections to business opportunities. This approach encouraged curiosity, value creation, and connection-making, core aspects of the EM.[7] Caplan et al.[8] explored the use of jigsaw techniques in engineering courses to foster curiosity and connection-making among students. The study found that approximately 50% of students exhibited behaviors linked to curiosity and entrepreneurial thinking during the jigsaw exercises. By providing partial information and requiring students to seek additional knowledge, the approach promoted engagement and independent learning.[8] In a hands-on jigsaw activity, Tabrizi[10] implemented a jigsaw in a digital systems course that required students to collaboratively assemble functional circuit systems with other students. The flexible and interactive nature of the task promoted creative thinking, curiosity, and system-level problem-solving, aligning with KEEN's entrepreneurial outcomes.[10] These are just a few of the

jigsaw activities found in the literature. Many more activities ranging from requiring one class[11-14] to weeks[15-18] of a semester can be found elsewhere.

By structuring learning around entrepreneurial principles, such as identifying opportunities and managing risk, jigsaw activities help students develop essential skills for innovation and adaptability in their future careers. This paper presents how the EM of students changed from the beginning to the end of the semester in a class that integrated alumni jigsaw activities with a focus on the EM survey results.

Methods

Participants and setting

From Jan. to April of 2024, four seminars were given by four different early-career professionals that are MSU chemical engineering alumni. The alums had a wide range of careers including consulting (‘19), process engineering for water treatment (‘20) and enzyme manufacturing (‘20), as well as a data scientist/project manager (‘19).

The spring 2024 seminar was advertised to all students, graduate and undergraduate, in the College of Engineering and held in a classroom with auditorium seating on the MSU campus. The seminars provided the students an opportunity to create a connection with a professional engineer, develop curiosity of the “real world” and what potential careers consist of, and hear how the professionals create value for their company. During the 50 min. seminar, the alumni discussed how they have used curiosity, creating value, and connections (3 Cs) throughout their education and in their early careers. Although open to all students, the majority of attendees were from the chemical engineering discipline with a few from environmental engineering and education. The typical seminar attendance was approximately 10 students.

After the seminar, all four alums presented a jigsaw activity that was developed with help from the instructor related to their jobs. The activity was presented in a junior-level, core chemical engineering course, mass transfer unit operations. The enrollment was 24 undergraduate students and three graduate students ($n = 27$). The class was 75 min long and convened directly after the seminar. The jigsaw activities ranged from 30 to 45 min in length and the format has been described in previous works.[19, 20]

Brief description of jigsaw activity

For the jigsaws presented, the alum developed an idea that I provided feedback to refine the activity. For the four speakers, a brief description of the jigsaw topics were:

1. You are a consultant with a budget. You need to give the company you are working for a quote for process equipment. The options are to reuse existing equipment or purchase equipment through an auction house, new vendor, or preferred vendor.
2. You are an engineer working at a facility that produces enzymes. Based on some data, you need to prioritize what your budget is going to be spent on. The options are an automated clean-in-place system, automated pH adjustment system, improved solid dosing system, and an additional enzyme concentrate system.
3. You are an engineer that needs to pitch a process to a new client for removing contaminants from wastewater. You can propose to use any combination of reverse

osmosis, ion exchange, electrodialysis removal, and/or adsorptive magnetic nanoparticle treatment but they all have fixed and annual operating costs associated with them.

4. You manage a software development team for a consulting company that is behind schedule in delivering a product. The options are to delay the client meeting, have multiple meetings, or have the employees work overtime to meet the deadline.

The students broke into three or four groups (called "expert" groups) and each group was assigned an option from the scenario. The "expert" groups then discussed the pluses and minuses of their option using large Post-It note boards and markers to record anything of importance. After about 15 min, an "expert" from each group joined one "expert" from each of the other groups to form a group of three or four (Figure 1). These groups then needed to make a decision on which option they would recommend based on the knowledge they each had. This discussion took about 15 min and then each group reported out their decision and why.[20]

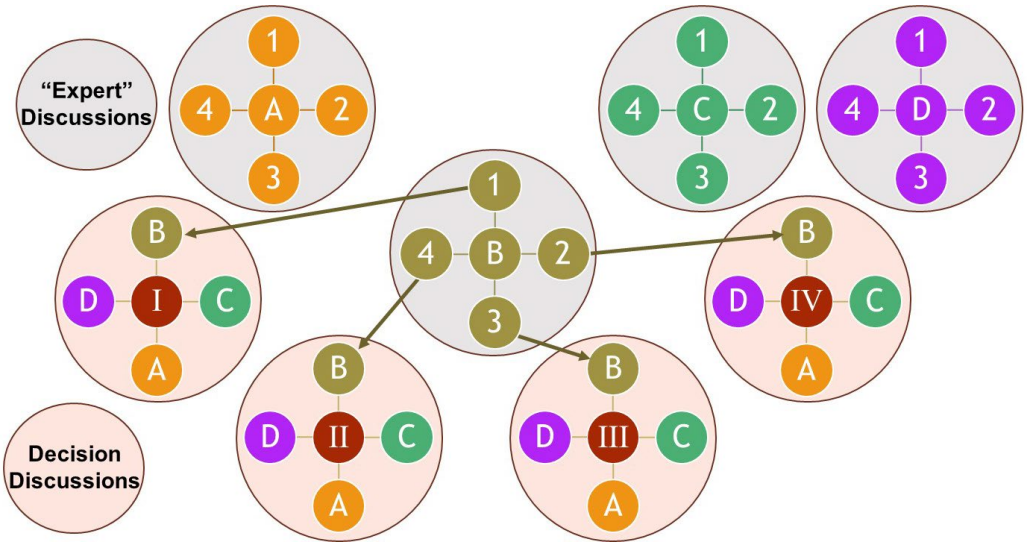


Figure 1: Diagram of jigsaw process with student breaking up into "expert group (gray circles) to discuss the pros and cons of the option followed by breaking into decision groups (light orange circles) with one "expert" from each topic in each group.

Seminar data collection

In order to get feedback from the seminar portion of the activities, during the question and answer portion of the seminar, a QR code was displayed on the screen from 2 to 15 min. that directed attendees to a three question survey administered via Qualtrics (Table 2). These questions were to get feedback on the value of the seminar in regards to the attendees' time and due to the low number of survey responses, were read and taken into consideration with no statistical analyses performed.

Table 2. Survey questions for seminar.

Question	*Question Type*
Was attending this seminar a good use of your time?	5 point Likert scale (Definitely, Sort of, Neutral, Not really, Not at all)
Why or why not?	Text entry
What is your major?	Text entry

Entrepreneurial Mindset data collection and analysis

In prior work by Li et al., a survey that measures the EM of engineering students was developed and 28 questions from the survey[6] were used for the pre- and post-measures during the spring term of 2024 (Table 3). The EM survey was optional, and students received a $10 Amazon gift card for completing it. Fourteen students responded to the pre-survey and 22 responded to the post-survey with 13 students responding to both. The students responded to the 28 questions using a Likert scale consisting of six responses (Strongly agree, Somewhat agree, Neither agree nor disagree, Somewhat disagree, and Strongly disagree) with the sixth response being "I do not understand". The surveys were covered by IRB Protocol 2024-1307.

Table 3. Survey questions for pre- and post-survey. All questions were answered on a 5 point Likert scale (Strongly agree, Somewhat agree, Neither agree or disagree, Somewhat disagree, or Strongly disagree) with an additional option of "I do not understand."

Item	*Please rate how much you agree or disagree with the following statements. If the statement is unclear to you, choose "I do not understand."*
1	I have a keen sense of curiosity
2*	When I see a complicated piece of machinery, I always like to find out how it works
3	I always actively seek as much information as I can in a new situation
4*	I consider myself to be a person who takes action when I'm curious about something
5*	I find myself being curious about a lot of things and people I encounter in life
6	I think business value creation is the company owner's concern
7*	I am able to define an engineering problem in terms of value creation
8	I am able to learn from failure
9	I believe the ability to cope with failure can be improved through training
10*	I am able to act effectively and creatively in difficult situations
11**	I am able to use the means at my disposal to handle situations effectively
12*	I have the ability to anticipate technical developments by interpreting surrounding societal trends
13*	I have the ability to anticipate technical developments by interpreting surrounding economic trends
14	I pay attention to the inefficiency in the market
15*	I actively think about how to correct inefficiencies
16**	Creative thinking skills can be acquired through training
17	I am able to apply systems thinking to solve complex problems
18**	I am able to tell if it is technically feasible to develop a new product or service
19	I am able to apply logical thinking to gathering and analyzing information
20	I am able to apply logical thinking to designing and solving problems
21**	I am confident in leading a team to work on a project
22	I am able to identify potential stakeholders for a new product or service
23	I am able to address stakeholder interests in a business plan
24	My career goal is to become an excellent engineer
25	My career goal is to become an engineer with an entrepreneurial mindset
26	I have had exposure to entrepreneurship during college
27	I have had exposure to entrepreneurship before entering college
28	There is/are entrepreneur(s) among my relatives

*denotes a positive change while **denotes a significant difference from pre- to post-survey

Responses to the two administrations of the survey were analyzed using inferential statistical tests and descriptive statistics. Both approaches to the analyses were conducted to answer the research question whether students expressed a change from pre- to post-surveys in their attitudes and beliefs about their EM in engineering fields. The five verbal responses of the Likert scale were transformed into numerical quantities such that Strongly agree = 5, Somewhat agree = 4, Neither agree or disagree = 3, Somewhat disagree = 2, and Strongly disagree = 1. Only 1% of the total responses were "I do not understand," and further analysis of them was not pursued. The responses from both the pre- and post-surveys were first analyzed for their reliability. Cronbach Alpha for the pre-survey was 0.89 and was 0.87 for the post-survey. Therefore, the items from the survey at both administrations showed high reliability. Because of the ordinal nature of the Likert data, the non-parametric related-samples Wilcoxon signed rank test was used to analyze differences between pre- and post-survey responses to each of the 28 items. This study was an initial investigation and therefore, a more liberal alpha level of 0.10 was used to make decisions about the rejection of the null hypothesis (i.e., no difference between pre- and post-survey responses). In addition, the small sample used in the Wilcoxon signed rank test (i.e., 13 students) called for a more liberal alpha level.

Results and discussion

Seminar series

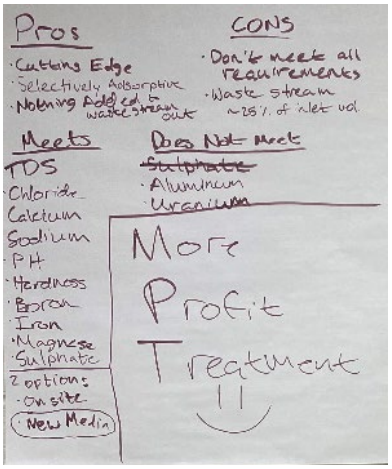
As previously described, each alumni gave a 40-50 min seminar on their career paths and how the 3 Cs impacted them throughout their journey. Main themes were that their curiosity was enhanced during their undergraduate engineering studies and that curiosity helps them often in their careers to find alternative options and to ask why things are happening. Connections help them trouble-shoot by being able to bring together different pieces of knowledge they have, but also to help find alternative careers through connections with people they have made. Creating value was at the core for all presenters as they need to bring value to the company or risk losing their job. Creating value took many forms from improving process efficiency to identifying new clients to developing new products. At the conclusion of the individual seminars, there was a question/answer period followed by a QR code being posted that linked to a survey that asked if the student felt that the seminar was a good use of their time and "why or why not?"

Of the four seminars, three of them had survey responses with 1, 2, and 10 responses for the software, consultant, and enzyme topic speakers, respectively. Unfortunately for the other speaker, the QR code was not left up long enough for students to respond; however, the following speaker left it up for over 10 min during the question/answer session and only received one response. When looking at the responses comprehensively, all of the students felt that the seminars were a good use of their time with 11 of the 12 students responding "Definitely" and one responding "Sort of." The reasons students felt the seminar was a good use of their time included that the speakers provided insights into future career paths and gave tips such as follow your intuition. The students saw the connection between undergraduate education and career paths as noted with comments such as "understanding…transition from university to career."

Jigsaw activities

The jigsaw activities took place immediately following the seminar in the junior-level unit operations course and are described in detail elsewhere.[20] Show in Figure 2 are examples from

both the “expert” (left) and decision (right) discussions of the wastewater jigsaw. The “expert” groups wrote down the pros and cons of their topic, which were posted for the room to see during the decision discussion time. It was observed that the students became more comfortable as the semester went on and that led to more robust decision discussions. One improvement that could be made was the order that the jigsaws were presented due to the complexity and open-endedness of some of them. Beginning with more closed-ended jigsaws would allow the students to become more familiar with the process. Then, as the semester progresses, the jigsaws progress to have more options for correct answers that lead to more discussion. This would allow students to be even more comfortable with their classmates in terms of discussion and with the jigsaw procedure.

a) 

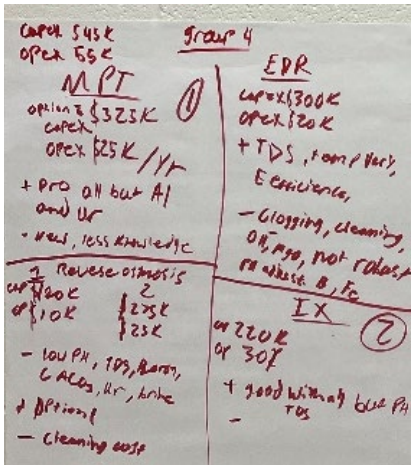
b) 

Figure 2: Examples of student work from jigsaw activities with a) an “expert” group page and b) a decision group page from the wastewater jigsaw.

Survey

The analysis of the descriptive statistics identified three themes in the data. First, 12 of the 28 items provided support for the assertion that positive change occurred from pre- to post-surveys (items 2, 4, 5, 7, 10, 11, 12, 13, 15, 16, 18, and 21; Table 3). These items showed that the percentage of students who responded with “Strongly agree” or “Somewhat agree” increased from pre-survey to post-survey, with increases ranging from 8 to 33 percentage points. Further support for positive change can be found in the ten items in which noticeable increases in the percentage of responses in the “Strongly agree” category occurred from pre- to post-surveys (items 2, 4, 5, 11, 16, 17, 18, 21, 22, and 23). Four of these changes were statistically significant (highlighted in Figure 3) and included:

- Item 11: “I am able to use the means at my disposal to handle situations effectively”
- Item 16: “Creative thinking skills can be acquired through training”
- Item 18: “I am able to tell if it is technically feasible to develop a new product or service”
- Item 21: “I am confident in leading a team to work on a project”

In previous research, Li et al. determined that items 11 and 18 loaded on the problem solving/logical thinking factor,[5, 6] item 16 on the ability to learn, and item 21 on team building.[5] However, as Zappe noted, the number of factors that emerged in the research suggests that the scale is not likely measuring one unidimensional construct[21] and constructs are extremely complex and are unlikely to be measured adequately within a short survey instrument.[22]

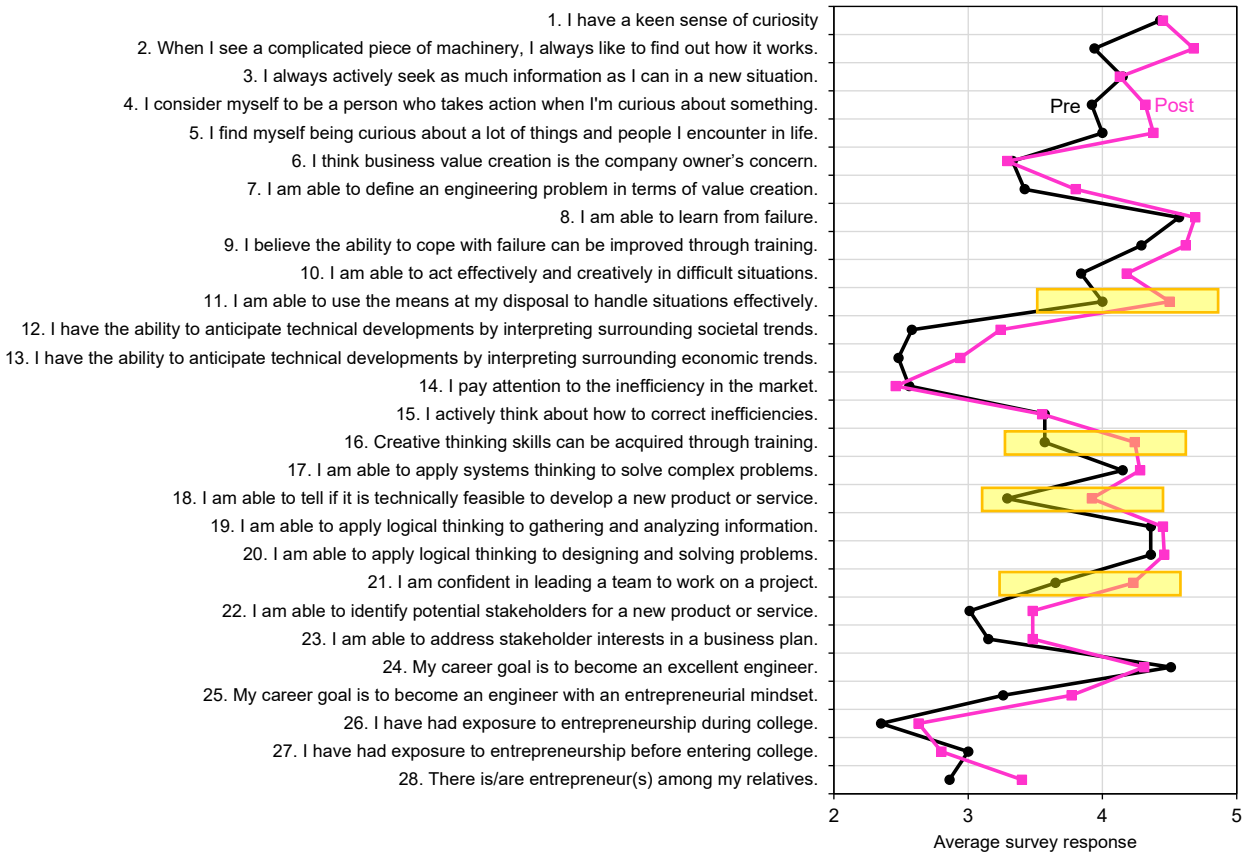


Figure 3. Pre (●) and post (■) survey data averages from the spring 2024 course where a response of "1" would be "Strongly disagree" and "5" is "Strongly agree." Significant differences in pre/post measures are highlighted in yellow.

Although it is not clear how item 18 would have been changed through the seminar or jigsaw activities other than hearing the stories of the seminar speakers, the other items may have been directly impacted by the interventions. In the case of item 16, the seminar series may have impacted the mindset of the students as several of the speakers discussed how they acquired the skill to learn as an undergraduate and with these skills, they were able to learn the skills they needed for their jobs. This was most evident in the presentation by an alum that started a career in the chemical sales industry but then pivoted to a career as a business analyst and project manager at a company that focuses on providing software solutions to clients. She emphasized that the ability to learn what she needed to was due to the skills she learned in the chemical engineering undergraduate curriculum. This was also mentioned by several of the other speakers. In the case of items 11 and 21, it is hypothesized that jigsaw activities may have contributed to the differences. For the jigsaw activity, the students were able to use the internet and ask questions of the speaker in order to acquire information for their assigned option. Being able to seek information out and apply it to the different situations given in the jigsaw may have built the students' confidence in handling situations effectively. For item 21, the expert and decision discussions were in groups, which may have helped students feel that they were confident in leading a team to work on a project.

Eight items showed little change in the overall responses to the pre- and post-surveys (items 1, 3, 8, 9, 17, 19, 20, and 24). However, the percentage of responses in the "Strongly agree" and "Somewhat agree" categories was already high in the pre-survey and remained high in the post-survey. Although not tested for ceiling effects, the high percentages in these two categories across administrations of the survey suggest that such an effect was certainly possible, making increases in these two categories difficult.

Of the items that specifically mentioned a form of "entrepreneurial" in the statement (items 25, 26, 27, and 28), the responses provided some support for the positive changes that occurred from pre- to post-survey. Responses in the "Strongly agree" and "Somewhat agree" ranged from 14-to-63 percentage points in the pre- and post-test surveys, and three of these four items showed increases from pre- to post-surveys. However, these strong percentages were offset by strong percentages in the two "disagree" categories ranging from 18-to-55 percentage points. Item 28 "There is/are entrepreneur(s) among my relatives" showed a slight decrease, which was surprising as Erdil and Harichandran reported, this would be unlikely to change between the beginning and the end of the semester.[23] Additionally, although not a theme, it is worth noting are the somewhat atypical responses to item 6 ("I think business value creation is the company owner's concern") and item 14 ("I pay attention to the inefficiency in the market"). There was little change from pre- to post-test surveys in the two "agree" categories as well as the "disagree" categories, with the percentages balanced among them. In sum, while students demonstrated some increase in agreement on certain survey items from before (pre-survey) to after (post-survey) the interventions, their overall attitudes and beliefs about the concept of the EM remained uncertain or mixed. There was some positive shift, but their views were not strongly conclusive or consistent.

Limitations

There are several limitations with the first being the small sample size, second, not repeating the intervention, and third, the results being self-reported. Additionally, comparison to previous literature was difficult given the changing variables across the research studies. A future study would be to complete the jigsaw activities without the participation of the alumni to see if the jigsaw activity alone would affect the EM of students as that is something faculty could incorporate without additional support.

Lessons learned

Although the feedback from students that attended the seminars was overwhelmingly positive, attendance was low with most of the students in attendance being from the class that the jigsaw activity was held in. Advertising the seminar included signage in the main engineering buildings, direct emails from faculty to students, and including the seminar dates in the weekly events email sent from the Dean's office to the engineering undergraduates. Both free food and a raffle that included items like Yeti brand mugs and MSU gear were used as incentives for attendance, but neither were sufficient to attract more attendees. It may be worth seeing if courses across the disciplines would offer extra credit for attending the seminar to improve crowd size. The 50 min total timeslot with approximately 15 min for questions and answers worked well and allowed for the majority of questions to be answered by the alumni. Additionally, the alumni being within

four years of graduating made them more relatable to the current students, which allowed for good discussion post-seminar.

In terms of the jigsaw activities, being open as to why the activities were taking place and the importance of developing skills that are not just technical in nature benefited the students. Only one student commented on the semester-end teaching evaluations that the jigsaw activities took away time from course topics; however, the same amount of material was covered as was in previous semesters due to exam reviews being moved outside of class time. It may be worth emphasizing this if done in the future as was mentioned in previous work,[24] or to adjust the jigsaw topics to be directly related to the coursework.

Conclusions

After receiving a KEEN Fellowship, an alumni seminar open to all students, along with jigsaw activities specifically designed for junior chemical engineering students, were held at MSU. A pre- and post-survey on EM was given to the students in the chemical engineering course that the jigsaw activity took place in, and it was found that there was a positive impact on several aspects of EM. The students reported a significant increase in the areas of problem solving, ability to learn, and team building. Students also mentioned the value of the student seminars and hearing the professional stories of recent alumni. Overall, implementing a seminar series and/or several jigsaw activities into a course that focus on the 3 Cs is a low-stakes way to expose students to EM. Additionally, future work could focus on performing the jigsaw activities without the alumni present or the seminar series to see if the change in EM is similar and a larger sample size of students would benefit the study.

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