Work in Progress: Do Growth Mindset Interventions Work? Observations from a Case Study in a Chemical Engineering Core Course

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Introduction

Designing and analyzing processes to manufacture products for the benefit of the society and the environment is the main role of a chemical engineer. When designs fail to meet the specified goal, it can be quite frustrating and demoralizing. Determining the underlying causes of the failure and engaging in an iterative process to better the design require continuous learning and improvement, which are the hallmarks of a growth mindset [1]. An engineer with a fixed mindset would consider oneself incompetent in the face of failure, ignore feedback for improvement, refrain from trying new things and exerting more effort, and ultimately fail to design an efficient process. As a growth mindset is crucial for successful process design, it is important to produce university graduates with this attribute. However, since a growth mindset cannot be developed in one day, it would be beneficial for undergraduate students in the chemical engineering program to get acquainted with the idea from the very beginning of their education. It could also help the students to navigate through the challenges of the program as chemical engineering has the reputation of being a hard major. We implemented growth mindset intervention strategies in the Mass and Energy Balances (MEB) course, which is offered twice in an academic year in the Chemical and Biomolecular Engineering department at Johns Hopkins University. The control group consisted of students from the Fall semester and the intervention group included students from the Spring semester. We previously reported our preliminary observations from the control group in Fall 2022 [2]. In this paper, we revisited the interventions and the study methods as well as focused on the comparison of the mindsets of the students from the control group (Fall 2022) and the intervention group (Spring 2023) at the end of the semester. As the results turned out to be quite interesting, we decided to continue this study with additional upgrades in our study.

Study information

Mindset interventions

We incorporated the mindset interventions in the MEB course in a way so that they were connected to the course contents and did not seem out of context. We kept the basic course structures similar during both Fall 2022 and Spring 2023 semesters. Both courses had the same grade distribution for class participation (5%), weekly group work or recitation session (5%), homework (20%), group project (15%), and the final exam (17.5%). The control group had 3 midterm exams, worth 37.5%. The intervention group had two midterm exams (worth 30%) and one group research presentation (7.5%). We included the research presentation for the purpose of the intervention. The mindset interventions [2] included the following tasks: (1) contemplating the idea of intelligence and the importance of having a growth mindset while studying chemical engineering after watching a talk [3] and a video [4] on growth mindset during the first week's group session, (2) having reflections on various attributes related to growth mindset (response to feedback, learning new things, response to making mistake or failure) through hypothetical scenarios incorporated into the homework problems, (3) practicing learning from mistakes by resubmitting midterm exams after correcting the errors, and (4) improving group research

presentation based on the feedback from the professor. We incorporated hypothetical scenarios in homework problems related to generation-consumption analysis, mass balance on a semi-batch process for antibiotic production, kinetics in a batch reactor, and liquid-liquid extraction [2]. After reflecting on the scenarios and watching a relevant video, TED talk, or reading an online article, the students wrote a response in their own words. For instance, for the antibiotic production problem, we included a hypothetical scenario at the end of the technical statement which directed the students to think about stoicism's approach to overcoming obstacles [5]. The hypothetical scenario is as follows:

"At the end of the workday, you realized that you failed to reach your target antibiotic production due to an issue with the oxygen supply in the fermentor. You would have to repeat the experiment tomorrow again. You feel demotivated and frustrated. Watch the following video on dealing with obstacles (the video link was provided to students [5]). How would you respond to your failed experiment? Write your response in your own words (maximum 150 words), based on the lessons from the video."

The group research presentation provided students the opportunity to not only learn about the applications of the course contents in advanced research areas but also receive the professor's feedback to improve the quality of their presentations before the final talks. The research topics were focused on drug delivery, plastic recycling, water purification, lithium-ion battery, artificial organ, polymer production, etc. The students prepared a short presentation on the assigned topics as part of a small group of 3-4 students. The presentation contained information about the background of the topic, the connection between the topic and the concepts learned in the course, limitations or challenges related to the topic, and future directions or alternative solutions. The students considered the global, economic, environmental, and social impacts related to the topics, which also fulfilled the ABET student outcomes.

Study participants and methods

A total of 35 undergraduate students, enrolled in the Mass and Energy Balances (MEB) course, were voluntary participants in this study, which was approved by the Institutional Review Board (IRB) of Johns Hopkins University. There were 18 students in the control group (Fall 2022) and 17 students in the intervention group (Spring 2023). Both groups completed the mindset survey during the last week of the semester. Considering there were 49 students enrolled during Fall 2022 and 40 students enrolled during Spring 2023, the survey participation was less than 45%. The students did not receive any form of incentive to complete the surveys, which we believed contributed to the overall lower participation. Our mindset survey contained 9 questions, focused on intelligence, response to feedback, learning new things, response to making mistake or failure, and the importance of smartness to survive in the chemical engineering major [2]. We collected the responses using a 6-point Likert scale. We assigned a mindset score between 1 and 2 to fixed mindset, a score between 2.1 and 4.9 to mixed mindset, and a score between 5 and 6 to growth mindset [2]. We calculated cumulative/single mindset scores (using all the survey questions) for three categories: gender, under-represented minority (URM) background, and first-generation background. We also calculated mindset scores for each survey question separately. To determine the internal reliability or consistency of our survey to assess mindset, we used Cronbach's α [2]. To investigate the correlation between the background of the students and their mindset for each question, we used χ^2 test of independence using α=0.05 [2]. We used the JMP software to perform all our statistical analyses for this study [2].

Results from the 2022-2023 academic year study

The Cronbach's α of 0.79 (control group) [2] and 0.76 (intervention group) supported the adequacy or internal reliability of the survey to measure mindset for both control and intervention groups. The cumulative/single mindset scores were mostly in the mixed mindset region (a score between 2.1 and 4.9) for all the categories for both groups. The data were inadequate to reach strong conclusions about the impact of the URM background as well as the first-generation background. However, we noticed an effect of gender on the mindset scores. The female students displayed a lower single mindset score (3.95 ± 0.68) compared to the male students (4.67 ± 0.56) in the control group [2]. Interestingly, the scores for male (4.57 ± 0.63) and female (4.37 ± 0.64) students were closer in the intervention group (Figure 1).

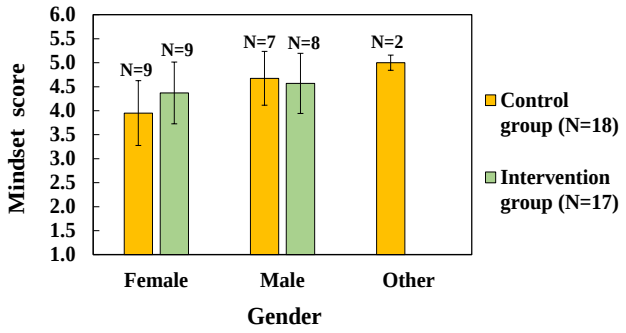

Figure 1: Mindset scores (cumulative/single), represented as average ± standard deviation, for the control group (N=18) and the intervention group (N=17). The data for the control group were reported in our previous study [2].

To investigate the reason behind the mindset score difference between male and female students in the control group, we used χ^2 test of independence on each question, focused on intelligence, response to feedback, learning new things, response to making mistake or failure, and the importance of smartness to survive in the chemical engineering major [2]. We observed a correlation (χ^2 =11.27, p=0.02) between gender and mindset for the question related to the major [2]. For the control group, the female students displayed a lower mindset score compared to the male students and those who did not identify as either male or female for this question [2]. However, for the intervention group, we did not observe any significant correlation (χ^2 =3.24, p=0.20) between gender and mindset related to the major as p-value was greater than 0.05. The female students in the intervention group (3.56 ± 1.88) scored higher than the male students (3.25 ± 1.28) for this question, although with a higher variability. The score for the female students in the intervention group (3.56 ± 1.88) was also higher compared to those in the control group (3.22 ± 1.30). However, the male students in the intervention group (3.25 ± 1.28) had a much lower score than those in the control group (5.00 ± 0.58), displaying a 35% drop.

The higher mindset score of the male students in the control group for the question related to the major could be attributed to their higher confidence to succeed and take on an engineering identity earlier than their female counterparts [6]. The environment they experience in the major could contribute to their level of confidence. Also, since the majority of the male students in the control groups were sophomores (5 out of 7), they could have a stronger engineering identity than the male students in the intervention group, all of whom were freshmen [6]. The trend was the opposite for the female students for the question related to the major. The majority of the female students in the control group were sophomores (8 out of 9) and scored lower than the female students in the intervention group, all of whom were freshmen. If female students tend to develop a more fixed mindset as they progress through the major, then mindset interventions might have a more beneficial effect on female students compared to male students. However, considering the

size of the studied population was small, our observations might not be significant in a larger population.

In addition to quantitative data, we also collected qualitative data for the intervention group at the end of the semester. We asked the students if the course had any impact on their previous beliefs about intelligence, receiving feedback, new learning, mistake or failure as well as the chemical engineering major. Out of the 17 students in the intervention group, 15 students responded to this question. While 9 of the participants mentioned moderate to significant impacts, 6 of the students reported no beneficial effects. Out of these 9 students, 5 were female students. These 9 students reported developing more positivity towards receiving feedback or criticism, learning new things, handling difficulty or failure as well as the major. Additionally, these students mentioned improved problem-solving skill, better studying habit, and liking the course and the professor, which were supplemental benefits of growth mindset intervention. We included four of the positive responses from the students below:

"Yes, I feel more capable at learning new and difficult things and I also feel more positive about failures and receiving feedback. I am excited to continue the ChemBE major and practice my skills for the next four years, having chosen it as my primary major."

"Yes, I think it helped me learn how to respond to failure and think through problems analytically and logically."

"Yes, it has helped me learn how to more gracefully accept criticism and reminded me that I have control over whether or not I want to implement the criticism."

"Yes, it helped me approach problems different ways proactively."

Conclusions and study upgrades

We reported results from a case study, conducted during the 2022-2023 academic year, where we analyzed the impact of growth mindset interventions incorporated in the Mass and Energy Balances (MEB) course. The most notable observation was the reduced gender gap regarding the mindset about the chemical engineering major in the intervention group (N=17) compared to the control group (N=18). However, we were cautious about generalizing this trend due to our small sample sizes in both study groups. The qualitative responses supported the benefits of mindset interventions, which was encouraging. We are continuing this study by making some new updates to the mindset interventions.

As mentioned earlier, the Spring 2023 intervention group watched a talk and a video on growth mindset during the first week's group session. However, since the task was optional, some students chose not to participate in this activity. For the Spring 2024 intervention group, we encouraged the students to watch the same talk [3] but replaced the video with a research paper [7], which examined the relation between growth mindset and brain signaling associated with error processing. Our purpose was to increase the credibility of our intervention by providing scientific evidence for growth mindset. We then asked the students to contemplate the usefulness of having a growth mindset for performing well in chemical engineering courses and share their thoughts with their peers or have a self-reflection. If the students thought having only a growth mindset is not sufficient for good learning and performance, they could share their own inputs. We made the

task mandatory, and the students were required to submit a short response after this activity, which was ungraded. The intervention group during Spring 2023 had two midterm exams, where all students were encouraged to work on their mistakes and resubmit the corrected problems to earn about 10% points back. However, student participation was low and those who performed poorly in the exams did not take the opportunity to improve. For the Spring 2024 intervention group, we replaced the midterm exams with 4 shorter quizzes (each worth 7.5%) as shorter, frequent, and lower-stakes tests aid in enhancing student performance [8]. In addition to the resubmission of the quizzes, we also allowed resubmission of the homework. We encouraged the students to resubmit their homework and quizzes if they had received a score below 90%. If the students were able to correct all their mistakes, then they received a 90% score for each resubmission. We did not award a 100% score for the resubmission to be cautious about grade inflation. Throughout the semester, the professor emphasized that continued practice and effort and learning from mistakes are essential for improving conceptual understanding, which was an additional upgrade to the interventions. When the professors display a growth mindset, it can facilitate positive psychological and learning outcomes for students [9].

For our surveys, we changed the "male" and "female" terms to "man" and "woman" respectively as they are more appropriate options for the gender choice.

References

[1] C.S. Dweck, *Mindset: The New Psychology Of Success*. Penguin Random House, 2006.

[2] N. Zerin, S. Ratanalert, " Work in Progress: Promotion of Growth Mindset in Introductory Mass and Energy Balance Course in Chemical Engineering," *ASEE Conferences*, 2023.

[3] "Developing a Growth Mindset with Carol Dweck," *Stanford Alumni*, October 2014. Available: https://www.youtube.com/watch?v=hiiEeMN7vbQ. [Accessed March 06, 2024].

[4] "Growing your mind," *Khan Academy*, August 2014. Available: https://www.youtube.com/watch?v=WtKJrB5rOKs. [Accessed March 06, 2024].

[5] "The obstacle is the way by Ryan Holiday," *FightMediocrity*, October 2015. Available: https://www.youtube.com/watch?v=2rQfr7XAQi0. [Accessed March 06, 2024].

[6] K.L. Meyers, M.W. Ohland, A.L. Pawley, S.E. Silliman, and K.A. Smith, "Factors relating to engineering identity," *Global Journal of Engineering Education*, vol 14, no. 1, pp. 119-131, 2012.

[7] J.S. Moser, H.S. Schroder, C. Heeter, T.P. Moran, and Y.H. Lee, "Mind your errors: Evidence for a neural mechanism linking growth mind-set to adaptive posterror adjustments," *Psychological science*, vol 22, no. 12, pp. 1484-1489, 2011.

[8] O.E. Fernandez, "Second chance grading: An equitable, meaningful, and easy-to-implement grading system that synergizes the research on testing for learning, mastery grading, and growth mindsets," *Primus*, vol 31, no. 8, pp. 855-868, 2021.

[9] K. Muenks, E.A. Canning, J. LaCosse, D.J. Green, S. Zirkel, J.A. Garcia, and M.C. Murphy, "Does my professor think my ability can change? Students' perceptions of their STEM professors' mindset beliefs predict their psychological vulnerability, engagement, and performance in class," *Journal of Experimental Psychology: General*, vol 149, no 11, pp. 2119-2144, 2020.