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The Influence of Both a Basic and an In-Depth Introduction of Growth Mindset on First-Year Engineering Students' Intelligence Beliefs*

EMILY DRINGENBERG and AMY KRAMER
Department of Engineering Education, The Ohio State University, 2070 Neil Ave, Columbus, OH 43210, USA.
E-mail: dringenberg.1@osu.edu, kramer.659@osu.edu

Growth mindset is a popular educational theory with empirical ties to motivation and persistence. Despite its popularity, the implementation of the theory in practice risks being over-simplified in the ways it is introduced to students and measured with established survey items. This oversimplification provides a limited research-based understanding of the complex ways in which students react to the theory or the influence that learning about the theory has on their personal beliefs. To expand prior work in this area, we conducted the current study by collecting both quantitative (survey) and qualitative (written reflections) data from first-year engineering students about their intelligence beliefs for (1) a sample of students who received a brief, in-class introduction to the theory (n = 66), and (2) a sub-sample of students who engaged in a more in-depth intervention (n = 6). Our findings show that neither the in-class introduction nor the more in-depth intervention had a statistically significant influence on students' intelligence beliefs, but the in-depth intervention did provide students with a more nuanced understanding of growth mindset theory. Many participants linked growth mindset exclusively to valuing effort. Implications of this study for engineering educators include that given the complexity of growth mindset, a brief introduction into mindset theory is not adequate for significant change in beliefs. Implications also include that survey items alone may not be indicative of growth mindset and qualitative approaches may be necessary for researchers to gain a more holistic understanding of students' intelligence beliefs.

Keywords: growth mindset; engineering; first-year

1. Introduction & Background

Carol Dweck developed a theory, popularly referred to as "mindset," to synthesize her 30-plus-year career of looking at differences in student motivation. This theory can be briefly summarized as follows: individuals hold implicit theories about intelligence—a person with a fixed mindset believes that intelligence is static and unchanging, while a person with a growth mindset believes intelligence can be developed with effort [1, 2]. Due to its roots in educational psychology, research in this area commonly accesses the construct of an individual's intelligence beliefs through Likert-style survey items, where participants rate their level of agreement with statements such as, "You have a certain amount of intelligence and you really can't do much to change it" [1]. Importantly, these items have been shown to measure a distinct construct—beliefs about the nature of intelligence—and to not be correlated with other scales such as self-esteem, optimism, cognitive or motivational styles [3, 4].

Mindset is a popular and powerful lens for both educational research and practice; extant work has demonstrated the empirical link between intelligence beliefs (growth or fixed), as measured by survey items, and important academic behaviors. In short, the beliefs that a person holds about intelligence are correlated with the types of learning goals that they are motivated to pursue, their views on effort, and the ways in which they react to challenges. To start, significant research has shown that an individual's mindset is correlated with the types of learning goals they prefer or are motivated to engage in. Individuals with a fixed mindset are more likely to choose performance goals where they can show that they are smart while individuals with a growth mindset are more likely to choose learning goals where they can improve their knowledge or skills [1, 5–11]. Second, researchers have demonstrated that individuals with a fixed mindset are more likely to believe that effort is a sign of low ability and that continued effort is futile while individuals with a growth mindset are more likely to view effort as a meaningful path towards mastery [5, 9, 12, 13]. Finally, an empirical link has also been found between an individual's mindset and the way in which they respond to challenges. Those with a fixed mindset are more likely to demonstrate helplessness and give up while those with a growth mindset are more oriented to view the challenge as an opportunity for learning and therefore persist [3, 6, 9, 11, 14, 15]. Researchers have also identified relationships between mindset and sense of belonging [16, 17], resiliency [18], help seeking behaviors [19], grades [19, 20] and active learning strategies, self-efficacy, use of collaboration and knowledge building beha-

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viors [20]. The abundance of evidence linking intelligence beliefs to other beliefs or characteristics needed for persistence and life-long learning set the stage for fostering a growth mindset in students to be a popular and desirable goal for education. As a result, promoting a growth mindset has gained significant popularity in the field of education.

It is not uncommon to hear educators talk about how they begin their course or school year by introducing students to a growth mindset, and the first author of this paper has done so herself. In engineering, which is commonly viewed as a rigorous and exclusive undergraduate experience [21, 22], the ability to foster resilience in students is especially desirable. Some research has reported very promising findings for being able to use an intervention to promote intelligence beliefs. For example, Blackwell and colleagues [9] found that students who initially demonstrated a fixed mindset but were taught growth mindset before their transition into middle school had positive changes in motivation and demonstrated an upward trend in their math achievement while those in the control group demonstrated a downward trend. Teaching growth mindset at the post-secondary level has been shown to mitigate stereotype threat for African American college students resulting in greater academic enjoyment, engagement, and achievement [23]. Furthermore, college students who were given a growth mindset intervention showed greater persistence in the face of failure [14]. A review of this area of research can easily leave a scholar feeling like growth mindset is the answer to all our problems! Despite the promise and appeal of such findings, other research has found short term shifts towards growth mindset based on interventions, but concluded that these changes were not sustained long term in participants [18].

Growth mindset has particular promise in engineering education, where it is commonplace to assume that students who persist will do so despite the perceived difficulty and misery of the undergraduate academic experience [21]. Relatedly, engineering education culture is one of superiority—engineering students view themselves as better than other students at the university because they believe the content of their coursework is inherently more difficult [21, 22]. This pervasive culture can be directly at odds with optimal functioning for engineering students [24]. In addition, many engineering students have a track record of high academic achievement coming into college, and the first-year can be a shock for students who have always done well with minimal effort [25]. With a culture of undergraduate engineering education being challenging, promoting growth mindset seems especially salient. However, the theory is significantly less popular in higher education, let alone in engineering. From a research perspective, several studies have utilized mindset theory in engineering education research tangentially [26–28], but only a few studies have specifically explored this theory in the context of engineering education research [20, 29].

While research utilizing Dweck's mindset theory as a theoretical framework has provided a strong foundation for the application of growth mindset in educational settings, we should be weary of the limitations of this theory as an easy "fix" for students who may struggle or appear to lack motivation. For example, one unintended consequence of mindset as such a popular educational theory is that a brief introduction of the theory to students risks being over simplified and inadequate for the intention of changing what are, in reality, implicit, deeply held, and contextual beliefs. To acknowledge this perversion of her work, Carol Dweck has published several statements warning against the oversimplification of growth mindset as all or nothing, simply about rewarding effort, or something that will just happen once it is espoused [30, 31]. In addition, just telling students about a growth mindset (or that they should have one) does not account for the cultural norms or institutional systems that are in place and work to perpetuate a fixed mindset. In alignment with the assumptions of educational psychology as a field, growth mindset is also limited in that it places the onus of responsibility (to have a growth mindset) on students. Researchers have recently called out the limitations of framing "ability" as limited to something inherent to an individual or as a function of socialization, without attention to the role of cultural construction [32]. This has been the case in previous engineering education research utilizing mindset theory. Reid & Ferguson [29] measured students' mindsets through survey items (passively) in order to arrive at their finding that engineering students who were given an opportunity for open-ended problem solving in their first year program showed less of a shift towards fixed mindset compared to peers without such an opportunity. Evidence that engineering students' intelligence beliefs were predictive of their knowledge-building was also based on quantitative data collected from students through surveys [20].

Because of the potential power of mindset as a lens for designing educational experiences that are inclusive and promote resilience in the face of challenges, it is important to expand our understanding of students' beliefs about intelligence. The current work aims to address the limitations of existing work by (1) investigating how both a brief and a more in-depth introduction to mindset influence the intelligence beliefs of first-year engineering students, and (2) using both quantitative and qualitative data to provide richer context for the traditional measure of intelligence beliefs through survey items. This contribution is a meaningful step towards a more holistic understanding of the effort to promote growth mindset in first-year engineering.

2. Research questions

In order to achieve our goal to better understand the influence of an introduction of growth mindset on first-year engineering students' intelligence beliefs, this project specifically answers the following research questions:

1. What do first-year engineering students believe about the nature of intelligence?
2. How does the introduction of growth mindset change first-year engineering students' beliefs about the nature of intelligence:
   (a) given a brief introduction in class for the general population of students?
   (b) given an in-depth intervention for a subpopulation of students participating in a reading group?

3. Method

In order to answer our research questions, we utilized a triangulation mixed-method design [33]. More specifically, we collected both quantitative and qualitative data simultaneously, analyzed these data separately, and then interpreted the results to understand whether they support or contradict one another. This approach is appropriate because while the majority of educational studies that look at educational beliefs collect and analyze quantitative data as a measure of students' beliefs, this data has no explanatory value. We are able to report on the statistical findings of the quantitative data for some level of generalizability to first-year engineering students more broadly, while also providing some more nuanced insights about the context from our qualitative data [33]. While the extant work related to growth mindset mostly prioritizes quantitative data to understand intelligence beliefs, in this study we prioritize our qualitative data in order to understand more of the nuance around the intelligence beliefs that first-year engineering students hold. We believe this is necessary because human beliefs are contextual, contradictory, and often implicit. Our use of a mixed method approach is a contribution to the mindset literature because it allows us to assess the influence of the interventions through quantitative approaches while also providing some explanatory power through the written reflection data.

3.1 Participants and context

The participants in this study were first-year engineering students at a large, Midwestern University. Specifically, the participants were all situated within a College of Engineering and were undeclared for their disciplinary major and therefore participating in a general engineering introductory course. This course was created and implemented by the first author and served as an introduction to engineering including both well- and ill-structured problem solving (e.g., design). The course exposed students to the different engineering disciplines available for study at the institution to aid in their selection of an academic major within the college. General topics such as teamwork, time management, study strategies, and technical communication were also introduced. Additionally, the instructor used class time (around 30 minutes during the second class of the semester) to introduce students to the growth mindset theory, which is the construct of interest for this study. During this in-class introduction, students were asked to self-quiz using established mindset items, and then the instructor had them translate their responses to a mindset 'score,' which indicated whether they tended towards a growth or fixed belief about the nature of intelligence. Next, the instructor provided an overview of the characteristics of both a growth and fixed mindset and assured students that they can 'choose' a particular mindset. She then briefly presented research findings that support the efficacy of growth mindset beliefs, showed them a brief video of Angela Lee Duckworth discussing her research on grit, and facilitated a think-pair-share discussion about whether students gravitate towards a fixed or growth mindset. She encouraged them to promote a growth mindset in their individual work and in their design teams. At the conclusion of this brief introduction to mindset, the instructor invited any students who were interested to join a mindset reading group. While all participants received a basic, in-class introduction to growth mindset theory, six of those students ended up participating in the more in-depth intervention by joining the reading group, in which they all read the popular text, Mindset [2] and met outside of class for five, hour-long sessions to discuss their reactions to the theory with the instructor and an additional engineering faculty from the college. For details of this reading group intervention and more elaboration on the qualitative research to understand those students' reactions to the in-depth intervention, please see [34].

3.2 Data collection

For the purpose of this study, both quantitative and qualitative data were collected from participants at both the start and end of the Fall 2016 semester. This data serves as pre- and post- data over the participants' first semester in the College of Engineering. Data was collected from all students enrolled in the general engineering introductory course as classroom assignments with completion grades. Of course, not all students completed each of the four data collection assignments (pre-survey, post-survey, pre-reflection, post-reflection). To maintain the same population of students for the quantitative analysis for the general population and the sub-population in the reading group, we only include data here for participants who completed both the pre-survey and post-survey, for a total of 72 participants. Of these 72 participants, six of them also participated in the reading group as displayed in Table 1. To maintain the richness of the qualitative data and since the qualitative analysis was more open-ended, all pre- and post-reflection responses were included. The sample sizes for the qualitative data collection is displayed in Table 2.

Table 1. Sample size for quantitative data collection

Sample Description	Sample Size
Number of students in Mindset introduction population who completed all pre-survey and post-survey data collection assignments.	66
Number of students in Mindset reading group population who completed all pre-survey and post-survey data collection assignments.	6
Total number of students who completed all pre-survey and post-survey data collection assignments.	72

Table 2. Sample size for qualitative data collection

Sample Description	Sample Size
Number of students in Mindset introduction population who completed data collection assignments.	85 (pre) 86 (post)
Number of students in Mindset reading group population who completed data collection assignments.	6 (pre) 5 (post)
Total number of students who completed data collection assignments.	91 (pre) 91 (post)

The quantitative data collected included the following demographic information to serve as independent variables: section, sex, ethnicity, race, prior experience with engineering, first-generation status and engineer parent/guardian. In addition, four items solicited Likert scale responses ranging from 1 (strongly disagree) to 7 (strongly agree) to the following four prompts, which have previously been established as valid and reliable [1]:

1. *Your intelligence is something very basic about you that you can't change very much.*
2. *You can learn new things, but you can't really change how intelligent you are.*
3. *No matter how much intelligence you have, you can always change it quite a bit.*
4. *You can always substantially change how intelligent you are.*

These same four items were asked in both the pre- and post- surveys to allow for comparison. Additional items such as engineering design self-efficacy and orientation to the field of engineering were also collected and used to inform classroom activities. Finally, the closed-ended portion of the data collection included an opportunity for students to provide consent (or not) to allow their responses to be used for research purposes.

Qualitative data was collected from participants concurrently. As a part of the course, students submitted reflections about their motivations to study engineering as well as their experiences with engineering problem solving. The data that was analyzed for this study included the students' submissions of written reflections to the following two reflection prompts:

Pre: What is your perspective of your own intelligence—do you tend towards a fixed or growth mindset? How do you think this will impact your pursuit of an engineering degree?

Post: What is your perspective of your own intelligence—do you tend towards a fixed or growth mindset? Has your mindset changed during this semester at all? If so, how? How do you think this will impact your pursuit of an engineering degree?

3.3 Data analysis

The pre- and post-survey quantitative data was analyzed. First, the survey data provided by any student who did not consent to their responses being used for research purposes was removed. Participants who did not complete both of the pre-survey and post-survey were also eliminated. This included students who dropped the class or did not submit either assignment. Also, any participant who did not correctly answer the survey item "If you are really reading these prompts, select 'Agree' on this one." correctly was removed on the assumption that their data would not be useful. After cleaning the data, the first two mindset items were reverse coded so that high values on the Likert scale indicate growth mindset beliefs and low values indicate fixed mindset beliefs. Next, all four items were averaged in order to generate a single, continuous dependent variable for growth mindset for each participant. This variable is referred to as MINDSET and serves as the dependent variable for analysis. Descriptive statistics of the data collected were generated and the data was tested for normality. A paired t-test and Wilcoxon sign rank test were utilized to determine statistical significance.

The de-identified pre-and post-reflection qualitative data were also analyzed. Both authors with the help of an undergraduate student iteratively developed a code book. The researchers worked separately conducting a line by line analysis of the written reflections. Values coding (Attitudes, Values and Beliefs) [35] was first used to develop codes for emergent themes. Due to the specificity of values coding, open coding was then utilized to broaden the scope of the codes and themes. After each researcher completed their line by line analysis of the first 25 pre-responses and 15 post- responses, the researchers compared their codes. This process was iterated several times until the researchers agreed on a single code book that captured the emergent themes. The researchers then utilized the analysis software, Dedoose, to code all the responses based on the developed code book. Again, the researchers coded the responses independently and then compared their codes and iterated this process until consensus.

4. Results

4.1 Research question 1: What do first-year engineering students believe about the nature of intelligence?

4.1.1 Quantitative

The frequency distribution of the four mindset survey items for the general population and the sub-population in the reading group are displayed in Table 3 and Table 4, respectively. For both frequency distribution tables, the first two mindset items were reverse coded so that "strongly agree" always indicates growth mindset and "strongly disagree" always indicates fixed mindset. For both student populations, more than two-thirds of students reported growth mindset beliefs as indicated by the distribution of the "strongly agree," "agree," and "mostly agree" responses on all four items of both the pre- and post-survey. With the exception of question four of the reading group pre-survey, 21% or less of students reported fixed mindset beliefs as indicated by the distribution of the "strongly disagree," "disagree," and "mostly disagree" responses on all other survey items.

The descriptive statistics for the average mindset of each participant was also generated. The continuous dependent variable, MINDSET, was created by averaging the responses of the four items for each participant. Displayed in Table 5 is the sample mean, standard deviation, minimum and maximum MINDSET for both student populations. Generally, the first-year engineering students for both populations tended towards a growth mindset.

4.1.2 Qualitative

Several themes emerged from the qualitative analysis of the student reflections. The themes presented in the following section are grouped by the students' self-identified mindset. A summary of the emergent themes of student beliefs about the nature of intelligence is displayed in Table 6.

Similar to the quantitative survey results, most students self-identified as having or tending towards a growth mindset in the reflection responses when

Table 3. Frequency distribution for introduction population (n = 66)

		Q1		Q2		Q3		Q4	
		Pre-Survey	Post-Survey	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey
Growth	Strongly Agree	12 18%	13 20%	8 12%	12 18%	8 12%	9 14%	10 15%	10 15%
↓	Agree	26 39%	32 48%	27 41%	26 39%	29 44%	32 48%	23 35%	28 42%
	Mostly Agree	11 17%	9 14%	15 23%	13 20%	15 23%	11 17%	21 32%	14 21%
	Neither Agree nor Disagree	3 5%	4 6%	3 5%	6 9%	9 14%	7 11%	5 8%	8 12%
	Mostly Disagree	8 12%	5 8%	4 6%	5 8%	2 3%	4 6%	2 3%	4 6%
	Disagree	5 8%	3 5%	8 12%	3 5%	3 5%	2 3%	4 6%	1 2%
Fixed	Strongly Disagree	1 2%	0 0%	1 2%	1 2%	0 0%	1 2%	1 2%	1 2%

Table 4. Frequency distribution for reading group population (n = 6)

		Q1		Q2		Q3		Q4	
		Pre-Survey	Post-Survey	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey
Growth	Strongly Agree	1 17%	1 17%	1 17%	0 0%	1 17%	0 0%	1 17%	0 0%
	Agree	2 33%	3 50%	2 33%	3 50%	2 33%	5 83%	2 33%	3 50%
	Mostly Agree	2 33%	2 33%	2 33%	2 33%	1 17%	1 17%	1 17%	2 33%
	Neither Agree nor Disagree	1 17%	0 0%	1 17%	0 0%	1 17%	0 0%	0 0%	0 0%
	Mostly Disagree	0 0%	0 0%	0 0%	1 17%	0 0%	0 0%	1 17%	1 17%
	Disagree	0 0%	0 0%	0 0%	0 0%	1 17%	0 0%	0 0%	0 0%
Fixed	Strongly Disagree	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	1 17%	0 0%

Table 5. Descriptive statistics of MINDSET

	MINDSET Introduction Population (n = 66)		MINDSET Reading Group Population (n = 6)	
	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey
Mean	5.22	5.40	5.17	5.50
Std. Deviation	1.25	1.14	1.45	0.79
Variance	1.56	1.31	2.09	0.63
Minimum	2.00	2.50	3.00	4.00
Maximum	7.00	7.00	7.00	6.00

NOTE: Mindset range from 1 to 7 based on Likert Scale. Responses to Question 1 and 2 were reverse coded so that high values indicate growth mindset and low values indicate a fixed mindset.

Table 6. Emergent themes of student beliefs about the nature of intelligence

Students self-identify as:	Themes
Growth Mindset (majority of students)	Misconceptions about growth mindset (i.e. growth mindset equals exclusively valuing effort). Effort and intelligence are separate (i.e. I need to work hard because I'm not as "smart" as others). Reflections on how students developed a growth mindset through interaction with teachers, coaches or parents instilling in them the value of hard work.
Fixed Mindset (fewer students)	Students don't like asking for help, fear appearing stupid, or get frustrated when they don't get a concept right away. Although students "admit" to having a fixed mindset, students perceived a growth mindset to be beneficial. Recognized societal pressures, the demands of schools, and the desire to get good grades as fostering a fixed mindset.
Mixed Mindset (fewer students)	Having a mixed mindset is helpful because developing a deep understanding of the subject material is important, but so is focusing on achieving good grades.

explicitly asked about their mindset. However, while explaining why they believe they have a growth mindset, the qualitative analysis revealed that the students have many common misconceptions about growth mindset. An emergent theme from the data is that students often equate growth mindset with other desirable attributes such as positivity, grit, optimism, and open mindedness.

For example, one student made the following statement equating looking on the "bright side" with having a growth mindset, yet made no mention in their response as to their actual beliefs about the nature of intelligence.

> "I still think that I have a growth mindset since. . .I look at the bright side of things and try to find the bright side instead of just quitting."

However, the most pervasive misconception about growth mindset is simply that growth mindset equals valuing effort. The idea that sheer effort alone leads to academic success was one of the most pervasive themes throughout the reflection responses. Although a willingness to put in effort is certainly a component of growth mindset, it alone does not make up growth mindset as many participants seemed to believe.

> "With my growth mindset, I know that although there are many things to engineering that I have yet to learn, I can learn it all if I put in the effort."

> "If you work hard enough and have enough grit and a little bit of a fire in your heart, then you will be just fine."

> "I believe that I can learn anything I want to, given that I am willing to put in the time and effort required to do so."

Another growth mindset misconception regarding effort revolved around the idea that effort and intelligence are separate. This dichotomy was articulated by several students. In the quotes below, the students self-identified as having a growth mindset, yet they also implied that effort and intelligence are separate and that some people are inherently "smarter" than others.

> "I came into college thinking this semester was going to be easy but I was definitely slapped in the face when I got back the first round of tests. I felt like I did the best thing though and accepted I was not as smart as I thought I was and that I'm going to have to put in work if I'm gonna want to do well in school."

> "If somebody really wants to be successful, they can if they put in the effort needed. Granted, some people might be inherently smarter and have better brains, but I don't think that should be used as an excuse to not try."

> "In high school I was told I was smart and passed all my classes with As and one B, but I don't consider myself smart now that I am in college. Seeing everyone around me in class understanding the concepts and stuff and I'm there like yeah, okay, I'll keep trying to figure it out. I would say I tend to lean towards more of a growth mindset."

Finally, students who self-identified as having a growth mindset tended to reflect on how they came to this mindset. This typically involved a story regarding a teacher, coach, or parent who instilled in them the importance of hard work. This messaging of hard work could be partly responsible for the pervasiveness of linking growth mindset exclusively to effort.

In the reflection responses, various students also did explicitly self-identify as having or tending towards a fixed mindset. However, this was less common. Students who identified as having a fixed mindset often said things such as, they don't like asking for help, they fear appearing stupid, or they get frustrated when they don't get a concept right away.

> "I still find myself acting in fixed mindset ways, like . . . being too shy to reach out to [college tutoring center] or the writing center because I have some lingering irrational fear of getting help."

> "During high school, I was very fixed mindset, always worrying about failure and appearing stupid in front of my peers."

Several students often phrased their self-identification as if they were "admitting" to having a fixed mindset. One student even stated that he knew having a fixed mindset was "not what you would like to hear." Ultimately, the students perceived a growth mindset to be beneficial. These self-identified fixed mindset students often stated that having a growth mindset is desirable but also recognized the difficulty in changing their mindset. These students also recognized the societal pressures, the demands of schools, and the desire to get good grades in fostering their fixed mindset.

> "My fixed mindset will make everything in this coursework harder as I will not seek out as much help and I will probably give up sooner. Due to that I would like to change my mindset to a more growth focused one. However, that is easier said than done as our society ingrains that mindset into us from the beginning."

> "I'm more of a fixed mindset. I do things thinking of the grade and GPA benefits instead of actually wanting to learn them. I am afraid to fail in classes."

> "My own intelligence is more fixed right now due to the fact in school grades is all anyone cares about, but I hope to become growth mindset in the future . . . I do not think my whole mindset on how one grows will change in one semester, it will [be] gradual and will come after I learn to mature as I grow older."

Similar to students who self-identified as having a fixed mindset, there were also students who self-identified as having a mixed mindset. One major theme that emerged from the self-identified mixed mindset students was that a mixed mindset is helpful because these participants believed that it's important to develop a deep understanding of the subject material but also to focus on achieving good grades.

> "I think my mindset runs both fixed and growth. I know I can do better and grow my knowledge through my education. On the other hand, I still believe that if I don't get great grades that I'm not going to do good in life."

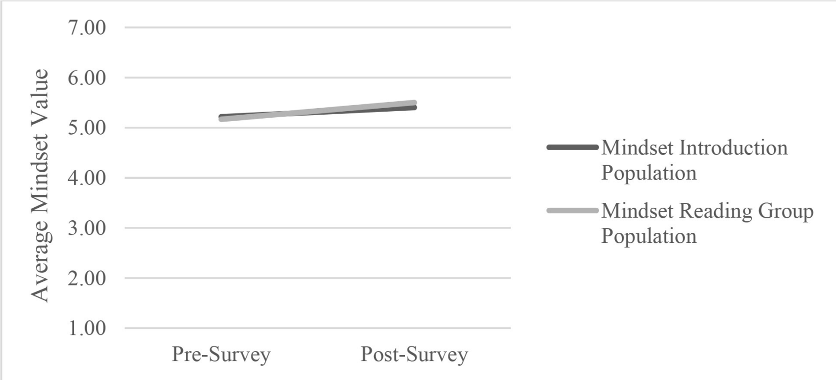

Fig. 1. Means of MINDSET.

> "I think my combination of fixed and growth mindset will help me in my journey to become an engineer. For me, the fixed part of my brain will give me the motivation to do good on all my work and stay on top of my busy college schedule. On the other hand, my growth mindset will teach me lessons of perseverance and determination to continue with this degree even when things get tough and I want to give up . . . I think most would say it would be ideal to have a perfect growth mindset to succeed in engineering but to me I think a balance between the two will help me grow and succeed without being on the extreme."

However, the dichotomy presented between a growth mindset and a desire to achieve good grades is yet another misconception about mindset. Students tended to believe that having a growth mindset means one no longer cares about grades. This is a misconception as one with a growth mindset may still desire to get good grades, they may just have a different motivation behind this desire. For example, one with a fixed mindset may desire a certain grade to maintain their status of intelligence whereas one with a growth mindset may desire a certain grade as a reflection of their understanding of the material.

4.2 Research question 2: How does the introduction of growth mindset change first-year engineering students' beliefs about the nature of intelligence?

4.2.1 Quantitative

In general, the student average mindset did slightly increase towards growth over the semester for both the general population and the sub-population in the reading group as displayed in Fig. 1. The general population mean MINDSET from the pre-survey responses was 5.22 and increased to 5.40 from the post-survey responses resulting in a 3.45% increase in the participant's mean MINDSET. For the population of students in the reading group, the participant's mean MINDSET from the pre-survey response was 5.17. When compared to the post-survey response MINDSET mean of 5.50, there was a 6.38 % increase in the participant's mean MINDSET.

A paired t-test was conducted for both student groups to determine if the average increase towards growth mindset over the course of the semester was statistically significant. The paired t-test was tested with a 95% confidence interval. In both populations the paired t-test resulted in a two-tailed $p > 0.05$, indicating no statistical significance. However, for both student groups, the pre- and post-survey data did not appear to follow a normal distribution. For the general population of students, the pre- and post-survey MINDSET data had a negative skew and neither passed the Shapiro-Wilk normality test. For the population of students in the reading group, the pre- and post-survey MINDSET data also had a negative skew. The reading group pre-survey MINDSET data did pass the Shapiro-Wilk normality test, but the post-survey MINDSET data did not. Although it can be argued that the paired t-test is robust enough to ignore the assumption of normality, a Wilcoxon sign rank test was also utilized to determine the statistical significance of the increase towards growth mindset for both student populations. The Wilcoxon sign rank test is a non-parametric alternative to the paired t-test and does not assume normally distributed data. A 95% confidence interval was again used. Similar to the t-test, for both populations the Wilcoxon sign rank test resulted in a two-tailed $p > 0.05$, again indicating no statistical significance. Although no statistical significance was found for either group of students, the statistical power was low for both populations, particularly for the reading group since there was such a small sample size ($n = 6$).

4.2.2 Qualitative

At the end of the semester, more students in the general population self-identified as having a growth mindset and fewer students self-identified as having a fixed mindset than at the beginning of the semester. However, the misconceptions regarding growth mindset were still present at the end of the semester. These misconceptions still primarily included equating a growth mindset to other desirable qualities, most notability, valuing effort.

> "This semester. . . I've also gotten better with having the mindset that I can achieve anything as long as I work hard on it."

In line with the lack of statistical significance in the overall change in mindset throughout the semester, approximately the same number of students explicitly stated that their mindset changed over the semester as those who explicitly stated it did not. The students whose mindset did change over the semester tended to change more towards a growth mindset. Several of these students discussed the difficulty and challenges faced during the semester resulting in the realization that taking responsibility for their own learning through focused effort and input from others was now necessary. This ultimately led them more towards a growth mindset.

> "I tend towards a growth mindset. Over the semester, I think that this mindset has become much stronger. College has shown me that no one will hold your hand, but also that individuals can achieve great things through great motivation."

> "I think I am growing every day in my learning and am taking responsibility for my learning, so I would now say that I am in a growth learning mindset."

The students who changed more toward a fixed mindset throughout the semester often mentioned how they began to "lose hope" or "give up" due to the challenging course work or unfavorable grades. However, these responses could suggest that the students always had a fixed mindset but may have been facing their first real academic challenge and thus for the first time testing their response to these academic challenges.

> "At the beginning of the semester and at the start of my engineering path, I felt as if I was a growth mindset, but my eyes were opened when classes began, and my grade began to sink deeper and deeper, making me lose hope and convert to a fixed mindset; where I am today."

> "Part of me feels as though my mindset is becoming more fixed as the semester progresses because when course work gets too hard, I am likely to give up."

The students who participated in the reading group did not express a meaningful change in mindset in their post-reflection responses. However, these students seem to have a much better understanding of the mindset theory and a more realistic view that changing one's mindset does not happen overnight.

> "I believe during this semester, I have definitely slowly drifted toward the growth mindset. I still have a long way to go before I consider myself growth mindset, but this semester has definitely put me on the right path. This will definitely help me towards my degree, by allowing me to use criticism more constructively and help me be more comfortable in situations where I would normally not be. This semester has had its rough spots, but I believe I will be better off in the future because of them."

Also, when compared to the general population students, those in the reading group had far fewer misconceptions about mindset in their post-reflection responses. Only one misconception was identified which equated a fixed mindset to a lack of effort.

> "As the semester goes on, and I get lazy, I sometimes start to slip into a fixed mindset."

The above quote from a member of the reading group who spent the semester participating in group discussions focused on understanding mindset theory, speaks to the pervasiveness of the misconception that growth mindset equals valuing effort alone.

5. Limitations

There were several limitations to this study. First, there was a limited sample size (n = 66, n = 6) for survey responses, which resulted in a reduced statistical power. However, this was partly balanced out by the qualitative data that was collected concurrently. Also, we did not control for any other variables and therefore no regression analysis was performed. The data collection was limited to a single PWI institution. The written reflections were one-way, and therefore not as rich or thick as interview data. Also, during the qualitative analysis, there were many insistences where follow-up questions were desired to better or more fully understand the responses. Finally, open-ended reflection responses have been known to result in the participants writing what they think the researchers want to hear as opposed to their actual beliefs [36].

6. Discussion & future work

This study provides a preliminary critical look at the application of Dweck's Mindset theory in undergraduate engineering education. While the theory has gained popularity, our findings challenge the temptation to briefly introduce growth mindset in an introductory course with the hopes that it will change students' beliefs and have a meaningful influence on their conceptions of intelligence, metacognition, or persistence in their first year of engineering at the college level. Despite the evidence of growth mindset as a foundational lens for educational persistence and achievement, the findings of this study indicate that a brief introduction into mindset theory is not adequate, may result in significant misconceptions, and leave students with the impression that growth mindset equals a positive attitude or is exclusively linked to effort. These findings align with the recent publications by Dweck in which she discusses the risk of oversimplifying her theory or presenting it as strictly dichotomous [30, 31]. For students to gain a meaningful understanding of growth mindset, educators need to do more than simply provide a brief introduction of the theory. Also, praising students on effort alone may actually be counterproductive and instead educators should emphasize the importance of engaging in activities such as seeking help from others, trying new learning strategies, and learning from failure [30, 31].

This study also indicates that students tend to separate intelligence and effort, for example if someone is "smart," then effort should not be required. This strict distinction between intelligence and effort contradicts growth mindset, although many of the students claiming to have a growth mindset discussed this very idea. The separation of effort and intelligence is pervasive in western culture [37]. Therefore, this misconception may be the result of deeply rooted cultural beliefs further indicating the ineffectiveness of a brief introduction to mindset theory.

The students who participated in the reading group resulted in fewer misconception about mindset theory, however, their beliefs about intelligence did not significantly change over the course of the semester. This could be partly because the students who were already invested in growth mindset were those who were interested in participating in the reading group, leading to a self-selection bias. Therefore, the in-depth mindset intervention for these students may not have been as meaningful as it would have been for the general population of students.

This study also provides insight in recognizing the limitation of survey data when assessing students' intelligence beliefs, or mindsets. Although the survey indicated that students' beliefs about intelligence tended towards a growth mindset, the qualitative analysis indicated that students had significant misconceptions about mindset theory including contradictory ideas involving effort and intelligence. Survey items may not be indictive of growth mindset and qualitative approaches are necessary for researchers to gain a more holistic understanding of students' beliefs about intelligence.

Future work could include an in-depth mindset intervention for a larger sample size of participants including all students in an introductory engineering course or beyond. Participants should also be expanded to include students from more diverse institutions such as HSIs, HBCUs, private institutions, or community colleges. Future work could also utilize interviews instead of written reflection responses to more richly understand students' beliefs about intelligence and how to effectively promote a growth mindset during the first-year engineering experience.

7. Conclusion

The education theory, growth mindset, has been growing in popularity in recent years, however, the implementation of the theory is often over-simplified when introduced to students. In this study, the complex ways in which first-year engineering students react to the growth mindset theory and the influence that learning about the theory has on their personal beliefs was explored. A mixed methods approach was utilized through the collection of quantitative and qualitative data from first-year engineering students. Specifically, data was collected regarding intelligence beliefs from (1) a sample of students who received a brief, in-class introduction to the theory and (2) a sub-sample of students who engaged in a more in-depth intervention. Our findings show that neither the in-class introduction nor the in-depth intervention had a statistically significant influence on students' intelligence beliefs, but the in-depth intervention did provide students with a more nuanced understanding of the growth mindset theory. Findings also show that students generally self-identified as tending towards a growth mindset, however, students' written reflections revealed significant misconceptions about the true meaning of growth mindset, such as equating it with being generally positive and exclusively valuing effort. Implications of this study for engineering educators include that given the complexity of growth mindset, a brief introduction into mindset theory is likely not adequate for a significant change in student beliefs. An additional implication is that survey items alone may not be adequate for capturing students' intelligence beliefs, and qualitative approaches may be necessary for researchers to gain a more holistic understanding of students' intelligence beliefs.

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Dr. Emily Dringenberg is an Assistant Professor at The Ohio State University in the Department of Engineering Education. Her research lab utilizes qualitative methods to explore beliefs in engineering. For example, she currently has two NSF-funded projects to study the beliefs that engineering students hold about (1) intelligence and (2) types of reasoning for decision making in the context of design. Her research has an overarching goal of leveraging engineering education research to shift the culture of engineering to be more realistic and inclusive. Dr. Dringenberg is also interested in neuroscience, growth mindset, engineering ethics, and race and gender in engineering. In general, she is always excited to learn new things and work with motivated individuals from diverse backgrounds to improve the experiences of people at any level in engineering education.

Amy Kramer is a graduate student and research associate at The Ohio State University in the Department of Engineering Education. She earned a BS and MS in Civil Engineering from The Ohio State University in 2010 and 2013, respectively. Most recently she worked as a structural engineering consultant in Columbus, OH where she specialized in the design of reinforced concrete and steel structures for industrial bulk material handling and storage facilities. Her current research interests in Engineering Education include engineering identity, diversity and inclusion, and engineering culture.