



Exploring Engineering Students' Beliefs on Effort and Intelligence

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Purpose

The purpose of the current study was to gain a better understanding of first year engineering students' motivational beliefs as a first step toward investigating the role that motivational beliefs play in academic achievement and retention of engineering students. Specifically, we investigated students' implicit beliefs about intelligence to determine if students thought intelligence was unchangeable. We also investigated students' beliefs about effort to determine if they viewed effort as positively contributing to academic success. Finally, we investigated students' perceptions of the relative contribution of effort and intelligence/ability to academic performance. A richer understanding of these beliefs might help to understand engineering students' behaviors and potentially lead to interventions to help improve student success.

Related Literature

Research on individuals' implicit beliefs about intelligence describes variation in how different people conceptualize the nature of intelligence as either changeable or unchangeable. Broadly, individuals can be classified into two types. Incremental theorists believe that intelligence is malleable and may be improved with effort. Entity theorists believe that intelligence is fixed and cannot be improved with effort. Students with an entity belief of intelligence are more likely to believe that poor performance is a result of low intelligence/ability and that only those students with low intelligence/ability need to exert effort to perform well.^{1,2}

Across a range of ages, incremental beliefs about intelligence have been positively associated with a host of beneficial outcomes including persistence during challenging endeavors, adaptive beliefs regarding the perceived causes of success and failure (attributional beliefs), and a focus on developing competence (mastery goal orientation) as opposed to a focus on demonstrating competence (performance goal orientation).^{3,4,5,6,7} Within an incremental view, failure is perceived as an indicator that one needs to work harder or adopt different strategies. In contrast, failure within an entity view is perceived as evidence that one is lacking in intelligence. Research with college students enrolled in a pre-medical track showed a positive relationship between mastery goal orientations and higher achievement and sustained persistence for students when faced with a challenging academic curriculum⁸, thus underscoring the importance of encouraging college students to adopt an incremental belief in intelligence. These findings also emphasize the importance of understanding students' implicit beliefs as a first step toward promoting adaptive motivational beliefs and behaviors among college engineering majors.

Relatedly, beliefs about effort refer to students' perceptions of the degree to which effort exertion results in positive outcomes. Research has shown an association between positive effort beliefs in mathematics and students' attributional beliefs and self-reported usage of positive, effort-based strategies,⁹ underscoring the importance of promoting students' positive effort beliefs. Incremental beliefs about intelligence have been associated with positive effort beliefs.^{10,11}

Research has shown beliefs about intelligence and effort may differ by gender and ethnicity. Female students tend to show an increased tendency to endorse incremental beliefs¹² and to place a higher value on effort than males.¹³ Investigations of ethnic differences have also shown Asian-Americans place a greater importance on effort than do Caucasian Americans.¹⁴

Although there is a body of research on students' beliefs on intelligence and effort, there is a lack of research that specifically investigates these issues with engineering students. Due to the rigors of the engineering curriculum, engineering students' beliefs on intelligence and effort are likely critical to academic success. Beliefs about intelligence and effort may be especially relevant for first year engineering students, who are often confronted with unusually challenging academic material¹⁵ and are also susceptible to dropout.¹⁶ One important factor that may be at play for first year students in the transition from high school to college is the changing academic environment which is becoming more challenging. Students may find themselves unprepared academically, particularly if they feel that they can succeed based on their ability alone.

Research Questions

This study is primarily exploratory in nature, with the primary purpose to understand first year engineering students' implicit beliefs about intelligence and beliefs regarding effort. This study represents an initial step in determining if engineering students' beliefs can be useful in understanding broader outcomes such as retention and academic success in engineering. In the current study, data from first year engineering students were utilized to address the following questions.

RQ.1 Are implicit beliefs about intelligence associated with more adaptive effort beliefs, and does the size of this relation vary by gender?

RQ.2 Do entering first year students in engineering endorse differing beliefs regarding the expected relative contributions of effort and intelligence/ability that are necessary for academic achievement in both high school and college?

Given prior research,¹⁷ we expected to find a positive association between implicit beliefs about intelligence and effort beliefs, such that incremental beliefs would be associated with more positive effort beliefs. Gender was examined as a potential moderator for both questions. Although ethnic differences are important to understand, the lack of ethnic diversity in the participants did not allow for statically valid analysis of ethnic differences.

Method

Participants

All 505 students in the 2013 freshman cohort of students enrolled in engineering in the fall of 2013 were invited to participate in the current study. Of these, 495 completed the survey (98% response rate). The final sample consisted of 479 students (95% participation rate) with complete data for all measures included in the analyses. Demographic information for the

sample is provided in Table 1. Of note, gender composition for our cohort is relatively comparable to national averages, but the cohort was less ethnically diverse than the national population of engineering students.¹⁸ Average ACT composite score for the participants was 28.5 ($SD = 3.16$) and the average ACT math score was 29.0 ($SD = 3.16$). Forty-one percent of the students had a weighted high school GPA of 4.0 or above.

Table 1. Sample Demographics

	2013 Cohort	Sample in study
<i>n</i>	505	479
Male	402 (80%)	384 (80%)
Female	103 (21%)	95 (20%)
White	436 (86%)	411 (86%)
Asian	18 (4%)	21 (4%)
Black/ African American	17 (3%)	17 (4%)
Two or more races	16 (3%)	16 (3%)
Hispanic/Latino	12 (2%)	11 (2%)
Unknown or Unspecified	3 (1%)	3 (1%)

Procedure

Survey data were collected from participants during the first week of class in the Fall 2013 semester. The survey was administered online during the students' Introduction to Engineering course, a mandatory course for first-time, full-time students. Constructs used in the current study were part of a broader study investigating student beliefs and behaviors with the ultimate goal of formulating ideas to assist students in increasing their academic performance and retention in the first year of engineering school. No rewards or credit towards grades were given as incentives for study participation.

Measures

Effort Beliefs

The nine-item Effort Beliefs Scale was used to measure the degree to which students believe that exertion of effort is associated with adaptive outcomes.¹⁹ This scale is composed of two subscales: one that measures the belief that effort leads to positive outcomes (4 questions) and the other that measures the belief that effort has a negative, inverse relationship with intelligence/ability and does not contribute to positive outcomes (5 questions). A sample item reads, "It doesn't matter how hard you work – if you're not smart, you won't do well." All the items of the scale are listed in the Appendix. Each item of the scale was answered on a six-point Likert scale (*Strongly disagree* = 1 to *Strongly agree* = 6). After reversing the five items measuring the inverse relationship, items were averaged to form a composite measure of effort beliefs, with higher scores reflecting a stronger belief that effort results in positive outcomes. Internal consistency reliability ($\alpha = .76$) for the current sample was acceptable,²⁰ similar to other research with this measure ($\alpha = .79$).²¹

A confirmatory factor analysis (CFA) was conducted to determine if the data supported a one-factor model (correlation matrix available upon request). Standardized factor loadings were between .414 and .659 which are lower than the recommended value to conclude all indicators measure a common factor.²² The model fit indices did not show good fit based on criteria supported by Kline²³ and were as follows: $\chi^2(28) = 153.47, p < .001, CFI = .845, TLI = .800$ and $RMSEA = .097$. An additional CFA model with two correlated latent factors improved the model fit ($CFI = .921, TLI = .891$ and $RMSEA = .072$). Standardized factor loadings ranged from .326 (for question 6, see Appendix) to .687. Internal consistency was diminished when the scale was split into two subscales ($\alpha = .59$ for the positive outcomes associated with effort and $\alpha = .71$ for the inverse intelligence/ability relationship). A one-factor model was retained for the current analyses, with the caution that relatively low factor loadings may indicate a threat to convergent validity. Means and standard deviations for each subscale are provided in Table 2 in the Descriptive Statistics section.

Implicit Beliefs about Intelligence

The three-item short form of the Implicit Beliefs about Intelligence Scale^{24,25} was used to measure students' implicit beliefs about intelligence. This scale consists of three items answered on a six-point Likert scale (*Strongly disagree* = 1; *Strongly agree* = 6). A sample item reads, "You have a certain amount of intelligence and you really can't do much to change it." Items were averaged to form a composite score; higher scores on the scale represent a stronger endorsement of the belief that intelligence is fixed (entity belief). Internal consistency for the current sample ($\alpha = .83$) was good.²⁶ Standardized factor loadings from CFA analysis were between .715 and .868, which are considered good. The model is just-identified with zero degrees of freedom, which means that a χ^2 value could not be calculated.

Perceptions of Relative Contributions of Effort and Intelligence to Achievement

Two additional items were constructed to measure students' perceptions regarding the relative contribution of effort and intelligence/ability to academic achievement. Participants reported on perceived relative contributions for high school ("Thinking about the grades you received in high school, what percentage of effort and intelligence/ability determined the grades you received?") and for college ("Thinking about the grades you expect to receive in your engineering classes..."). For both questions, participants were asked to provide a value between 0 and 100 for both effort and intelligence/ability and the sum was forced to be 100%.

Analyses

All analyses for this study were performed in SPSS version 21. Linear regression with all variables entered into the model was used to determine the relationship between implicit beliefs about intelligence, gender and effort beliefs. The dependent variable was the score on the Effort Beliefs Scale (Effort_Score) using all nine items. The independent variables were the score on the Implicit Beliefs on Intelligence Scale (Intel_Score) and gender, with males coded as 0 and females coded as 1. Independent and paired sample *t*-tests were used to analyze students' beliefs regarding the relative contributions of effort and intelligence/ability to high school and college engineering achievement.

Results and Discussion

Descriptive statistics

Descriptive statistics for effort beliefs, implicit beliefs about intelligence, and beliefs regarding relative contributions of effort and intelligence to achievement are provided in Table 2. The mean of the overall effort score, 4.66, was identical to the mean reported for junior high students in previous research.²⁷ This represents fairly positive beliefs about effort.

Table 2. Descriptive Statistics for Male, Female and All Students ($n = 479$)^a

	Male <i>M (SD)</i>	Female <i>M (SD)</i>	All Students <i>M (SD)</i>
Effort beliefs (total scale score)	4.62 (.63)	4.80 (.52)	4.66 (.61)
<i>Positive outcome subscale</i>	4.67 (.70)	4.82 (.65)	4.70 (.69)
<i>Effort beliefs subscale^b</i>	4.58 (.74)	4.79 (.61)	4.62 (.72)
Implicit beliefs about intelligence	2.66 (1.02)	2.43 (.97)	2.62 (1.02)
Perceived percent contribution of effort to high school GPA (vs. intelligence)	39.65 (22.56)	45.14 (23.62)	40.73 (22.85)
Perceived percent contribution of effort to college engineering GPA (vs. intelligence)	63.65 (18.40)	68.98 (20.11)	64.70 (18.85)

Note.^a Italicized constructs were not used in analyses.

Note.^b A higher score represents the belief that effort and intelligence are positively related, as opposed to inversely related.

Note.^c Higher scores reflect stronger beliefs in the fixed nature of intelligence (entity belief).

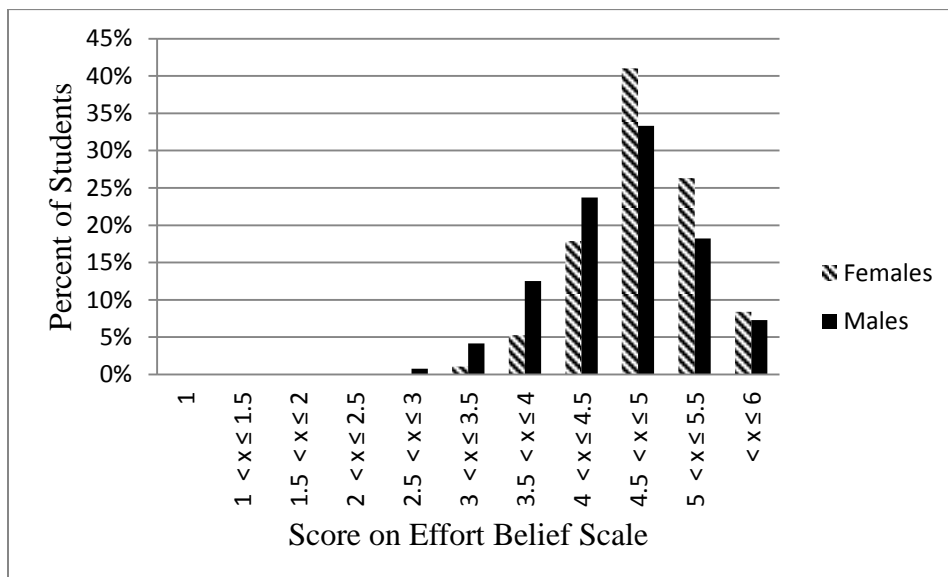


Figure 1. Distribution of the Scores on the Effort Beliefs Scale for Males ($n = 384$) and Females ($n = 95$)

On average, female students endorsed more positive effort beliefs than male students, $t(170) = -2.98, p = .003$, as determined by a t -test assuming unequal variances (see Figure 1 above). This means on average female students perceived a stronger relationship between effort and positive outcomes than did male students. However, the effect size as measured by Hedges' g was .29 which is considered small.²⁸

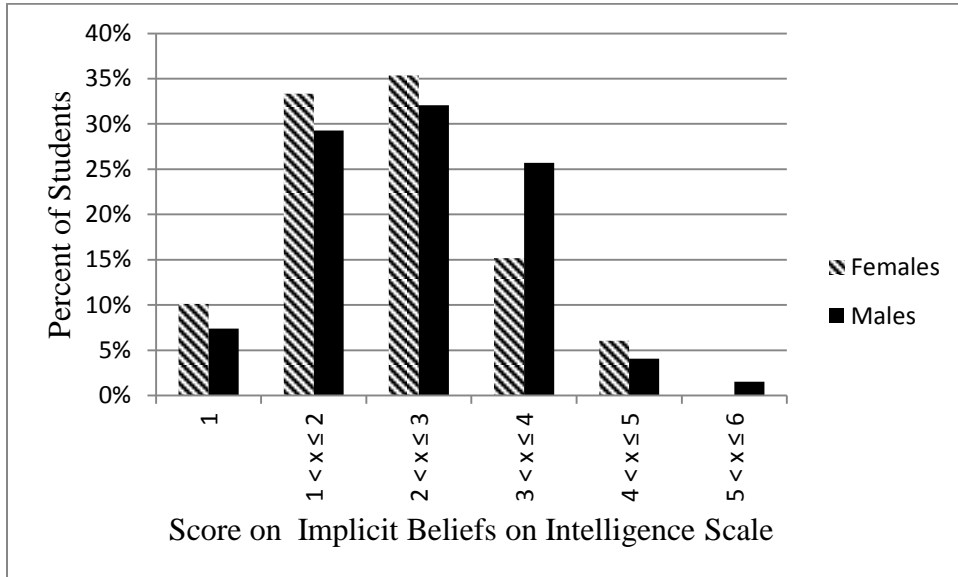


Figure 2. Distribution of Scores on Implicit Beliefs of Intelligence Scale for Males ($n = 384$) and Females ($n = 95$)

Figure 2 shows the distribution of scores for the Implicit Beliefs about Intelligence Scale. Lower scores reflect an incremental belief (intelligence can be improved with effort) and higher scores reflect an entity belief (intelligence is immutable). Using the traditional classification scheme of dichotomizing scale scores into entity and incremental beliefs,²⁹ sum scores of 2.0 and below are considered to indicate incremental beliefs and sum scores of 4.0 and above are considered to indicate entity beliefs. According to this method, 38% of the students in the current sample would be considered incremental theorists, 13% would be classified as entity theorists, and 49% of the sample would be considered not to have strong beliefs on intelligence. However, we elected to maintain continuous scores for this measure, as has been done in prior research.^{30, 31}

Implicit beliefs about intelligence differed significantly by gender, $t(490) = 2.05, p = .04$, with female students endorsing stronger incremental beliefs than male students (see Table 2). Using the traditional classification scheme, 15% of male students but only 6% of female students would be classified as entity theorists, and 43% of female students but only 37% of male students would be classified as incremental theorists.

RQ.1 – Relation between implicit beliefs about intelligence and effort beliefs

A linear regression analysis was conducted to explore if implicit beliefs about intelligence predicted adaptive effort beliefs, and if this relation was moderated by gender (see Table 3). The resulting model significantly predicted overall effort beliefs, $F(2, 476) = 80.07, p$

< .001, and explained 25% of the variability in effort beliefs. The analysis showed that implicit beliefs were a significant predictor of effort beliefs. Gender was not statistically significant in the model ($p = .059$), but should be further evaluated due to the low p value. The results suggest that, on average, an increase of one point on the implicit beliefs scale (toward stronger entity beliefs), results in a 0.3 point decrease in effort beliefs (away from the belief that effort positively contributes to performance).

Table 3. Results from Linear Regression Model to Predict Score on Effort Beliefs

	B (unstandardized)	S.E.	β (standardized)	t	Sig	95% CI
Implicit Beliefs	-.30	.02	-.489	-12.28	< .001	[-.34, -.25]
Gender	.12	.06	.075	1.89	.059	[-.004, .24]

RQ. 2 - Beliefs regarding relative contributions of effort and intelligence to achievement

For this question, we examined students’ responses to perceptions of relative contributions of effort to achievement in both high school and college engineering courses. Because the survey responses for effort and intelligence/ability were restricted to sum to 100%, any differences in the perceived contribution of effort would also imply an equal difference in the perceived contribution of intelligence/ability. Therefore, only scores for perceived effort contributions were utilized in analyses.

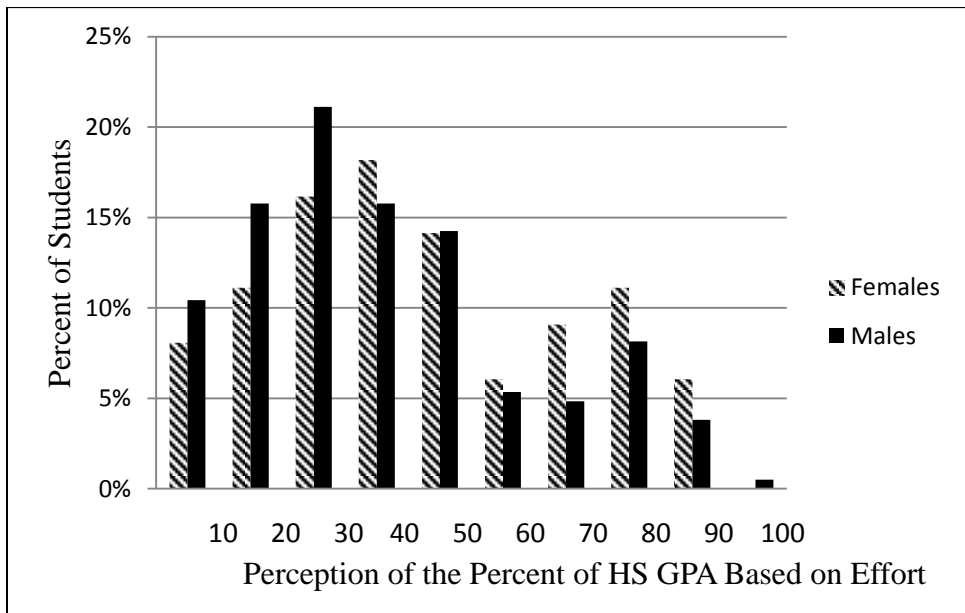


Figure 3. Distribution of Students’ Perceived Contribution of Effort to High School Achievement for Males ($n = 384$) and Females ($n = 95$).

The mean score for expected contribution of effort to achievement in high school was 41% ($SD = 22.85$), indicating that on average, students perceived that academic success in high school was determined by 41% effort and 59% intelligence/ability. Based on an independent t -

test the difference in the perceived contribution of effort and intelligence/ability was significant $t(476) = -8.858, p < .001$. The graph of the responses (see Figure 3 above) shows a bimodal distribution with the responses above 50% for effort forming a bell shaped distribution with a peak between 70% and 80%, and a larger bell shaped curve for responses below 50% with a peak between 20% and 30%. Thus, there appears to be two sub-populations of students: one for whom intelligence is the primary contributor to achievement, and another smaller group for whom effort is the primary contributor.

Male and female students' perceived contributions of effort for high school were statistically significantly different, $t(490) = -2.118, p = .035$. On average, female students perceived effort to contribute more to achievement in high school ($M = 45\%$, $SD = 23.62$) than male students ($M = 39\%$, $SD = 22.56$).

Overall, students believed effort would be more important in determining grades in engineering school than it was in high school, $t(487) = -20.836, p < .001$. On average, students perceived that achievement in college engineering classes was determined by 65% effort (compared to 41% effort for achievement in high school). Comparison of individual responses showed the following relationship between effort and grades in high school compared to engineering school: 77% of the students indicated effort was *more* important in engineering school (assigned a higher percent in engineering school than in high school), 12% indicated it was of the *same* importance, and 10% indicated it was *less* important in engineering school than in high school.

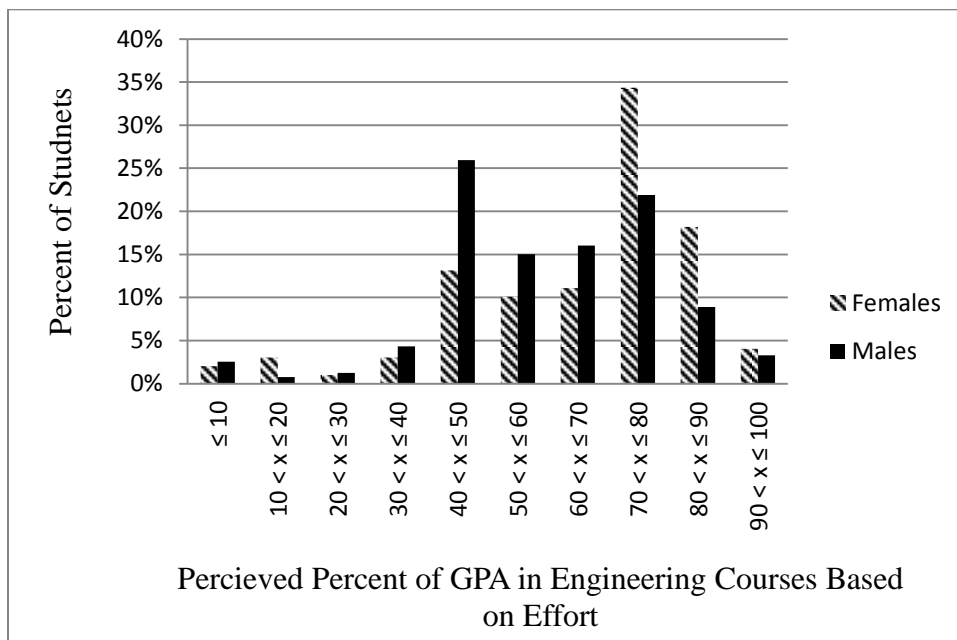


Figure 4. Distribution of Perceived Contribution of Effort to Achievement in Engineering Courses for Males ($n = 384$) and females ($n=384$).

Similar to the findings regarding perceived contributions for high school achievement, female students anticipated a greater importance for effort in engineering school achievement, 69% ($SD = 19.75$) than did male students, 64% ($SD = 18.31$), $t(490) = -2.664, p = .008$. Figure 4

shows the distribution, for both males and females, of the students' perception of the contribution of effort to achievement in engineering school. As seen in the figure, the majority of the students perceived that effort would contribute greater than 40% to achievement in engineering. The mode for females, which was between 70% and 80%, was much higher than the mode for males, which was between 40% and 50%.

Conclusions and Future Directions

Findings from the current study revealed considerable variability in first year engineering students' beliefs about intelligence and the role of effort in academic success. The data supported some differences in beliefs based on gender.

In general, first year engineering students in the current sample displayed variability with regard to implicit beliefs about intelligence. These implicit beliefs have been linked to important outcomes, which may help to explain variability in engineering students' persistence and retention in the major. Incremental beliefs about intelligence are linked to mastery goal orientations, in which the students' focus is on developing, rather than demonstrating, competence.^{32, 33, 34}

Statistically significant gender differences were observed, such that female students endorsed stronger incremental beliefs and perceived that effort plays a stronger role for achievement in both high school and college. Although the effect size was considered small, this is consistent with prior research that concluded female students show an increased tendency to endorse incremental beliefs³⁵ and often place a high value on effort.³⁶ These differences should be investigated further with a larger sample of female engineering students.

As expected given prior research,^{37,38} students' implicit beliefs were strongly related to students' positive effort beliefs. There data did not support the significance of gender as a moderator based on a significance level of .05. Since the value for p (.059) was so close to .05, this warrants further investigation with a larger sample size.

Future research with the data gathered in this study will examine if students' implicit beliefs about intelligence, as well as their beliefs regarding effort, are related to later academic performance, retention in engineering and time invested in their studies. If it is determined that student's beliefs on effort and intelligence are related to their performance and retention in engineering, efforts could be made to change students' beliefs by drawing on strategies from successful intervention programs with similar goals.

Students also varied in their perceptions of the relative contributions of effort and intelligence for academic achievement in both high school and college engineering courses. On average, students thought effort was less important than intelligence/ability for performance in high school, but was more important than intelligence/ability in engineering school. Although students recognized that effort would become more important in engineering school than it was in high school, some students still believed that effort had very little impact on grades in engineering school compared to intelligence/ability.

The responses on perception of importance of intelligence/ability and effort were recorded during the first week of college. Future research could investigate whether students' perceptions change after attending engineering school for a year and they are more familiar with the demands of the engineering curriculum.

Certain limitations should be considered alongside these findings. First, additional validation is needed for the items asking students to report on perceptions of relative contributions of effort and intelligence to achievement. Second, findings from the CFA for the effort beliefs scale suggest that additional construct validation is warranted. Third, there was a relative lack of ethnic diversity in the sample; thus, additional research is needed to determine generalizability to under-represented minority populations of engineering students.

In conclusion, this study gives insights into a sample of engineering students' beliefs on effort, intelligence and the importance of both to academic performance. Though these findings do not yet provide direct guidance on policy changes, they may serve as guidance for future research in this area with a long-term goal to enact policy or curricular changes to support incremental beliefs among engineering students. Understanding these beliefs may help instructors understand students' behaviors and in turn help instructors find ways to assist struggling students. Interventions aimed at changing students' implicit beliefs about intelligence toward incremental beliefs have demonstrated much success with other groups of students.³⁹ Engineering educators should be aware of students' implicit beliefs about intelligence and seek to provide assistance to the subset of students who believe that intelligence is resistant to change. Finally, future research could explore how engineering students develop these beliefs, and the later stability of these beliefs throughout their undergraduate engineering career.

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Appendix - Effort Beliefs Scale Items

1. The harder you work at something, the better you will be at it.
2. It doesn't matter how hard you work – if you're not smart, you won't do well.
3. If you're not good at a subject, working hard won't make you good at it.
4. When something is hard, it just makes me want to work more on it, not less.

5. If you're not doing well at something, it's better to try something easier.
6. If you don't work hard and put in a lot of effort, you probably won't do well.
7. To tell the truth, when I work hard at my schoolwork, it makes me feel like I'm not very smart.
8. If an assignment is hard, it means I'll probably learn a lot doing it.
9. If a subject is hard, it means I probably won't be able to do really well at it.