Assessing Changes in Mindset of Freshman Engineers

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Abstract

The goal of our research is to benchmark "mindset" or attitudes toward intelligence and learning ability in freshman engineering students and begin to understand how this attitude toward learning changes over the first year of engineering studies.

Mindset in our study is operationally defined as having elements of either a growth orientated mindset and fixed orientated mindset. The proportions of both mindset beliefs in a freshman engineer or their overall leaning or preference toward intelligence or learning is the key factor. This operational definition and the accompanying mindset measurement instrument was developed by Carol Dweck of Stanford University. Preliminary results from a sample of freshman engineers show promise that the incorporation of open ended design experiences may have a significant impact on mindset changes in freshman engineers. Understanding experiences that contribute to shifts in mindset will help toward our long-term goal of determining which engineering curriculum experiences affect a student engineer's mindset and the direction and magnitude of those influences.

Our initial pilot study looked at freshmen engineering students, comparing them across multiple campuses and with students majoring in business. Mindset measurements of were collected as a pre-test in the beginning of the freshman year. A post-test measurement was done at the end of the freshman year after completion of a team-based freshman design project as a design intervention. A second pilot study was done with pre-test and post-test samples for an experimental group of freshman engineers and control samples of freshman technology students at similar sized institutions without the design intervention.

Background: Persistence in Engineering

Engineering is considered a difficult discipline and is often misunderstood as simply "math and science". While math and science are certainly tools within successful engineering, the importance of design, innovation and creativity must also be considered. However, many engineering programs base admission decisions and enrollment in extracurricular programs to facilitate student success purely on cognitive characteristics, largely focusing on math and science (grade point average, SAT scores, etc.) Research indicates that other affective or noncognitive characteristics may be just as or more important in predicting student success. Research from Lin, Imbrie and Reid [1-3] have shown that noncognitive characteristics such as self-perception of leadership ability, motivation to study engineering and academic self-efficacy tended to be at least equal to cognitive characteristics as inputs to models to predict retention into the second year of study in engineering. Research from the Center for the Advancement of Engineering

Education showed that students who persisted in engineering were largely similar in cognitive measures, but differed in confidence in their abilities in math and science and sense of engagement in the classroom [4].

While students enter college with certain affective characteristics, their experience early in their collegiate career undoubtedly has an effect on these noncognitive characteristics: for example, a student's self-efficacy toward their study of math or physics may be positively or negatively affected by their experience in math or physics courses.

Fixed vs. Growth Mindset

Carol Dweck of Stanford developed an assessment of mindset, operationalized by two different mindsets: fixed or growth [5-10]. The fixed mindset is one where the individual believes that the intelligence they possess is all they will ever possess and cannot be changed; the 'amount' of intelligence is fixed. Students with a fixed mindset tend to believe that making a mistake means they lack ability; if they had the ability and intelligence, they should be able to succeed. Students with a growth mindset believe that intellectual ability is can be affected by education; thus individuals have a chance to increase their intelligence by learning more. These students are more likely to believe that it is more important to learn in a class than to receive a specific grade [10]. For students with a growth mindset, success is about learning or becoming smarter.

A critical aspect of the mindset approach to instilling entrepreneurial behavior in engineers relates to pedagogical instruction in the classroom. In order to develop an individual's growth mindset, it is preferable to praise an individual's process of learning rather than their intelligence. Praise of their intelligence simply encourages students not to take more risks to avoid failure. [5-10]. In this context, we assume that a change to a more growth orientated mindset means the student engineer is potentially more creative and entrepreneurial. Ideally, we would have students appreciate the value of learning as its own intrinsic reward: to do more than master obtaining a given grade regardless of learning. In other words, we want students to tend toward a more growth mindset. However, our research shows that students tend toward a fixed mindset in their first year of study.

Our research questions:

- Do engineering students change their mindset over their first year of study, and
- Can the introduction of an open-ended design activity help students progress toward a growth mindset?

Methodology

The mindset instrument authored by Dweck is a 27-item survey designed to assess fixed vs. growth mindset. Exploratory factor analysis showed there to be two distinct constructs. This agrees with other validation of the instrument which had primarily been involving younger students in K-12.

The open ended design problem is assigned as an 8 -12 week project in an Introduction to Engineering II course at Ohio Northern University. Student teams are assigned a project to design a device to alleviate an effect of poverty in a country or population which was assigned to the team. The problem was framed

as a Call for Proposals. Teams submit a formal proposal detailing the device to be designed, built and tested. There are few constraints on the allowable designs; however, students are dissuaded from proposing a water filter. Teams are encouraged to design something that solves a need which is unique to their population. For example, the level of arsenic is alarmingly high in the country of Bangladesh [11]: a device to remove arsenic would be very appropriate.

Request for Proposals:
Design of Poverty-Alleviating Devices

Summary:
The Other 90 Design, Inc. (TO9D), is a not-for-profit multinational corporation that has as its mission to develop products that will benefit the 90% percent of people on Earth who are poor by helping them out of "absolute poverty", which was defined by the World Bank in 1990 as the earning of an equivalent income of $2 a day or less. TO9D attempts to accomplish this goal through focusing development efforts on products that either allows people to earn their way out of poverty or allow people to spend less time, money and/or effort on the necessities for life.

Among the products developed to date are:
- Solar-powered flashlight for nighttime illumination (replacing kerosene lamps)
- Low-cost drip irrigation and water storage systems (for locations with both rainy and dry
- seasons)
- Donkey carts (for material deliveries in roadless areas)

TO9D is now accepting proposals for new products designed for alleviating poverty in one or more impoverished countries.

Specifications:
The proposal must identify a real world poverty situation in a specific nation where at least 40% of the population earns less than $2 a day…

Figure 1: Summary of Request for Proposals

In order to investigate the change in mindset over the first year of study, the Dweck instrument was entered as an online survey and taken by all first-year students early in the year (within the first two weeks of classes) and late in the year (the final two weeks of classes). An initial study compared these students in the project-based course to first-year business students; a second test compared these students to students in a typical course with no significant open-ended design project in Technology.

Statistical significance was determined using a Mann-Whitney nonparametric test of comparison, using SAS (version 9), *proc npar1way* with *wilcoxon* option. Nonparametric tests were selected to avoid a required assumption of data normality. The effect size, or Cohen's *d*, is a measure of the magnitude of the effect or the importance of the difference [12,13] Cohen's d is found by:

$$d = \frac{(M_1 - M_2)}{\sigma_{pooled}}$$

(1)

where M1 and M2 are the means of the populations under comparison. The pooled standard deviation, σ_{pooled}, is the root-mean-square of the standard deviations of the two populations [12]. That is, the pooled standard deviation is:

$$\sigma_{pooled} = \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}} \qquad (2)$$

When the two standard deviations are similar (as is typically the case), the root mean square differs very little from the simple average of the two variances. Effect size is reported because statistical significance of differences is influenced by sample size, and a statistically significant difference does not *necessarily* imply a meaningful or important difference – only that a true difference most likely exists. Effect size describes the importance of a difference. The magnitude of effect sizes is accepted as: near-zero, $d \leq 0.10$; small, $0.11 < d \leq 0.35$; moderate, $0.36 < d \leq 0.65$; large, $0.66 < d \leq 1.0$; and very large, $d > 1.0$ as they apply to research in the social sciences.

Results

I. Initial study: 2011 cohort

The initial data was collected three times during the first year of study for first-year engineering students (n=84) to see the change in mindset over the first year for the incoming class of 2011. Additional data was collected from first-year business students (n=64) as an initial attempt to compare the population of engineering students to an outside population. Comparisons were made for both fixed and growth mindset.

Engineering students showed a very slight drift toward fixed mindset and away from growth mindset over the course of their first year. Results were not statistically significant but did show a small effect size (fixed: p=0.265, |d| = 0.135: growth: p=0.282, |d| = 0.113) over the entire year (Table 1, row 1). There was evidence to show that the shift toward fixed was less in the second semester (the semester of the design project), while there was a slight shift toward growth in the second semester for engineering students.

Table 1: Changes in mindset, Engineering students, 2011

Mindset changes	Fixed Mindset			Growth Mindset		
	mean	d	p	mean	d	p
ENGR 1 > ENGR 3	2.74 vs 2.83	**-0.135 (small)**	0.265	3.36 vs 3.28	**0.113 (small)**	0.282
ENGR 1 > ENGR 2	2.74 vs 2.77	-0.053	0.740	3.36 vs 3.21	**0.185 (small)**	0.323
ENGR 2 > ENGR 3	2.77 vs 2.83	-0.053	0.386	3.21 vs 3.28	-0.079	0.920

Comparing incoming engineering students to business students showed that engineering students were statistically significantly more fixed and less growth mindset than incoming business students (fixed:

p=0.036, |d|=0.311 : growth: p=0.046, |d|=0.321). Data at the end of the year for business students was not available. (Table 2):

Table 2: Business vs. Engineering students, 2011

Mindset changes	Fixed Mindset			Growth Mindset		
	mean	d	p	mean	d	p
ENGR 1 > BUSN	2.74 vs 2.52	**0.312 (moderate)**	0.0.036	3.36 vs 3.28	**0.320 (moderate)**	0.046

II. Comparison: 2013 cohort

Data was collected at the beginning and end of the year for students in the same design-oriented curriculum within engineering and a control group of students in a Technology program at a large, Midwest university. Comparing the populations shows significant differences in fixed and growth mindset at the beginning and end of the year (Table 3):

Table 3: Engineering vs Control, 2013

Mindset	Fixed Mindset			Growth Mindset		
	mean	d	p	mean	d	p
Early: EN pre > CN pre	3.15 vs 2.70	0.972 (large)	<.001	2.89 vs 3.54	1.42 (very large)	<.001
Late: EN post > CN post	3.11 vs 2.78	0.628 (mod-large)	<.001	2.87 vs 3.44	1.07 (very large)	<.001

Measuring *changes* in mindset over the course of the first year of study shows first year engineering students who are involved in the design project remained stable with little drift toward or away from fixed or growth mindset. Students from the control group showed the expected trend toward a more fixed mindset (see Table 4).

Table 4: Engineering vs Control, 2013

Mindset changes	Fixed Mindset			Growth Mindset		
	mean	d	p	mean	d	p
ENGR: EN pre > EN post	3.15 vs 3.11	0.116 (small)	0.737	2.89 vs 2.87	0.052	0.581
Cntl: CN pre > CN post	2.70 vs 2.78	0.113 (small)	0.129	3.54 vs 3.44	0.153 (small)	0.386

Discussion

Two rounds of data analysis seem to indicate that the introduction of an open-ended design project shows promise in mitigating (or eliminating) an expected change in mindset toward a more fixed and less growth mindset over the first year of study in engineering. Further, this intervention may be more important for students in engineering as the data showed they may be more fixed-mindset at the beginning of their college careers.

In answering the research questions, it seems:

- First-year students typically drift toward a fixed mindset and away from a growth mindset in their first year, and
- It seems the introduction of open ended problems can have a positive effect toward a growth mindset.

The authors hypothesize that the introduction of the open-ended design is in contrast to assignments in other courses in the first year of study which allow for little to no creativity: the students finds the correct answer or does not. A students with a more fixed mindset that finds an incorrect answer could feel that this is because of their limited intelligence, confirming the fixed mindset. Progressing through a design problem gives the student the opportunity to see that answers are not always right or wrong and in explaining or working with their proposed solutions, discover that the amount they "learn" is changing, emphasizing a growth mindset.

Further work remains to determine if there is a direct cause and effect relationship between design projects and mindset change, and whether the change in mindset in individual students may be a direct indicator in student retention.

Conclusions

Multiple rounds of data collection and analysis indicate that the introduction of open ended design projects may tend to help students from moving away from a fixed to a growth mindset. This would tend to lead to students who are more interesting in learning for the intrinsic value of learning rather than finding intelligence as a limiting factor, and striving for a grade.

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Biographical Information

Kenneth Reid is the Director of Engineering Education, Director of First-Year Engineering and Professor in Electrical and Computer Engineering at Ohio Northern University. He was the seventh person in the U.S. to receive a Ph.D. in Engineering Education from Purdue University. He is active in engineering within K-12, serving on the TSA Boards of Directors and over 10 years on the IEEE-USA Precollege Education Committee. He was awarded with an IEEE-USA Professional Achievement Award in 2013 and named NETI Fellow (National Effective Teaching Institute) in 2013 and the Herbert F. Alter Chair of Engineering in 2010. His research interests include success in first-year engineering, introducing entrepreneurship into engineering, international service and engineering in K-12.

Daniel M. Ferguson is a research associate at Purdue University and the recipient of three NSF awards for research in engineering education. Prior to coming to Purdue he was Assistant Professor of Entrepreneurship at Ohio Northern University. Before assuming that position he was Associate Director of the Inter-professional Studies Program and Senior Lecturer at Illinois Institute of Technology and involved in research in service learning, assessment processes and interventions aimed at improving learning objective attainment. Prior to his University assignments he was the Founder and CEO of The EDI Group, Ltd. and The EDI Group Canada, Ltd, independent professional services companies specializing in B2B electronic commerce and electronic data interchange. The EDI Group companies conducted syndicated market research, offered educational seminars and conferences and published The Journal of Electronic Commerce. He was also a Vice President at the First National Bank of Chicago, where he founded and managed the bank's market leading professional Cash Management Consulting Group, initiated the bank's non credit service product management organization and profit center profitability programs and was instrumental in the breakthrough EDI/EFT payment system implemented by General Motors. Dr. Ferguson is a graduate of Notre Dame, Stanford and Purdue Universities and a member of Tau Beta Pi.