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What is the Relationship between Mindset and Engineering Identity for First Year Male and Female Students? An Exploratory Longitudinal Study

Ms. Heather Lysbeth Henderson, West Virginia University

With a background in English, philosophy, science, and all levels of education, Heather is currently a doctoral student in curriculum and instruction and educational psychology. She is interested in psychological barriers affecting retention and success for students. Having been raised by an engineer, this project is close to her heart.

Dr. Karen E Rambo-Hernandez, West Virginia University

Karen E. Rambo-Hernandez is an assistant professor of educational psychology in the department of Learning Sciences and Human Development in the College of Education and Human Services at West Virginia University. In her research, she is interested the assessment of student learning-particularly the assessment of academic growth, issues related to diversity and inclusion, advanced statistical modeling, and the evaluation of curricular change.

Ms. Christina Paguyo, Colorado State University

Christina H. Paguyo, PhD, is a postdoctoral fellow in the College of Engineering at Colorado State University. Her research interests focus on mixed methods approaches for designing and examining educational environments grounded in research, theory, and equity. She has co-authored peer-reviewed articles published in the Peabody Journal of Education and the Encyclopedia of Diversity in Education.

Dr. Rebecca A Atadero, Colorado State University

Rebecca Atadero is an associate professor in the Department of Civil and Environmental Engineering at Colorado State University, specializing in structural engineering. She conducts research on the inspection, management and renewal of existing structures, and on engineering education.

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Undergraduate students who leave engineering are most likely to do so during the first two years of coursework (Litzer & Young, 2012). During these first two years, students often encounter difficult coursework that may be not be overtly related to engineering (e.g., advanced calculus, physics; Suresh, 2006) while simultaneously developing their initial engineering identities. Students possessing a fixed mindset (e.g., intelligence based on genetics) versus a growth mindset (e.g., intelligence based on effort and hard work) are more likely to disengage when confronted with highly challenging coursework (Rattan, Savani, Chugh, & Dweck, 2015; Robins & Pals, 2002), which may be related to lower engineering identity. Implicit person theory argues that persons are more likely to persist with challenging tasks if they believe that intelligence is malleable (Robins & Pals, 2002). Additionally, it is well established that women are underrepresented in the field of engineering (Singh, Fouad, Fitzpatrick, & Chang, 2014). While a plethora of research exists to examine what factors contribute to the persistence of women in engineering, such as institutional factors and student characteristics, we focus on the relationship between mindset and engineering identity in this paper. The purpose of this study is to explore whether mindsets influence a student's engineering identity over time and to see if this relationship differs by gender.

One definition of professional identity is "personal identification with the duties, responsibilities, and knowledge associated with a professional role" (Eliot and Turns, 2011, p. 631). Development of an engineering identity thus requires students to (Stevens, O'Connor, Garrison, Jocuns & Amos, 2008 ; Trede, Macklin and Bridges2011): (1) understand the roles of engineers and acquire the necessary disciplinary content through doing; (2) interact with others in the profession and be recognized as an engineer (identities are inherently social), and (3) engage in sensemaking to reconcile the beliefs and identities the student brings with them to engineering with the expectations placed on them by the profession. The process of developing a professional identity is impacted by the socialization process within a particular profession (Seron, Silbey, Cech & Rubineau2016). Seron et.al.(2016) looked at the rituals of professional socialization in engineering. One of the key experiences they identified for incoming engineers was student recognition that there is a "pecking order" and the realization for most students that they are no longer in their accustomed position at the top of the class. Seron and colleagues also looked at how men and women students responded to this experience and found that women were more likely to look to teachers and grades for validation, while men more often pointed to external factors to explain their position. Because women are more likely to interpret their performance in challenging courses as an indication of their own ability and belonging in engineering, we hypothesized that those women who have a growth mindset will be more likely to develop a stronger identification with engineering.

Dweck (2006) uses the terms fixed and growth mindsets to explain the differences in how people approach learning and their worldview on intellectual capabilities. Students who believe that ability is a fixed trait tend to retain their entity orientation throughout college (Robins and

Pals, p. 322, 2002). Students possessing a fixed, or entity mindset (e.g., intelligence based on genetics) versus a growth, or incremental mindset (e.g., intelligence based on effort and hard work) are more likely to disengage when confronted with highly challenging coursework (Robins & Pals, 2002). Whether students approach or avoid tasks is driven by whether they view intelligence as fixed or as able to grow. Classroom interventions intended to prime growth mindsets are most effective for students with fixed mindsets and high skill levels in math. Also, priming students with activities encouraging growth mindsets led to increased motivation for all students, regardless of mindset orientation (Burns and Isbell, 2007). Classroom growth mindset interventions have also been effective in ceasing downward course grade trajectories (Blackwell, Trzesniewski, & Dweck, 2007). Educators want to create an environment where students feel comfortable developing their competence regardless of the difficulty of the tasks and this is best achieved with students embracing a growth mindset.

Considering the dearth of literature about mindset, engineering identity, and gender, we explore whether fixed or growth mindsets influence how students identify as engineers and see if this relationship differs for women and men. Understanding whether mindset contributes to engineering identity can help engineering educators understand how to design and create learning opportunities that cultivate engineering identities and promote engineering student persistence, particularly among women.

The Current Study

The purpose of this study is threefold: (a) to explore how does engineering identity develop during the first semester of engineering course work, (b) to determine if the development of engineering identity is related to how students view intelligence, and (c) to examine whether the relationship between views of intelligence and engineering identity differs by gender.

This study focused on the following exploratory research questions:

1. How does engineering identity change during the first semester of engineering courses?
2. How do fixed and growth mindsets relate to the development of engineering identity?
3. Do men and women’s engineering identity change in the same way during their first semester of engineering courses, and does the relationship between engineering identity and fixed or growth mindsets vary by gender?

Methods

Participants

This study was conducted in four first year engineering courses. Three of the courses are discipline specific (mechanical, civil, and chemical and biological engineering), while one course is for students who have not selected their official discipline. Engineering students, 266 male and 131 female, in four sections of first year engineering classes at a large research university participated in the study.

Procedure

Students were surveyed at five time points using scales to measure fixed and growth mindsets and engineering identity (Dweck & Leggett,1988; Estrada et al., 2011). We modeled the data using multilevel modeling to account for the nested nature of the data, repeated measures (level-1) nested within persons (level-2). At level 1, we used use fixed and growth mindsets as time-varying covariates. At level 2, we included gender as a predictor of the level-1 intercepts and slopes.

Measures

Students participated in five online surveys throughout the fall semester. The first survey used complete scales for all measures. The second, third, and fourth surveys contained short versions of each scale. The fifth survey was comprised of short scales for the mindset measures and a complete scale for engineering identity. Only the means of the short scales were used in these analyses.

To measure engineering identity, items from Chemers' science identity survey were adapted to engineers (Chemers et. al., 2010; Estrada et. al., 2011). The engineering identity measure contained items such as, "Being an engineer is an important reflection of who I am." Responses ranged from a scale of 1 (strongly disagree) to 7 (strongly agree). The engineering identity scale had acceptable internal consistency ($\alpha = .78$).

To measure fixed and growth mindsets, the implicit person theory scale (Dweck & Leggett, 1988) was divided into two scales measuring growth items such as "No matter who you are, you can significantly change your intelligence level" and fixed items such as "The kind of person someone is says something basic about them, and it can't be changed very much." Responses ranged from a scale of 1 (strongly disagree) to 6 (strongly agree). The fixed mindset scale had internal consistency of $\alpha = .63$. The growth mindset scale had internal consistency of $\alpha = .74$.

Plan of Analysis

Descriptive statistics were analyzed using IBM SPSS Statistics 24. The multilevel analyses were conducted with HLM v. 7 (Raudenbush & Bryk, 2002). The time variable was centered on time 1 (time 1=0, time 2=1, time 3=2, time 4=3, time 5=4). Dummy coding was used for the sex variable (males: gender=0, females: gender=1). Fixed mindsets and growth mindsets were grand mean centered on the first time point. Thus, only students who took the first survey were included in the analysis, and the analytic sample was smaller than the total sample ($n = 302$).

To answer the first research question, we estimated four competing models: (a) assumed no change in identity over time, (b) assumed linear change in identity, (c) assumed linear and quadratic change (e.g., an initial decrease followed by a slight increase in identity), and (d) assumed linear, quadratic, and cubic change over time (e.g., a slight decrease, followed by an increase, which eventually tapered off). Because the models were nested, we used chi-square difference tests to determine the model that best fit the data.

Next, we answered research question 2 by adding student fixed and growth mindset scores as time varying covariates at level one to the best fitting model from question 1. Thus, identity at each time point was also predicted by student fixed and growth mindset scores at the same time point.

Finally, to answer research question 3, we entered gender as a predictor of the intercept and each of the slopes to determine if males and females had different engineering identities, if their identity development differed across time, and if the relationship between fixed and growth mindsets on identity varied by gender.

Results

Descriptive Statistics

The descriptive statistics for engineering identity at each time point are provided in Table 1. At each time point, female students reported averaged lower engineering identities than males. The descriptive statistics for mindsets at each time point are provided in Table 2. Males and females reported similar fixed and growth mindsets over time.

Correlations for Level-1 and Level-2 variables indicate statistically significant positive relationships between time and fixed mindsets, fixed mindsets and identity, fixed mindsets and gender, growth mindsets and gender, and identity and gender. Statistically significant negative relationships were indicated between time and growth mindsets, and fixed and growth mindsets. Correlations are provided in Table 3.

The null HLM model indicated 31.5% of the variability in engineering identity was between students. Conversely, 68.5% of the variability was within students, (i.e., Intraclass correlation coefficient (ICC)= τ_{00} /[τ_{00} + σ^2]= .451/ [.451=.980]= 31.5%).

Research Question 1

The best fitting time only model indicated the model that included linear, quadratic, and cubic time parameters was the best fit to the data. The final model is reported in Table 4. The model implied trajectory is displayed in Figure 1. Overall, engineering identity started relatively high and then decreased slightly where it remained stable until the end of the semester when it dropped slightly again.

Research Question 2

Next, we added fixed mindset and growth mindset as time varying covariates of engineering identity. In this model, identity was predicted from the best fitting level one model, which included linear, quadratic, and cubic change over time, and also fixed and growth mindsets scores collected at each time point. Both fixed and growth mindset were positively predictive of identity; however, increase in growth mindset resulted in greater increases in engineering identity than increases in fixed mindset.

Figure 2 illustrates the model implied trajectories for five prototypical students who had: (a) average initial fixed and growth mindsets, (b) fixed mindset one standard deviation above average controlling for growth mindset, (c) growth mindset one standard deviation above average controlling for fixed mindset, (d) fixed mindset one standard deviation below average controlling for growth mindset, and (e) growth mindset one standard deviation below average controlling for fixed mindset. As shown in Figure 2, students with average fixed and growth mindset are illustrated with a solid black line. Students with above average growth mindsets consistently had the highest engineering identity (dotted gray line), followed closely by students with above average fixed mindsets (double gray line). Conversely, students with below average growth mindsets had the lowest engineering identity (dotted black line), while students who had below average fixed mindsets had slightly higher engineering identity (double black line) than students with below average growth mindsets. However, to put these results in context, the difference in engineering identity for students with above average and below average identity were only predicted to be about 0.26 units. The engineering identity scale had a standard deviation of .89 at the first time point, so the difference in engineering identity between above and below average in growth mindset was relatively small, i.e. around 30% of a standard deviation.

Research Question 3

Finally, we added gender (male: gender=0, female: gender=1) as level-2 predictors of the intercept (i.e., initial engineering identity), each of the time predictors (linear, quadratic, and cubic change), and the effect of fixed and growth mindset on engineering identity. None of the effects of gender were statistically significant, which indicated male and female initial engineering identity was not different at the beginning of the semester, males and females change in identity was similar over time, and the relationship between fixed and growth mindsets and engineering identity did not differ between males and females. However, we would like to note that two of the estimated parameters had *p* values that approached the threshold of $p < .05$, the effect of gender on initial engineering identity and the effect of gender on the relationship between growth mindset and engineering identity.

Discussion

Both fixed and growth mindsets were statistically significantly related to engineering identity. What we did not find was an impact of gender on the relationships between mindsets and engineering identity. Our result suggest that female students with fixed mindsets were no less likely than men to de-identify with engineering. The ability to identify as an engineer was greater for students with growth mindsets when compared to fixed mindsets. The same was true for women with growth mindsets in our study. Men and women with above average growth mindsets had similar engineering identities. Our results indicate women in first year classes enter engineering with essentially the same sense of identification with the field of engineering as men. Over the course of a semester, both male and female students saw similar dips in their engineering identity.

The lack of difference between males and females is potentially encouraging. It is possible that at least for some constructs the differences between men and women are becoming less obvious in first year courses in engineering. However, more research is needed. For example, we did not collect data on how difficult the students perceived the classes to be, and students with growth mindsets have been shown to persist in the face of difficulty. Therefore, the perceived difficulty of the class may have been a moderating factor of mindsets on engineering identity that we did not capture. We would also like to know if the similar engineering identity observed in our study between men and women persists into upper level classes.

Limitations

In this study, the students were all from one large, Midwestern research intensive university with a large engineering program. The results may not be generalizable to students in smaller programs or other types of universities. Also, not all students took the survey at every time point, and because of the way we chose to center the data, students who did not participate in the first survey were not included in the data analysis.

Future Research

The effects of fixed and growth mindsets were examined while holding the other constant (e.g., the effect of having a fixed mindset that was above average while holding growth mindset at its average). However, another approach might be to examine whether the relationship between identity and mindsets is a function of how different students are on the growth and mindset scales. For example, when a student encounters engineering content they find difficult, one might suspect a student who has a high growth mindset and low fixed mindset would be more likely to continue to think of themselves as an engineer while someone with a high fixed and low growth mindset in the same situation might be more likely to disengage from their engineering identity. Thus, interaction effects might need to be explored.

Engineering faculty may benefit from engaging their students in interventions over the course of a semester which target developing growth mindsets in all students. Our study has shown that engineering identity does slightly change over time for students- unfortunately, engineering identity decreased.

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Table 1.

Descriptive Statistics for Engineering Identity Separated by Gender

	Time 1		Time 2		Time 3		Time 4		Time 5	
	N	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*
Male	194	5.28 (1.03)	184	5.30 (1.18)	193	5.19 (1.25)	183	5.31 (1.30)	197	5.21 (1.31)
Female	108	5.09 (0.98)	106	4.93 (1.06)	108	5.00 (1.14)	98	5.04 (1.25)	108	4.94 (1.37)

Table 2.

Descriptive Statistics for Mindsets by Time and Gender

		Time 1		Time 2		Time 3		Time 4		Time 5	
		N	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*
Fixed	Male	194	3.22 (0.93)	183	3.34 (0.94)	193	3.27 (0.94)	183	3.24 (1.08)	197	3.46 (1.04)
	Female	108	3.02 (0.93)	106	3.25 (1.01)	108	3.17 (1.04)	98	3.20 (1.09)	108	3.21 (1.03)
Growth	Male	194	4.80 (0.88)	183	4.67 (0.90)	193	4.58 (0.89)	183	4.62 (1.09)	197	4.55 (0.93)
	Female	108	4.82 (0.86)	106	4.58 (0.97)	108	4.52 (1.09)	98	4.65 (1.05)	108	4.36 (1.00)

Table 3.

Correlations for Level-1 and Level-2 Variables

Measure	1	2	3	4	5
1. Time	-				
2. Fixed Mindset	.05*	-			
3. Growth Mindset	-.10**	-.25**	-		
4. Identity	-.02	.11**	.22**	-	
5. Gender	.00	.07*	.03	.10**	-

Notes. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Table 4.

Fixed and Random Effects for the Final HLM models for Research Questions 1, 2, and 3

Fixed Effect	Research Question 1: Best Fitting Time Model	Research Question 2: Fixed and Growth Effects on Identity	Research Question 3: Gender on Level 1 Effects
For Intercept, π_0			
Intercept, β_{00}	5.21 (0.06)***	5.21 (0.06)***	5.28 (0.07)***
Female, β_{01}			-0.20 (0.12) $^{+}$
For Linear time slope, π_1			
Intercept, β_{10}	-0.23 (0.10)*	-0.20 (0.10)*	-0.15 (0.12)
Female, β_{11}			-0.14 (0.2)
For Quadratic time slope, π_2			
Intercept, β_{20}	0.13 (0.06)*	0.12 (0.06) $^{+}$	0.09 (0.08)
Female, β_{21}			0.08 (0.13)
For Cubic Time slope, π_3			
Intercept, β_{30}	-0.02 (0.01)*	-0.02 (0.01) $^{+}$	-0.02 (0.01)
Female, β_{31}			-0.01 (0.02)
For Fixed Mindset slope, π_4			
Intercept, β_{40}		0.08 (0.03)*	0.09 (0.03)*
Female, β_{41}			-0.05 (0.06)
For Growth Mindset slope, π_5			
Intercept, β_{50}		0.14 (0.04)**	0.18 (0.04)***
Female, β_{51}			-0.12 (0.06) $^{+}$
Random Effects			
Level 2 intercept, r_0	0.783***	0.709***	0.699***
Linear Time slope, r_1	0.614***	0.526*	0.541**
Quadratic Time slope, r_2	0.248***	0.201*	0.204**
Cubic Time slope, r_3	0.005**	0.004*	0.004*
level-1, e	0.252	0.263	0.260

$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

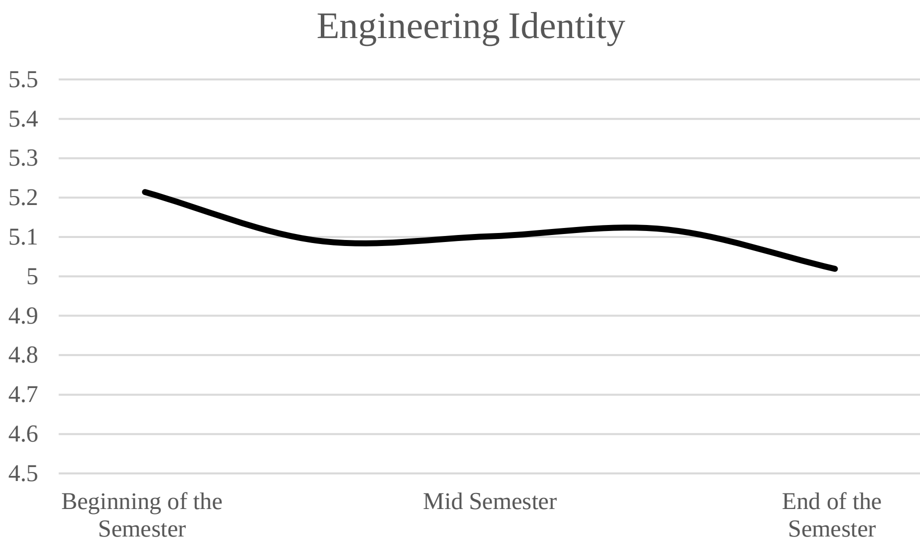

Figure 1. Change in engineering identity as a function of time.

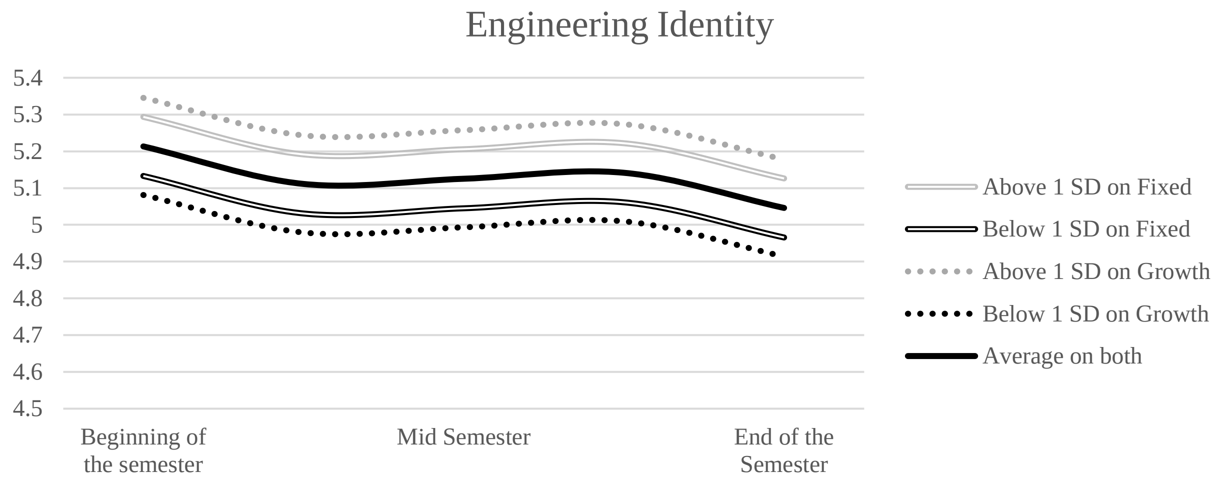

Figure 2. Engineering Identity as a function of fixed (*SD*=1.00) and growth (*SD*= 0.96) mindset.