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Changes in Engineering Identity Among First-Year Undergraduates During the COVID-19 Pandemic

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ASEE Paper Title: Engineering Identity Among Pre-Major Engineering Undergraduates Measured Prior to and During the Covid-19 Pandemic

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Introduction

Prior to the pandemic, universities nationwide were struggling with retention and representation problems in their engineering programs. Engineering is among the college majors with the largest net losses from switching. Astorne-Figari and Speer (2019) estimate that 31% of students nationally who declared Engineering majors switched out of them. While there is strong evidence of the importance of having a strong engineering identity for student retention in the engineering field (Carlone & Johnson, 2007; Chemers et al., 2011; Estrada et al., 2011; Merolla & Serpe, 2013, Oseguera et al., 2020), there is limited research on how the Covid-19 pandemic may have impacted scientific and engineering identity (Sheppard et al., 2022). Our work uses survey data from before and during the Covid-19 pandemic to compare changes in students' engineering identity and examine how students' reported Covid-19 stressors were associated with engineering identity during the pandemic. Our work focuses on the first and second-year experience of engineering students, as these two years are critical to academic success and retention in the engineering field. During these transitional years, students begin to bridge connections to peers and faculty, develop motivational beliefs, and make career choices (President's Council of Advisors on Science and Technology, 2012; Oseguera et. al., 2019; Robinson et al., 2019; Jones, et al., 2010).

The educational disruption caused by the pandemic likely reduced engineering students' opportunities to engage with faculty members and participate in undergraduate research and support programs, which are facilitators of engineering identity development. Sheppard et al. (2022) in their work on engineering student sense of belonging and identity found that the pandemic had disparate impacts on students depending on the position in the curriculum. While all students experienced challenges with the pandemic, upper-class students found it easier than first-year students to move to remote coursework because relationships with peers, staff and faculty were mostly already established.

Our work highlights engineering identity by various social identity groups, including gender, racial/ethnic identification. Disparities between diverse social identity groups in terms of representation within the Engineering field exist. For instance, Latinx students earn 12% of the total awarded engineering bachelor's degrees, African Americans earn 4%, and women 19%. Discordantly, however, Latinx individuals represent 19% of the U.S. population, African Americans 13%, and women comprise 51% of the U.S. population (National Center for Science and Engineering Statistics, 2021). This work studies whether the Covid-19 pandemic exacerbated existing inequalities by focusing on changes in early academic career students' engineering identity during the pandemic and how such changes differ among students from diverse social identity groups.

Building on previous work, we use a dataset that includes engineering identity questions measured when students were in the fall of their first year of college (collected prior to the pandemic) and re-administered to the same group of students during the fall of their second year of study (collected during the pandemic). The survey included only those students who were enrolled in the College of Engineering as engineering pre-majors. We hypothesize that, for a cohort of college students, engineering identity will decrease after the onset of the pandemic, because such identity development is influenced by day-to-day interactions within students' engineering community and their reflections about these experiences (Carrino & Gerace, 2016).

We also hypothesize that the magnitude of changes in students' engineering identity will vary by self-identified gender, and racial/ethnic student subpopulations.

Our work explores the relationship between students' engineering identity prior to the pandemic and during the pandemic by gauging student performance, competence in engineering, and feelings of recognition within the field, which are all factors that have been recognized as the drivers of disciplinary identity development (Carlone & Johnson, 2007; Godwin, 2016). To explore our research questions: How does engineering identity change between students first to the second year of study? What is the relationship between performance, recognition, and competence on students' second-year engineering identity? What is the relationship between Covid-19 related stressors and engineering identity?

Literature Review

Engineering Identity

The importance of developing an engineering identity on student success has been established in the literature (Carlone & Johnson, 2007; Lane, 2016; Ong et al., 2018). Stronger engineering identity has also been linked to retention (Matusovich et al., 2010; Pierrakos et al. 2009). Researchers have posited that engineering identity is not a static trait. Instead, engineering identity is "produced" (Tonso, 2006). Scholars have suggested that exposing students to significant engineering-related experiences is critical for the production of an engineering identity (Pierrakos et al., 2009). Furthermore, recent findings suggest that students develop their engineering identity over time (McLean et al., 2022). McLean et al. (2022) used a longitudinal qualitative approach to study students' engineering identity, and they found that there were changes in students' engineering identity over time, and that the tempo of the engineering identity development varied among diverse group of students. They observed that much of the changes in students' engineering identity were slow, rather than quickly produced by one special moment.

When students question their discipline identity, they have higher chances of experiencing discipline disengagement, which reduces their engagement in behaviors that are necessary for their career success (Estrada et al., 2018). Women, underrepresented racial/ethnic minorities (URM), and gender non-conforming students encounter challenges within engineering programs (Fleming et al. 2013; Tonso, 2006) which then can result in lower reports of healthy engineering identity. However, scholars have established that women and URM who have successfully navigated the engineering environment have frequently developed an identity that is a combination of their engineering and other salient identities, such as gender and racial/ethnic identities (McGee, 2016). In this discipline identity development process, URM students redefine what it means to be a scientist (or engineer) and a person of color for them (Herrera et al., 2012; Tran et al., 2011), and women develop compatibility between their discipline and gender identities (Cech & Waidzunas, 2011; Rosenthal et al., 2011).

Other research on engineering identity identified which college experiences facilitate its formation. Research shows contact with faculty (Carlone & Johnson, 2007; Eagan et al., 2012), participation in support programs (Merolla & Serpe, 2013, Oseguera et al., 2020; Lane, 2016; Ong et al., 2018), undergraduate research (Davis & Wagner, 2019), involvement with individuals outside the classroom (Rodriguez et al., 2018), and participation in co-ops or internships

(Matusovich et al., 2011) positively influence engineering identity formation. Similarly, researchers have identified that certain types of interactions foster students' engineering identity development, such as student participation in professional and peer networks (Crede & Borrego 2010; Dehing et al., 2013). Likewise, interacting with role models also facilitates students' engineering identity formation (Dehing et al.2013).

Campus Closures and their Effects on Students

Campus closures during the first year of the pandemic disrupted developmentally typical experiences for students, such as time spent with friends, faculty members, student affairs personnel, and advisors (Graf & Bolling, 2022). According to early research, this disruption had a significant impact on students' mental health (Cao et al., 2020; Copeland et al., 2021; Liu et al., 2020; Torales et al., 2020; Odriozola-González et al., 2020; Fruehwirth, Biswas, & Perreira, 2021; Gopalan et al., 2022). The pandemic disruption also affected diverse social identity groups differently, as researchers have shown that out-of-state students experienced differences in available resources during the pandemic (Lederer et al, 2020). Sheppard et al. (2022) found differences between self-identified men and women students' sense of belonging, as men reported lower effects of the pandemic on their sense of belonging than their woman peers (Sheppard et al., 2022).

Researchers are working to understand the pandemic's influence on other phenomena, which might have a long-term effect in engineering persistence and graduation, like engineering identity. In this regard, research has suggested that the Covid-19 pandemic posed challenges that were particularly relevant for the development of a STEM identity. Furthermore, researchers have posited that, while remote learning limited every student's opportunities to enact their STEM identities in the classroom and to 'do STEM' in other settings outside of the classroom, it was particularly women and minoritized students who highlighted the importance that seeing and interacting with STEM people who share their social identities have for developing their own STEM identities (Stewart et al, 2023). This paper aims to contribute to this body of research by focusing on the changes in disciplinary identity perceptions and the relationship between Covid-19 stressors and disciplinary identity during the first year of the pandemic. We hypothesize that the pandemic may play a role in decreasing engineering identity from the first to the second year.

Engineering Identity Theoretical Framing

The theoretical framework guiding this study is Carlone and Johnson's (2007) Science Identity Model, which has been used by other scholars to examine engineering identity (Godwin, 2016).

Figure 1: Carlone and Johnson's (2007) Science Identity Model

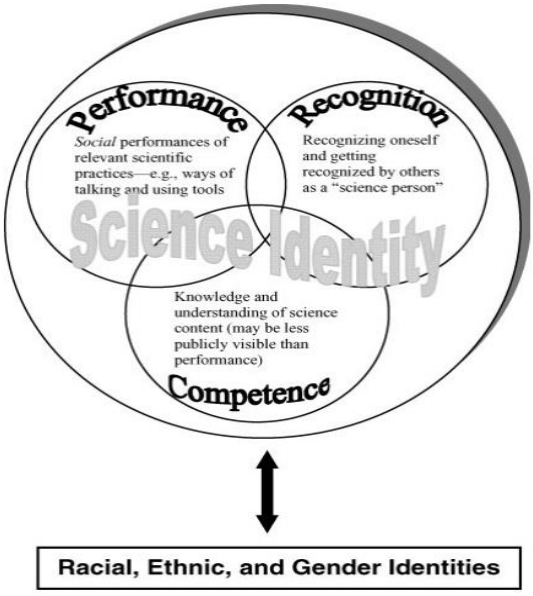

Figure 1. Model of science identity that guided our initial analysis.

Three interrelated dimensions comprise disciplinary identity: social performance of relevant disciplinary practices, competence –understood as having the knowledge and understanding of the discipline–, and recognition, which includes both self-recognition and recognition by others as a member of the disciplinary field (Carlone & Johnson, 2007). Acquiring any disciplinary identity requires a developmental process of exploration (Carrino & Gerace, 2016), where engagement in discipline-specific learning activities is essential. In this process, both our personal background –including our demographic characteristics– and cultural beliefs and practices intersect with the disciplinary contexts (Davis & Wagner, 2019). Hence, engineering identity arises when, "as a result of an individual's competence and performance, a person is recognized by meaningful others as an engineer" (Carlone & Johnson, 2007, p. 1192), while simultaneously recognizing herself/himself as an engineer.

For the purposes of our study, we supplemented the Carlone and Johnson (2007) science identity model to include Covid-19 stressors. Covid-19 stressors were added to determine if there is a relationship between stressors and engineering identity.

Data

We used two data sources to construct our analytic dataset. The first source is from a multi-wave panel survey that was administered to engineering students at a large public research university in the northeast. This study uses the survey data collected in the fall 2019 (as first-year students) prior to the pandemic and in the spring 2021 semesters (as second-year students) during the pandemic. During both waves, students were asked about their engineering identity, academic abilities, sense of belonging and academic validation, with pandemic-specific questions incorporated in the spring 2021 wave. While the second-year survey was administered in spring of 2021, survey questions asked students to reflect back to the prior semester of fall 2020. The fall 2020 survey was postponed to the following spring due to concerns about survey fatigue.

The framing of the question was important because we wanted to compare the first and second-year student fall experience. For context, the cohort responding to this survey entered their second year in the middle of a pandemic when most campus services were limited or restricted and most courses were only offered remotely and who also had the spring of their first year of college interrupted when campuses had to abruptly switch to remote instruction. There were also strict restrictions for students electing to return to on-campus housing and weekly Covid-19 testing policies in place for students. Even with the remote education requestions, in the fall of 2020, approximately 40% of students who responded to the survey were living in on campus housing, 35% where within the same local area as the university and 25% were off campus and outside of the campus metro area.

The participants for this study were drawn from the entire population (N=1767) of the fall 2019 entering first-year cohort. The first-year survey was administered online in the fall of 2019 when students were in their first semester of their first year of college. A second-year experience survey was administered to all second-year students (N=1632) in the spring of 2021 asking students to reflect back upon their experiences in their fall semester experience of their second year in college. The College of Engineering experienced an 8% attrition rate (135 students)from the start of first to second year. Monetary incentives were offered to students who participated in the survey. Students were given the option to opt out of participation in any research or the collection of personal information. Furthermore, students were given the option not to respond to certain questions. The second source of data is derived from institutional-level databases. The College of Engineering at the institution included in the study, provided administrative-level data for students who agreed to participate in the research. The administrative data was then used to construct student subgroup categories such as gender, state residency, and underrepresented minority (URM) categories and included a student's academic performance metric of grade average. The URM category includes all students identified as Asian, Black, Latinx, and Multi-race. It is important to note that the collapsed URM group is predominantly domestic Asian students. There were too few Black, Latinx and Multi-race students who responded to the survey to include as separate subgroups. Overall, the population of students who participated in the survey were relatively representative of the full population, with women in-state students slightly overrepresented, and men, and out-of-state slightly underrepresented to the full population. For URM and White students groups, the proportion of students survey matched the proportions of the full sample. We also examined the proportion of students who did not respond to the survey in both years, as well as the students who responded to the first-year survey, but not the second-year survey. We found similar subgroup proportions described in the overall sample population. Student administrative data was merged with the survey responses to create one complete dataset for analysis. Because we were interested in understanding change in measures between time 1 (i.e., as first-year students) and time 2 (as second-year students), we limited our sample to those students who responded to both surveys. For the engineering identity means tests, the number of observations was N=142 due to missing observations for some questions. Survey responses from international students were dropped because we had a low response rate for international students.

Table 1: Sample Demographics Student Respondents by Subgroups

Proportion by demographics	Fall 2019 First-Year Student Population	N	Survey respondents across both first- and second year surveys	n
Gender				
Woman	0.26	453	0.37	52
Man	0.74	1314	0.63	90
State residency				
In-state	0.62	1090	0.77	110
Out-of-state	0.38	677	0.23	32
Race/ethnicity				
White	0.73	1298	0.73	104
URM	0.27	469	0.27	38

Methods

To analyze our survey and administrative data, we conducted a quantitative analysis using t-tests and ordinary least squares (OLS) analysis. First, descriptive statistics and t-tests were used to determine if there were any statistically significant changes in responses of all respondents and then respondents by subgroups between the two periods. These subgroups include identified gender, in-state or out-of-state residency, and race/ethnicity (see Table 1). Paired sample t-tests were then used to compare raw engineering identity scale response means within gender and racial/ethnic subgroups in the first and second-year student experience periods. Finally, t-tests were also conducted between gender and racial/ethnic subgroups in the two periods.

Next, we applied an OLS regression analysis using student responses during their second year which coincided with the pandemic. For our dependent variable, we used the scores from Chemers (2006) scale that assess science identity, and expanded it to include engineering identity (Oseguera et. al., 2019; De Los Rios et. al., 2022). Next, for our independent variables, we operationalize the three dimensions (performance, competency, and recognition) of Carlone and Johnson's (2007) science identity model to frame our OLS regression analysis. Three interrelated dimensions comprise disciplinary identity: performance, competence, and recognition (Carlone & Johnson, 2007). To measure performance, we used grade averages. We used fall first-year GPA data over fall second-year GPA data to operationalize performance as the university switched to an optional alternative grading policy during the pandemic which resulted in less reliable GPA data. For competency, we used students' self-rating of academic skills to operationalize how competent a student is in the material. Finally, recognition was measured using the academic validation scale which includes questions on whether faculty recognized student performance. The scales have been validated in the literature and we also ran a confirmatory factor analysis with these data. We also incorporated a Covid-19 Stressors scale (Alpha=.73) to determine the relationship the pandemic had on students' engineering identity. The individual items that make up these factors are included in the appendix. As a control, we included gender, race/ethnicity and engineering identity scores measured as first-year students.

Results

Within-group differences between first and second year

Statistical means testing results were mixed. First, when reviewing engineering identity means scores before applying any statistical tests, in-state, white and men students all had increases in mean scores for engineering identity from the first year to the second year. Women, and out-of-state students had mean score decreases from fall of their first year to fall of their second year (see Table 2). When applying paired t-tests for the means by subgroup, we did not find any statistically significant differences between the two periods (p-value>.10). Although none of the within-group differences were statistically significant, the results are interesting because they suggest that engineering identity remained relatively stable from the first year to the second. This is an important finding because independent from the pandemic, identities tend to changeover time (McLean et al., 2022). A potential reason for the stagnation in identity is that remote instruction may have reduced opportunities for students to interact with each other in an academic context.

Between group differences in the two periods

To explore changes in engineering identity by subgroup before and during the pandemic, paired t-tests were conducted. When reviewing means differences within subgroups (see Table 2), in the first year there were statistically significant (p-value<.01) differences between URM and White students, with URM students having lower mean scores. In the second year, the results were similar (see Table 2), with a statistically significant difference between URM and White response means in the second year. In context with the results for the within group differences, the between group results also show that while there were differences between some subgroups, the differences persisted from the first year to the second year. This finding is interesting because it also indicates that engineering identity stagnated between the two periods, which is inconsistent with the literature indicating that this identity, although slowly, is continuously changing over time (McLean et al., 2022).

Table 2: Engineering Identity Mean Scores by Subgroup (N=142)

	Fall 2019 1st Yr Mean (s.e)	Fall 2020 2nd Yr Mean (s.e)	Diff. in Means by category between 1st and 2nd Yr	Diff. in Means between subgroup in 1st Yr (s.e)	Diff. in Means between subgroup in 2nd Yr (s.e)
Overall	3.91 (0.06)	3.95 (0.07)	0.04		
Gender					
Women	3.92 (0.10)	3.88 (0.10)	-0.04	0.01 (0.13)	-0.12 (0.13)
Men	3.91 (0.08)	4.00 (0.09)	0.09		
State Residency					
In-State	3.89 (0.07)	3.97 (0.07)	0.08	-0.08 (0.07)	0.06 (0.15)
Out-of-state	3.97 (0.12)	3.91 (0.13)	-0.06		
Race/ethnicity Groups					
White	4.01 (0.07)	4.06 (0.08)	0.05	-0.34*** (0.13)	-0.38*** (0.14)
URM	3.67 (0.11)	3.68 (0.11)	0.01		

** p<0.10, ** p<0.05, *** p<0.01*

Table 3: Correlation Table

	Eng. Identity 1stYr	Eng. Identity 2ndYr	Fall 1stYr GPA	Fall 2ndYr GPA	Academic Skills 1stYr	Academic Skills 2ndYr	Academic Validation 2ndYr	Stressors 2ndYr
Eng. Identity 1stYr	1.00							
Eng. Identity 2ndYr	0.54	1.00						
Fall 1stYr GPA	0.07	0.06	1.00					
Fall 2ndYr GPA	0.10	0.13	0.86	1.00				
Academic Skills 1stYr	0.42	0.21	0.51	0.46	1.00			
Academic Skills 2ndYr	0.45	0.39	0.56	0.60	0.64	1.00		
Academic Validation 2ndYr	0.32	0.22	0.01	0.06	0.17	0.26	1.00	
Stressors 2ndYr	-0.04	-0.16	-0.28	-0.34	-0.20	-0.34	-0.10	1.00

**Questions on academic validation and questions about stressors related to Covid-19 were added to the survey in the second-year. See Appendix A for item scaling.*

Table 4 summarizes the regression results of our outcome factor "engineering identity at the second year" for the overall sample. Results shows that engineering identity during the first year of college is the only one predictor of the Model 1 that had a significant effect on students' engineering identity at their second year. Results of Model 1 also show that women students (as compared to men students), and URM students (as compared to white students), had lower engineering identity score than their men and white counterparts during their second year; however, the relation between these independent variables and the outcome variables is not significant. Similarly, the results of Model 1 indicate that, while first-year GPA is positively associated to students' second-year engineering identity, this relationship is not significant.

Model 2 included all the control variables that were included in Model 1, along with the the dimensions of the theoretical framework used to capture competence, performance and recognition. The regression coefficients for first-year fall cumulative GPA demonstrated significant changes after second-year self-assessed academic skills and the academic validation factor were included. In model 1, first-year GPA exhibits a positive relationship with the dependent variable, however, once students' self-assessment of their academic skills and academic validation are taken into account, the coefficient for first-year GPA becomes negative.

In terms of the changes in R^2, with the addition of the two predictors of model 2, it increased from .285 to .307, indicating the strength of the relationship between students' second-year self-assessed skills, academic validation, and engineering identity at their second year of college, controlling for the other independent variables in the model. The results of model 2 show that, while neither students' gender, racial or ethnic social identities have any effect on their engineering identity at the second year, students who exhibit a strong first-year engineering identity, and students who positively assessed their skills during the second year are significantly more likely to exhibit a strong engineering identity during their second year of college. Unexpectedly, according to our results, students' experiences of academic validation in the classroom do not have a significant effect on students' engineering identity at the second year of college.

Finally, in model 3, a variable gauging Covid-19 stressors was included in the model. The results of model 3 show that there was a small increase in the R^2, which implies that the measured Covid-19 stressors did not have a strong effect on students' engineering identity at their second year.

Table 4: Ordinary Least Squares Regression of Engineering Identity on Contributing Factors for the Second-year Student Experience

	Model 1	Model 2	Model 3
Constant	1.75	2.26	2.67
	(.71)	(0.79)	(0.90)
Controls			
First-year Engineering Identity (Factor)	0.53***	0.42***	0.44***
	(0.08)	(0.08)	(0.09)
Woman (Versus: Men)	-0.15	-0.09	-0.06
	(0.17)	(0.16)	(0.16)
URM (Versus: White)	-0.29	-0.24	-0.23
	(0.18)	(0.18)	(0.18)
Disciplinary Identity Model			
Performance			
First-year Fall Cumulative GPA	0.05	-0.29	-0.32
	(0.19)	(0.24)	(0.24)
Competence			
Second-year Academic Skills (factor)		0.29**	0.25**
		(0.12)	(0.12)
Recognition			
Second-year Academic Validation (factor)		0.01	0.01
		(0.09)	(0.09)
Covid-19 Stressors			
Second-year Stressors (factor)			-0.09
			(0.08)
Adj. R-Squared	0.285	0.307	0.311
Obs	142	142	142

Note: All factors have been rescaled to 0-5. See appendix A for factor scaling.

Limitations

There are several limitations to our study. First, our study only included students who responded to our survey in both their first and second year. Additionally, we did not study students who left the college after their first year. This is important as the students who may have matriculated out of the College of Engineering may have provided different results regarding identities. While the number of students who left the college from the first year to the second year was only 8%, the students who left may have provided valuable insight about their engineering identity.

Another limitation of our study is that we did not have a large number of observations. Almost half as many students who responded in the first year did not respond to our survey in the second year. More observations would have improved our analysis. Finally, the Covid-19 stressors we used were developed early in the pandemic. As education research relating to the pandemic developed, so did the types of survey instruments used to measure Covid-19 stress. While we operationalized a disciplinary identity framework that was not designed for this study, we believe that based on the results are still helpful in understanding the relationship between engineering identity and the disruptions created by the Covid-19 pandemic.

Significance of Work

In furthering educational research, this work's significance lies in its ability to investigate changes in Engineering Identity before and during the pandemic, as well as whether Covid-19 stressors influenced engineering identity. Overall, when comparing means by subgroup for before and during the pandemic, we did not find any statistically significant differences for subgroups. This finding indicates that engineering identity remained stagnant for students after the onset of the pandemic. This finding is interesting because other research suggests that identity scores should change as a student spends more time in the program. Our between group results also indicated that when gaps between groups existed prior to the pandemic, the gaps persisted even after the pandemic. The stagnation in engineering identity may be due to the lack of in-person curricular and extracurricular activities. These findings are also important to faculty and staff working with students. The results suggest that emphasis may need to be placed on developing engineering identity for current students as a retention effort.

Our regression model results also provided some interesting insights. When including Covid-19 stressors in our model, we did not find statistically significant results. This was illuminating for us, as we had hypothesized that engineering identity would decrease from the first year to the second year because of the abrupt shift from in-person to remote experiences. The regression results with the Covid-19 stressors are also consistent with our paired t-test results for within and between groups in that the pandemic experience did not seem to have a negative effect on the mean engineering identity score. However, the pandemic may have not allowed engineering identity to grow.

Researchers hoping to further the work should continue to investigate whether the different dimensions of the discipline identity model factors become significant as students build identity into their junior and senior academic years. Furthermore, more work should be done on students who started as engineering pre-majors in the fall 2020 cohort. The reason being that for fall 2020 students, starting in an academic environment with social distancing restrictions may have impacted their ability to develop and grow their identities.

Appendix A

List of Selected Survey Items in each Construct

Construct in the Analysis	T1	T2
Engineering Identity Scale (5 Items) • I derive great personal satisfaction from working on a team that is doing important research. • I have come to think of myself as an 'engineer/computer scientist.' • I feel like I belong in the field of engineering/computer science. • The daily work of an engineer/computer scientist is appealing to me. • I am developing a strong sense of belonging to the community of engineers/computer scientists	Alpha=0.81 RMSEA=0.176 CFI=0.919 TLI=0.838	Alpha=0.83 RMSEA=0.073 CFI=0.988 TLI=0.976
Competency (Self-Assessed Academic Skills) (5 Items) • Critical thinking skills • Ability to manage your time effectively • Academic ability • Mathematical ability • Writing ability	Alpha=0.67 RMSEA=0.166 CFI=0.907 TLI=0.814	Alpha=0.65 RMSEA=0.073 CFI=0.974 TLI=0.947
Recognition (Academic Validation Scale)(6 Items) • College of Engineering faculty were able to determine my level of understanding of the course material • Felt that College of Engineering faculty provided me with feedback that helped me assess my progress • Felt that my contributions were valued • Felt that College of Engineering faculty encouraged me to ask questions and participate in discussions • College of Engineering faculty encourage me to meet with them after or outside of class time • College of Engineering faculty show concern about my progress	N/A*	Alpha=0.83 RMSEA=0.08 CFI=0.977 TLI=0.961
Covid-19 Stressors (6 Items) • Meeting entry to major requirements • Keeping up with coursework requirements • Doing well in college • Health of loved ones • Juggling other priorities beside academic work (e.g. family care) • Other (Please specify)	N/A*	Alpha=0.73 RMSEA=0.07 CFI=0.989 TLI=0.966

**Items not administered in the first-year.*

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