First-year Engineering Students' Sense of Belonging: Impact of COVID-19 and Efficacy as a Predictor of Graduation

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FIRST-YEAR ENGINEERING STUDENTS' SENSE OF BELONGING: CHANGE OVER THE FIRST SEMESTER AND EFFICACY AS A PREDICTOR OF GRADUATION

Introduction

This Complete Paper presents findings aggregating across seven cohorts (all students starting this engineering program in years 2015-2021) that examined how first-year engineering students' sense of belonging in college changed over the course of their first semester of engineering, how the COVID-19 pandemic impacted their sense of belonging, and the efficacy of sense of belonging as a predictor of graduation. This paper is part of a larger set of studies conducted by an interdisciplinary group of researchers interested in retention of first-year engineering students. These researchers include STEM professors and teacher educators as well as cognitive scientists from units across the university. The research group has conducted longitudinal research on first-year engineering students' attitudes and beliefs about engineering, college, sense of belonging, as well as demographic and performance data since 2010. They collect much of the data on a survey given to all engineering students during their first semester introduction to engineering course. Since 2015, sense of belonging has been included on this survey, and with an extensive historical database, we make the comparison of how COVID-19 affected first-year students' sense of belonging in college, as well as exploring the efficacy of freshmen year sense of belonging as a potential predictor of graduation.

Research Questions

1. How does sense of belonging in first-year engineering students change over the first semester?

2. Can a short sense of belonging measure given in the first year for engineering students be predictive of future graduation?

Sense of Belonging

Social belonging is defined as feeling acceptance in a group [1]. The sense of belonging scale used in this paper is a four-item scale to assess students' perceptions about sense of belonging in college [2]. Sense of belonging has been studied as a possible predictor for student retention and efforts to increase a sense of belonging can help increase student retention [1]. Previous research on the need to belong in the context of schooling shows that academic classrooms and/or the school as a whole are important to contextualize the individual experience such as interpersonal connections that can inform a sense of belonging [3].

Persistence to Graduation

A parsimonious yet meaningful belonging scale as a predictor to graduation is desirable to prevent overloading the students in terms of survey fatigue, since other measures are also included in their survey. Exploring sense-of-belonging in the freshman year as a viable predictor for ultimately graduating with an engineering degree would be quite useful, even accepting that many things in the years between first year and graduation can have substantial impacts on degree trajectories. We would like to have a prediction measure within the first semester of the program to viably estimate students' eventual graduation so that we can identify those individuals for whom an early intervention might be most beneficial. We are exploring if it is possible to identify students within their first semester who, based on their sense of belonging scores, could be targeted with interventions early enough to impact their persistence to graduation.

Sense of Belonging as a Predictor of Success

A sense of belonging in college is defined primarily by perceptions of acceptance, fit, and inclusion on campus [4], [5], [6], [7]. A positive sense of belonging has been shown to improve academic and social adjustment [8], [9], involvement and intention to persist in college [10] and reduce burnout in college [11]. We aim to use the sense of belonging measure to determine if this short, 4-item scale can be a useful predictor of future graduation, and if so thus be useful for determining students who could benefit from an early intervention to retain them.

COVID-19 Pandemic

The response to COVID-19 during the Fall 2020 semester shifted much of in-class instruction to completely remote or hybrid course formats. As a result of this unanticipated shift of course instructional formats, the potentially socially isolating nature of remote course instruction may have impacted students' sense of belonging. This may have subsequent longer-term impacts on student success since sense of belonging in college has been linked to retention, persistence, academic success, and graduation [1]. Because sense of belonging is linked to persistence, then there is the potential for COVID to have an impact on future graduation for the COVID (starting fall 2020) cohort.

Methods

Participants were first-year engineering students in seven consecutive cohorts from 2015 through 2021. A total of 2880 students from an urban, southeastern, research university participated by completing all questions on the relevant constructs of the survey at the beginning of their first semester in engineering, and then completing the same survey again at the end of

their first semester. The survey includes a four-item sense of belonging scale modified from Yeager [2]. 78% of participants are white, 6% are Asian, 5% are Hispanic, 4% are Black, and 4.5% are two or more races. 76% of participants are male, and 24% are female. All student demographic labels were self-selected by the students as part of their enrollment at the university.

To analyze sense of belonging in college by race we exclude Asian students from racial analysis following prior established research [12], recognizing that while Asians are an ethnic minority in the US, they are generally not underrepresented in STEM [13]. We compared the mean change in sense of belonging of white students and under-represented minorities. Excluding the Asian students from this analyses, the resulting distribution of race remaining in our sample was: 82% white, 5% Black, 5% Hispanic, and 5% two or more races. For the gender analysis we included the entire sample and compared the mean change in sense of belonging of men and women.

A series of paired sample t-tests were employed to compare the change in sense of belonging in individual students over the course of their first semester. The series of t-tests were used to analyze the change in sense of belonging over 7 cohorts, from 2015-2021. To explore research question 2, we use a logistic regression to explore the predictive possibility of sense of belonging for persistence to graduation.

Logistic Regression

Logistic Regression (also referred to as logit model) predicts the likelihood of an event occurring by fitting data to a logistic curve. A logit function is applied on the odds of an event occurring, p/(1-p), where p is the probability of an event occurring. The ln(p/(1-p) is known as

the log odds and is used to create the probability of an event occurring based on all predictor variables. The outcome is a probability based on a dichotomous dependent variable bounded between 0 and 1.

As is typical in regression analysis, logistic regression uses predictor variables that can be either discreet or continuous. In this study, the dichotomous dependent variable is whether a student graduates college or not based on our predictor variable of sense of belonging. For the logistic regression analysis, we define a cutpoint—ultimately a predictor variable value—at which we wish to establish the cutoff for predicting graduation success. We would like to identify the cutpoint within our logistic regression model at which we get the best prediction of actual non-graduates in the model's prediction. When establishing a cutpoint for data that is skewed, it is acceptable to change the prediction of an event happening away from 0.5 (equal odds, which is typically the default cutpoint for a logistic regression absent any compelling reasons to set it differently) to a different number scaled to the particular dataset. The data analyzed here represents students who are predicted to graduate. Identifying an overall graduation rate of about 70% from simple descriptive summaries of our total data set, we set our logistic regression model cutpoint to 0.70. This means that we are seeking to fit the best logistic model to explore if the predictor variable sense-of-belonging can meaningfully predict those more or less likely to graduate than the group mean.

Logistic regression analysis is used to predict the success outcome of graduation in 5 years. We used a 5-year graduate rate since inspection of our longitudinal data showed that 94% of students who would ultimately graduate had done so by 5 years. Given the 5-year lag time necessary between freshman year survey measurement and for this graduation outcome to be present in the data, only cohorts beginning in fall of years 2015-2017 had reached the 5-year

graduation window at the time of our analyses, and so only those cohorts were used for this portion of the analysis. A logistic regression model was built separately exploring the model's predictive ability of sense of belonging measured at the beginning of the first year, and again for the same measure taken at the end of first semester. Since logistic regression requires a large sample size to be an effective analysis tool, no subgroup analysis was done.

Results for Research Question 1

A paired samples t-test comparing the mean sense-of-belonging change from beginning of freshman year to the end of first semester was computed for seven cohorts of students: fall 2015 – fall 2021 starting semesters (see Table 1 and Figure 1 which represents the same data visually). In addition, we reported the effect size of any statistically significant difference as Cohen's *d*. This effect size captures the magnitude of any difference in standard deviation units. A commonly accepted interpretation of the magnitude of Cohen's *d* effect size is: small *d* = 0.2, medium *d* = 0.5, large *d* = 0.8 [14] which must be interpreted within the context of the study.

Table 1. Mean Change in Sense of Belonging per Year

	Mean Change	Effect Size (Cohen's *d*)
2015	0.39*	0.11
2016	0.44*	0.13
2017	-0.10	-
2018	-0.32	-
2019	-0.80*	0.23
2020	-0.95*	0.30
2021	-0.11	-

* Statistical significance

Figure 1: Mean Change in Sense of Belonging in College Across Cohorts 2015-2021
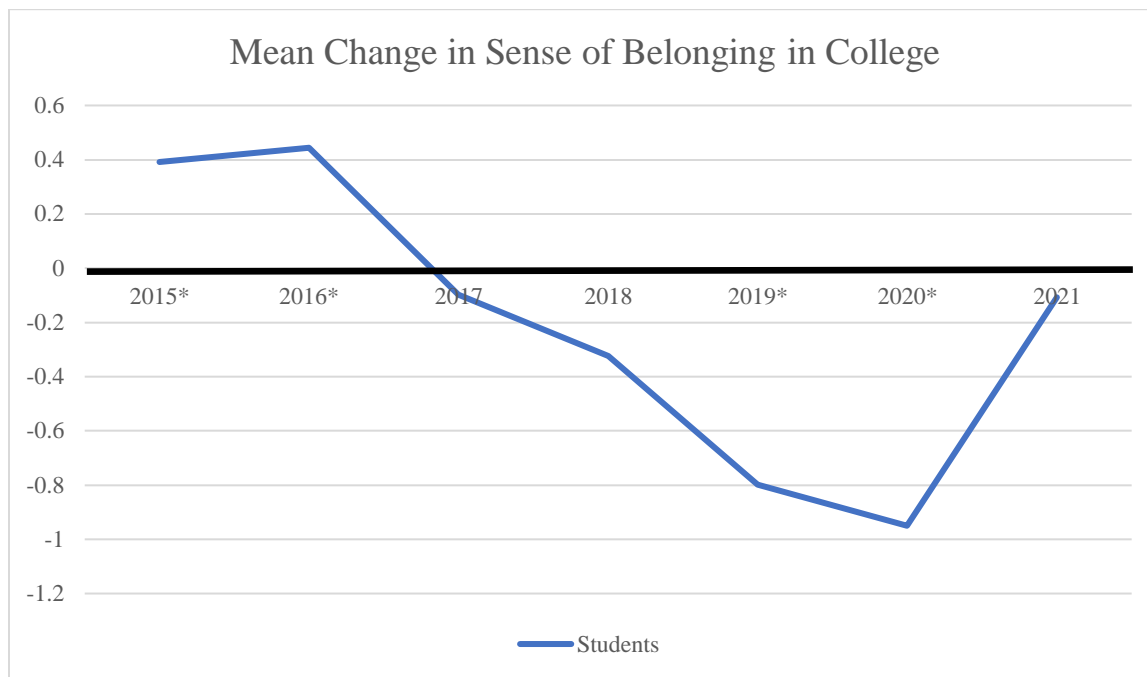

Sense of belonging statistically increased across the first semester for cohorts 2015 and 2016, remained statistically the same for cohorts 2017, 2018, and 2021, and statistically decreased for cohorts 2019 and 2020 (fall 2020 is the COVID-cohort). Of particular note is that the largest decline in sense of belonging over the course of the first semester was during the 2020 COVID cohort year.

This suggests that the first-semester social experience for the COVID-cohort may have been negatively impacted and was reflected in their reported sense of belonging. While the effect size is small for all cohorts, the 2020 (COVID-cohort) reported the highest effect size with Cohen's $d = 0.30$, up to three times larger than in previous cohorts.

We next repeated the same analyses of change in sense of belonging over course of the first semester, but separately for white students and underrepresented minority students. Figure 2 shows the results of this analysis.

Figure 2: Mean Change in Sense of Belonging Comparing White and Underrepresented Minority

Students

Mean Change in Sense of Belonging in College for White and Underrepresented Minority Students
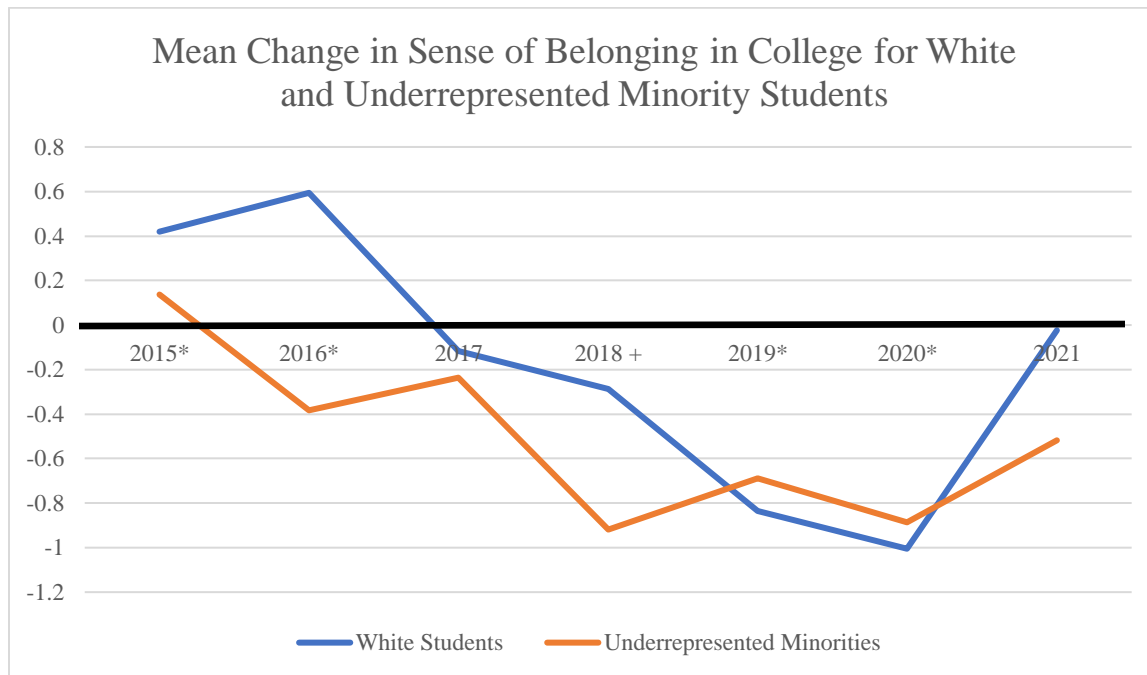
= significant for White students, + = significant for underrepresented minorities

Note in Figure 2 there were significant positive differences in change of sense of belonging for white students in 2015 and 2016 while there were no significant differences for underrepresented minorities in those years. There were no significant differences for either White or underrepresented minorities in 2017 and 2021. But there were significant negative differences in change in sense of belonging in 2018 for underrepresented minorities only, while in 2019 and 2020 the results showed a significant negative change for white students only.

Our next comparison was to explore change in sense of belonging of men separately from women, using the same seven cohorts of students from 2015 – 2021. Figure 3 shows the results of this analysis.

Figure 3: Mean Change in Sense of Belonging Comparing Men and Women
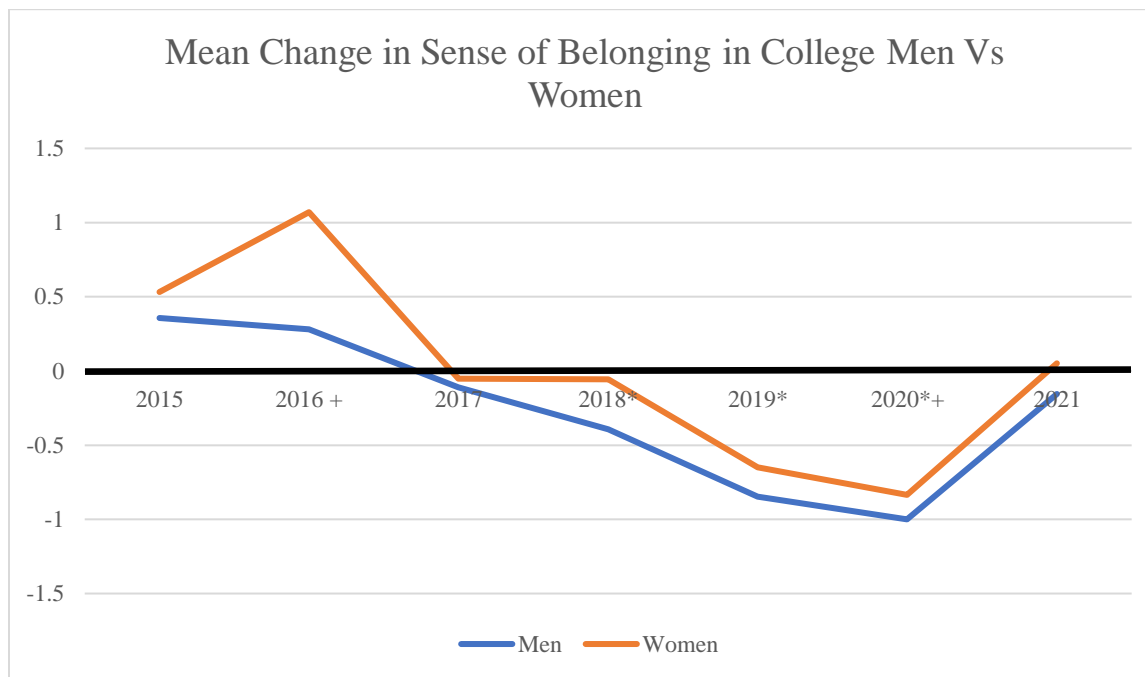
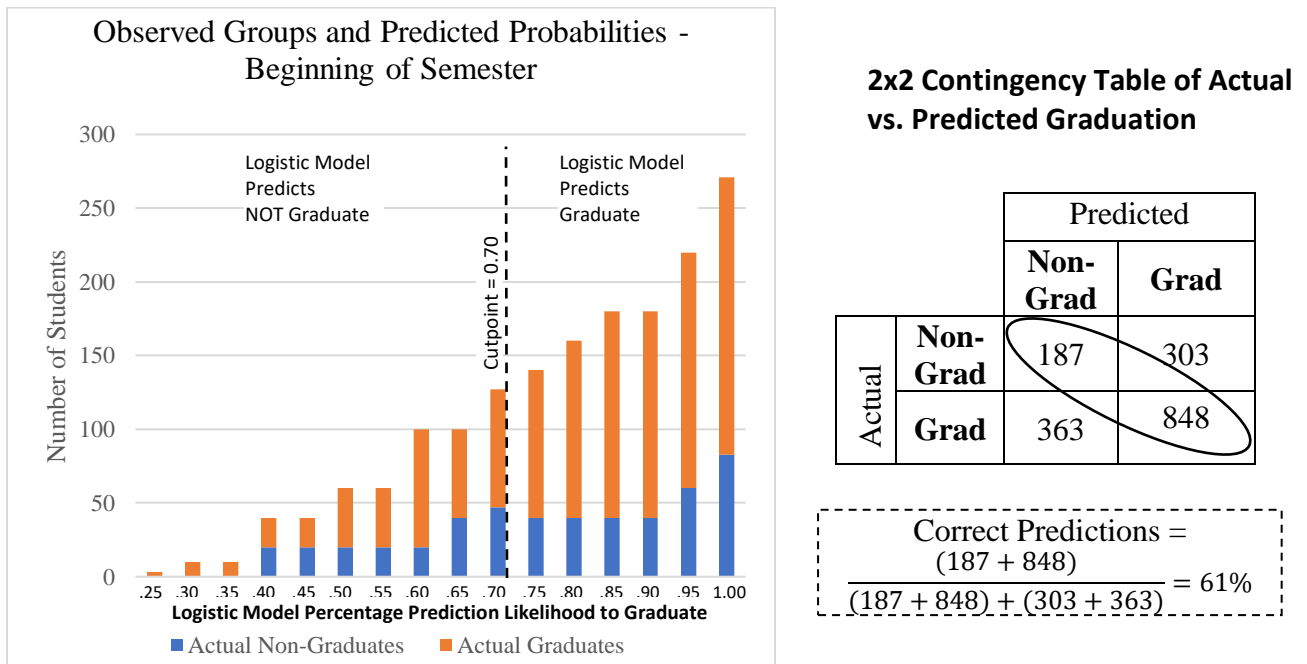*= significant for men, + = significant for women*

As is shown in Figure 3, we can see that there were significant positive differences in the change in sense of belonging for women in 2016 but not for men in that same cohort. There were significant negative drops in sense of belonging for men in 2018 and 2019, whereas women remained statistically similar over the first semester in their sense of belonging for those two cohorts. In the 2020 cohort (the COVID cohort), both men and women reported a statistically significant drop in sense of belonging over their first semester of college.

Results for Research Question 2

For research question 2, the logistic regression analyses described earlier was used to explore the predictive potential of a freshman-year measure of sense of belonging as a possible

predictor for graduation within 5 years. We report the outcome of that logistic regression model

in terms of a 2x2 contingency table capturing the correct predictions on the primary diagonal

(e.g. predicting graduation when they in fact did graduate, and predicting non-graduation when

in fact they did not graduate) and capturing incorrect predictions on the off-diagonal (see Figure

4). In addition to the 2x2 contingency table of model prediction vs. actual, we report the

frequencies of predicted graduations and non-graduations for individuals whose sense-of-

belonging score placed them on a continuum from the model predicting 25% chance of

graduating to 100% chance of graduating (see Figure 4).

Figure 4. Output of Logistic Regression Model Predicting Graduation Based on Sense-of-

Belonging Measured at Beginning of First Semester

2x2 Contingency Table of Actual vs. Predicted Graduation

		Predicted	
		Non-Grad	**Grad**
Actual	**Non-Grad**	187	303
	Grad	363	848

$$\text{Correct Predictions} = \frac{(187 + 848)}{(187 + 848) + (303 + 363)} = 61\%$$
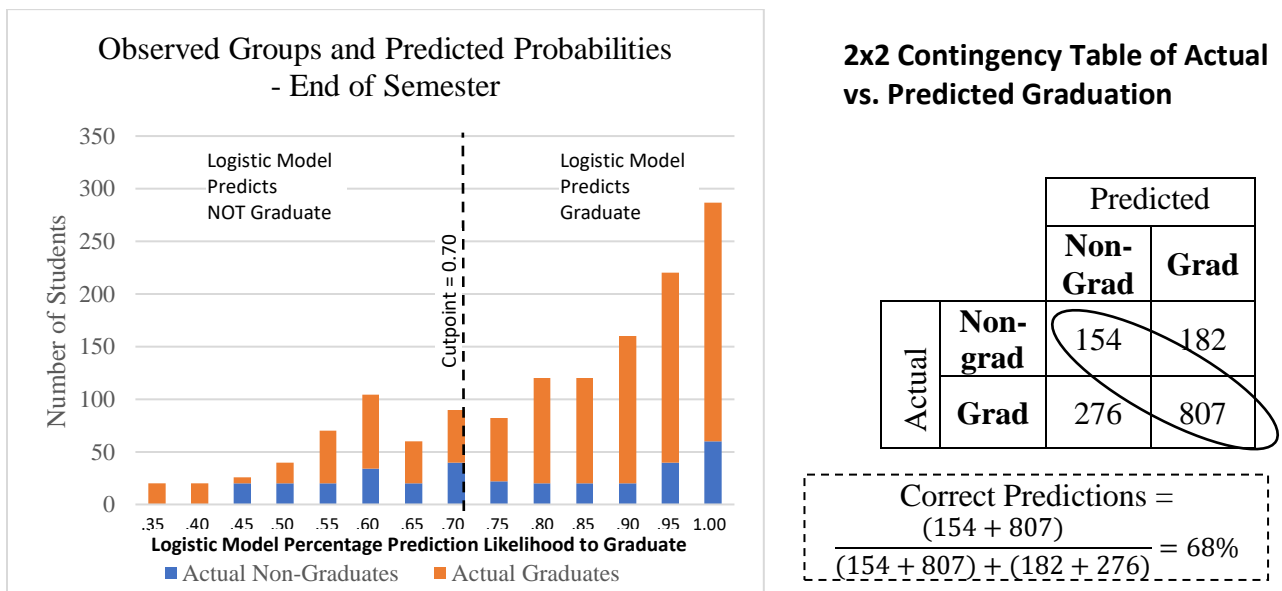
The logistic regression results in Figure 4 showed that, at the very beginning of the

freshman year, there is some predictive ability from a 4-item sense of belonging scale to predict

potential future graduation. This model accurately predicted the graduation status of 61% of students based on sense of belonging in college at the beginning of the semester.

The same logistic regression analysis was repeated using the sense of belonging measure at the end of the first semester rather than at the beginning (see Figure 5).

Figure 5. Output of Logistic Regression Model Predicting Graduation Based on Sense-of-Belonging Measured at End of First Semester

The model using sense of belonging data from the end of the semester accurately predicted 68% of students' graduation status. Compared to results from the logistic regression model using beginning of semester data (Figure 4), this represents a somewhat substantial increase in accuracy. This could likely be explained by recognizing that while the beginning of first year sense-of-belonging was judged by students before even experiencing any of the engineering program, but even one semester later offered them a perhaps more grounded and

informed perspective (in terms of ultimate persistence to graduation) from which they judged their own sense of belonging.

Discussion

Sense of Belonging

Based on the results there appears to be sensitivity in the sense of belonging scale that captured, for some students in some cohorts, a change in sense of belonging by the end of the semester. Results in Figure 1 indicated that the COVID cohort had the largest drop in sense of belonging, with the largest effect size up to three times larger than previous years. There is also a difference in sense of belonging between White students and underrepresented minorities. For most cohorts underrepresented minorities reported significant less belonging in college than their White counterparts, with the exception of 2019 and the COVID-cohort. Since underrepresented students may already experience some isolation from being underrepresented in their major, their sense of belonging may not have been as severely decreased by the isolating structure of course delivery during the COVID-cohort.

Overall, there did not appear to be any systematic differences in the change in sense of belonging in college between men and women during the seven cohorts. For example, both populations' sense of belonging in college were impacted similarly during the COVID-cohort (see Figure 3). For the assortment of cohorts and populations of students for which there were differential changes in sense of belonging over the course of their first semester, it is likely that those differences could be attributed to a number of factors such as; instructor, grade received, participation/exclusion, or changes to a hybrid (face-to-face and online) course structure used during the COVID cohort in fall 2020.

Sense of Belonging as a Predictor of Graduation

In spite of the very long lag time between end of first semester and graduation 4 or 5 years later, the model showed that mid-year freshmen sense of belonging was a statistically significant predictor of graduation ($p<.001$) with 68% of the model's prediction being correct. However, as might be expected, given the complexity and duration of experiences throughout the years of their college program, this model only had a relatively weak effect size (Nagelkerke R^2 = .047). The model tended to be more accurate at predicting who does graduate than at predicting who does not graduate. Many students with high sense of belonging in college, which the logistic regression model would predict as having a high percentage likelihood of graduation (see Figures 4 and 5), ultimately did not go on to graduate. This could be due to a number of outside factors that the single-predictor model does not account for. However, given that the sense of belonging measure was very brief (4 items on a 5-point Likert scale), it is encouraging that there is at least some sensitivity in that measure that can predict, even with a weak effect size, the eventual graduation of students based on sense of belonging.

This is an initial step in ongoing research to capture students' sense of belonging, how it can affect retention or graduation, and how the COVID-19 pandemic impacted first-year engineering students' sense of belonging. Some future research goals to be pursued by us are to explore identification of students at the beginning of the first semester who may benefit from targeted interventions and combining the sense of belonging scale with other scales for stronger predictive power. Similarly, we anticipate repeating the identification and intervention process based on end of the semester measures to explore supporting an additional group of students who may have been overlooked the first time.

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