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Validity Evidence for Parsimonious Sense of Belonging Scales for Engineering Students*

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Sense of belonging has substantial evidence of being related to success in engineering and is of high interest to the engineering education field, but validation evidence for sense of belonging measurement scales is sparse. This study presents a suite of validity evidence in several categories for two parallel 4-item belonging scales; belonging in college and belonging in engineering. Data from over 3600 first-year engineering students in 8 cohorts were used to present internal consistency reliability (Cronbach alpha) evidence as well as validity evidence in 3 categories: respondent engagement validity, convergent validity, and sensitivity to societal contexts. Results are reported for whole group as well as two sets of subgroups of interest to the engineering education field: women/men and underrepresented/non-underrepresented groups. Results showed substantial evidence for both internal consistency reliability (alpha > 0.82 for all time points, all subgroups) as well as multiple strands of validity evidence for all 3 categories for supporting interpretations both whole group as well as by subgroups. Across all results, we conclude that there is substantial evidence supporting validity of interpretations from the two parsimonious sense of belonging scales for first-year engineering students.

Keywords: sense of belonging; first-year engineering; validity evidence; belonging measurement; belonging scales; COVID-19

1. Introduction

While sense of belonging has various definitions, for this study the guiding definition was the degree to which a student feels accepted in a group [1]. This perspective on belonging emphasizes the social aspect of feeling connected and valued by others, whereas a sense of belonging is sometimes operationalized by an individual's sense of academic competence. While both aspects of belonging may be present or absent, the social nature of belonging often underlies students' perceptions since even academic competence is often judged compared to one's peers.

As summarized in later sections of this paper, sense of belonging is a key construct linked to success in pursuing degrees in science, technology, engineering, and mathematics (STEM fields). In spite of substantial research of this relationship and thus high interest within the field for measuring sense of belonging, high-quality measures of sense of belonging are still not yet well established (see section below). This study explored an array of evidence supporting interpretations with validity for two parsimonious scales (limited to 4 items each to minimize survey fatigue and subsequent inattentive response patterns) measuring first-year engineering students' sense of belonging. One scale focused on sense of belonging in college, and a parallel scale focused on sense of belonging in engineering. As detailed in [2], validity is a unitary concept that undergirds confidence in any interpretations one might draw from measurements. For this paper, we present an accumulation of a variety of evidence that supports interpretations of these two scales as meaningful measures of social belonging that discriminate between belonging in college and belonging in engineering. We acknowledge that a four-item scale does not capture all relevant dimensions of the complicated construct of sense of belonging; however, the various strands of evidence will show that the scales produce results that can be interpreted as providing a meaningful measure of our students' sense of belonging.

Our work was part of a larger set of studies conducted by an interdisciplinary group of researchers interested in retention of first-year engineering students. Researchers include engineering professors, teacher educators, and cognitive scientists from units across the university. Since 2010, the group has engaged in longitudinal studies examining first-year engineering students' attitudes and

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beliefs about engineering and college, along with demographic and performance data. Much of the data was collected on two surveys given to all engineering students at the beginning and end of their first-semester introduction to engineering course; these survey data were leveraged for the study reported here. Since 2015, sense of belonging has been included in this survey, and with the availability of this historical database, we analyzed validity evidence of the 4-item sense of belonging in college scale, as well as our modification to the scale to include sense of belonging in engineering specifically.

2. Literature Review

2.1 Measuring College Students' Sense of Belonging

As noted recently [3], while there have been extensive studies published related to sense of belonging, it is difficult to find comparative information on instruments for measuring college students' sense of belonging. From a systematic review of the literature using their university's databases, Yang and colleagues identified and compared ten instruments used in empirical studies of college populations with quantitative scale development or modification and some type of validity evidence. Eight of the ten involved multidimensional instruments and two were unidimensional with a number of items ranging from eight to 44. They summarized information including the theoretical framework that grounded the instrument, the dimensions of belonging that were included (general, social, academic, or institutional), and reliability and validity information. They concluded that selecting an appropriate instrument is not always clear-cut for researchers and noted that two of the most used scales were adaptations of instruments developed for adolescents.

Other researchers have discussed the challenges in measuring college students' sense of belonging [4, 5]. As stated eloquently, and summarized here, Slaten et al. [4] explained that a major problem with belonging research has been the lack of a valid and reliable standardized scale to measure the belongingness construct. Researchers continued to either attempt to modify a scale [6–9] that was originally developed and validated for a noncollege student population (e.g., Psychological Sense of School Membership (PSSM), [10] or to create an ad hoc scale for their study (e.g., [11–15]. While researchers often provided a rationale for such measurement choices, including preliminary evidence of reliability and basic validity, it is difficult to compare studies since scales often vary in length, wording and the domains measured.

Hoffman et al. [16] developed and tested an instrument to understand why students persist in college. They refined their sense of belongingness scale (SOBS) to 26 items representing five factors: perceived peer support, perceived faculty support/comfort, perceived classroom comfort, perceived isolation, and empathetic faculty understanding, and they used it to examine differences in classroom environments, finding that learning communities improved sense of belonging compared to freshmen seminar courses. While the overall measure demonstrated high reliability, but as acknowledged by the authors, no additional steps were taken to assess its factor structure or to examine validity evidence of the measure. In fact, in a follow-up study by Tovar and Simon [17] who performed both an exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) on the SOBS, the SOBS's original five-factor structure was not replicated, and instead, Tovar and Simon [17] proposed an entirely new factor structure.

Slaten et al. [4] developed and provided validity evidence for a multidimensional, 24-item University Belonging Questionnaire (UBQ) at their single institution on a predominately white student body. The goal of that study was to develop a valid and reliable measure of the university belonging construct. Measurement items were developed from a thorough review of the literature, consultation with belonging researchers, and previous qualitative work. They performed two studies: an EFA on a large pool of items generated for the scale and, then a CFA and validity testing of the UBQ. The final scale of 24 items involved a 3-factor model (i.e., university affiliation, university support and acceptance, faculty and staff relations).

However, a very recent paper claimed that "despite efforts to improve students' sense of belonging in postsecondary settings, there is a gap in the available instruments" [5, pp. 79–80]. Lingat and colleagues further suggested that often existing instruments have been used widely but frequently with somewhat limited validity evidence. Their research contribution was a unidimensional 10-item scale (Brief Course Belonging Scale, BCBS) based on a sample of 4,851 students that measured sense of belonging across different classroom learning contexts. They noted the comprehensive nature of the scale developed by Slaten et al. [4] but highlighted the need for brief instruments for use with college students. Other research has shown that brief scales can be psychometrically robust and serve as an alternative to longer ones [18–20].

Knekta et al. [21], adapted and evaluated Goodenow's PSSM scale [10] and extended university sense of belonging to include belonging within a department. Factor analysis of the final 20-item

scale showed three factors representing sense of belonging: valued competence, social acceptance, and involvement. They performed confirmatory and exploratory factor analysis but noted that validation of an instrument is an iterative and continuous process and further validity evidence would be needed.

Recent studies also combined sense of belonging scales within other instruments, such as Leibowitz et al. [22]. Their study attempted to gauge the impact of residential learning communities on underrepresented students in STEM. They developed a 28-item survey that included items adapted from three previous instruments to measure three constructs: academic engagement; self-efficacy; and sense of belonging to the academic major, institution, and residential community. They performed an EFA test for internal consistency for their combined instrument. Belonging to the university, belonging to an academic major, and belonging to a residential learning community emerged as separate factors, indicating that students appeared to distinguish between these different types of belonging during their college experiences.

The scholarship by Lee et al. [23] specifically highlighted the challenges of defining and measuring sense of belonging as they developed a framework for studying international engineering doctoral students' sense of belonging. Their extensive literature review informed their conceptualization and revealed a lack of consistency in the conceptual structure of belongingness in both higher education and engineering education research. They argued that sense of belonging was introduced to higher education as a precursor of students' social and academic integration based primarily on Tinto [24], but the concept has been understudied as an independent, theoretical concept [16, 25].

All of this research points to the challenges of measuring belonging and the need to provide validity evidence for the scale used within the context of the situation. The sense of belonging scale we have used since 2015 is a slight modification of a 4-item belonging scale to assess students' perceptions about sense of belonging in college used by Yeager et al., [26], which in turn was an adaptation of a 3-item scale used by Walton and Cohen [27]. While widely used (e.g., Holmes et al. [28]), validity evidence for either scale, if published, is difficult to find. We contribute analyses of evidence of the reliability and validity of the brief 4-item scale [26] that we have used to measure sense of belonging in college and also for a parallel scale we adapted to measure sense of belonging in engineering as part of our research interests related to first-year engineering student retention. While the use of brief scales may provide limited scope for capturing the complex concept of belonging [21], a truly parsimonious scale is valuable, especially for use in the first year when students are often over-surveyed, and when fostering a sense of belonging is especially important in the transitional time of the first year [7].

2.2 Sense of Belonging

Research has shown that college students' sense of belonging is a key affective construct linked to engagement and persistence in STEM [8, 14, 29]. More generally, sense of belonging among all college students has been associated with persistence, retention, and graduation [24, 25, 30, 31]. A sense of belonging in college settings has been defined primarily as perceptions of acceptance, fit, and inclusion on campus [32–35]. This body of research established that a positive sense of belonging was related to academic and social adjustment [36, 37], involvement and intention to persist in college [38], and decreased burnout in college [39].

Given the potential importance of sense of belonging as a precursor to a number of positive academic outcomes, many researchers are interested in exploring the belonging of various specific subgroups of students. For example, Hausmann and colleagues [38] studied White and African-American first-year students attending a public institution and found that a belonging intervention they instituted had similarly positive associations for both groups of students in improving their intent to persist in college. Stephens and colleagues [40] found that a strong sense of belonging reduced performance gaps between students identifying as members of minoritized and non-minoritized groups.

However, there is a substantial body of research highlighting that sense of belonging can vary across key demographic groups of students of interest to the education community. A number of studies (e.g., [13, 25, 34, 40–43]) have shown that students who identify as part of an underrepresented group in college often expressed a weaker sense of belonging in comparison to students with non-underrepresented identities. A weaker sense of belonging has also been found for a variety of demographic subgroups of students, including women (e.g., [42, 44–48]) and low-income students (e.g., [37, 49, 50]) among others. Given the potential importance of sense of belonging as a covariate with many positive academic outcomes and the potential differences in belonging for demographic subgroups of students, it is helpful to present validity evidence of any belonging measures by subgroups as well as by whole group.

2.3 Sense of Belonging in Engineering

Sense of belonging in engineering is of great interest

because studies show lack of belonging is a reason for attrition from engineering programs [51]; specifically for women and underrepresented groups [52, 53]. Lack of belonging is a challenge for these populations not only in engineering but for STEM majors in general [12, 54]. Demographically, women and many students of color (e.g., African American, Hispanic, American Indian, and Alaska Native students) are underrepresented in engineering [55], and underrepresentation in specific settings can cue limited belonging [56].

While factors related to sense of belonging differ by student education level, several factors have been shown to promote undergraduate students' sense of belonging in engineering in the context of higher education, although comparison of different studies is difficult [23]. A sample of studies in engineering confirmed engineering contexts influence belonging; the more engineering students questioned their belonging, the more poorly they performed [57]; thus, systemic issues of belonging tied to identity in engineering can contribute to continued equity gaps.

At the same time, scholarship suggests that certain factors within engineering environments can support student success and belonging. Rodriguez and Blaney [58] echoed the value of having identity-based STEM organizations for Latina women because of ways in which interrelated experiences of discrimination, marginalization, and limited belonging contributed to students questioning their academic abilities. In a sample of over 700 engineering students within 4 institutions, Vogt [59] found faculty distance was inversely related to both academic confidence and self-efficacy, suggesting that faculty may play a key role in fostering aspects of student belonging. Boone & Kirn, [11], using a 3-item sense of belonging scale, studied first-generation students in engineering where they created predictive models for belongingness and identity for junior and senior-level engineering students at a four-year Western land grant institution. They found that first-generation students had a higher sense of belonging to their major and class than continuing-generation students. Motivation and social capital were shown to predict both identity and belongingness. They concluded that persistence in engineering by the first-generation students was likely due to their higher sense of belonging.

More recent studies of belonging in engineering include Dennehy & Dasgupta [60] who found that increased belonging and self-efficacy were significantly associated with retention in their study of female engineering students based on the effect of female mentors for entering female students. Their survey items measuring belonging in engineering were four questions adapted from Good et al. [46]. Scheidt et al. [61], in a large multi-institution study of 2339 engineering students, examined 28 noncognitive and affective factors via a survey, of which belongingness was one construct measured using four items. They conducted both exploratory and confirmatory factor analyses on the constructs used in their study and concluded that all of the factors showed validity evidence. They also collected self-reported test scores and current GPA. Using Gaussian mixture modeling to group respondents into clusters, the four distinct clusters for roughly three-fourths of the students with varying patterns of factors appeared to act in concert. While not statistically significant in this larger study, they reported that subsequent analyses at a single institution showed decreased GPA over time with students in clusters showing low sense of belonging and identity. A suggestion for future work was that support programs should be created to focus on developing sense of belonging and identity.

Patrick et al. [62] studied engineering students at Hispanic Serving Institutions (HSI) and found that race/ethnic and gender identity are important to the sense of belonging in engineering for students at HSIs. They used a 3-item scale adapted from Hurtado & Carter [25]. Buckley et al. [63] recently studied the impact of COVID-19 on sense of belonging for first-year engineering students via focus groups. Results highlighted opportunities to support sense of belonging and learning for diverse students in engineering across course formats. Engineering environments, therefore, are a unique, important context for examining belonging. Given the efforts and potential value of examining sense of belonging in engineering students, including a focus on particular subgroups of students, the quality of measurements of sense of belonging for these students is of interest to the field.

2.4 Evidence Based on Belonging Relations to Other Constructs

2.4.1 Self-Efficacy

Self-efficacy is an individual's belief in one's own ability to master a task [64]. Sense of belonging has been linked to the construct of self-efficacy in many studies. For example, sense of belonging had a significant positive relationship with self-efficacy and cognitive engagement among high school students [65]. Sense of belonging and self-efficacy are also both significant predictors of student retention. Lytle and Shin [66] found that STEM self-efficacy predicted sense of belonging and was associated both with STEM engagement and persistence. Apriceno et al. [67] assumed a relationship between self-efficacy and sense of belonging as positive predictors of STEM retention.

More studies, including Tinto [24], also showed that self-efficacy influenced sense of belonging, which in turn affected motivation. A similar study of college freshmen by Freeman et al. [6] suggested that sense of belonging was associated with academic motivation in college-level students, just as it had been shown to be in younger populations [10, 68–70]. Specifically, students' sense of academic self-efficacy was quite strongly associated with their sense of belonging [6].

The established link between sense of belonging and self-efficacy suggests that convergent validity evidence could be established if those two constructs were strongly correlated in groups of students who completed both measures. In this study, we provided one piece of validity evidence for our belonging measures by correlating our 4-item belonging scales to another extensively used scale that includes a self-efficacy subscale, the Motivated Strategies for Learning Questionnaire (MSLQ) [71].

2.4.2 Perceived Cost

Perceived cost is a component of Expectancy Value Theory (EVT) that looks to examine how students' perceptions about the cost of pursuing their major impact their retention, achievement, and academic decisions [72, 73]. Perceived cost can be broken into three types of cost: psychological (stress), opportunity (losing friendships), and effort (worth the work required). Similar to sense of belonging, perceived cost is also especially salient for STEM majors due to the high workload, competitiveness, and tougher grading policies and these perceived costs can negatively impact student retention [74].

Sense of belonging has been correlated to academic motivation and belonging uncertainty identified as a motivational cost [5, 75]. Wang's [76] study of high school students' mathematics learning concluded that a lower sense of belonging could lead to reduced motivation in learning mathematics (higher cost). The established link between sense of belonging and perceived cost suggests that convergent validity evidence could be established if these two constructs were strongly correlated among groups who completed both measures. We correlated our parallel 4-item sense of belonging scales to a perceived cost scale with validity evidence used with college STEM majors [72]. Higher scores indicated higher cost; therefore we expected the cost scale to be negatively correlated to our sense of belonging scales for which higher scores indicated stronger belonging.

2.5 Research Questions

For the context of first-time, first-year engineering students at a comprehensive public research university, this study addressed the following research questions:

1. What validity evidence exists to support interpretations of sense of belonging measured by two parsimonious (4-item) belonging scales: belonging in college and belonging in engineering (see Appendix A)?
2. What validity evidence for those same two scales exists that supports the validity of the measures for subgroups of students: women/men and underrepresented groups (URG)?

3. Methods

3.1 Participants

Participants were first-time full-time engineering students (i.e. transfer students omitted) at a comprehensive public university in the southern part of the United States. This study included data from eight consecutive student cohorts entering the university engineering program in the fall of 2015 through fall of 2022. A total of 3617 students participated by completing questions on the relevant constructs of the survey at the beginning of their first semester in engineering and then repeating the survey at the end of their first semester.

Students at this university self-identify their race upon admission to the university. Using the categories from the institutional database, 79.6% of participants identified as White, 5.5% as Asian, 4.8% as Hispanic/Latino, 4.6% as African American/Black, 4.7% as two or more races, and 1% as non-US citizens. To analyze sense of belonging in college by race, Underrepresented Groups (URG) in engineering, as defined by the National Science Foundation [77], included Black, Hispanic or Latino, multiracial, and Indigenous students. 76.4% of participants identified as men, and 21.2% identified as women, 1% as non-binary, 0.2% as transgender women, 0.2% as transgender men, and 1% as other gender identities (i.e. genderfluid, agender, genderqueer). For gender analysis, we included transgender men with men and transgender women with women. All other gender identities were excluded from gender analysis due to very low sample sizes.

3.2 Measures

The survey completed by these first-year engineering students at two time points (beginning and end of the first semester, labeled "pre" and "post" in results to come) contained two parallel 4-item sense of belonging scales modified from Yeager [26]. We chose to use 4-item scales because this is the minimum length in the existing literature which offers promise to capture sense of belonging. One of the

two scales targeted belonging in college (completed by cohorts 2015–2022; see Appendix A) while the parallel scale targeted belonging in engineering (completed by cohorts 2019–2022; see Appendix A). We also had demographic data for each student that included self-identified gender and race that came from the university database. In addition, as part of the overall survey administered to students in all cohorts from 2015–2022, they completed measures that included the self-efficacy subscale of the MSLQ [71] and perceived cost [72].

3.3 Analyses

We present evidence for internal consistency reliability alongside validity evidence for the two belonging scales. The three sources of validity evidence are evidence based on respondent engagement, convergent evidence from comparisons to similar constructs, and sensitivity to societal contexts. For internal consistency reliability, we computed Cronbach alpha for each measure at both time points for the whole group, and for the subgroups by gender (women/men) and by underrepresented group status (URG/non-URG). For respondent engagement validity, we present two independent pieces of evidence supporting the conclusions that respondents overall were meaningfully engaged in reading and thinking about the specific questions. We compared response patterns of the college belonging scale to the engineering belonging scale to explore if there was any evidence of student discrimination between the two, despite the very similar nature of the scale items (only one word was changed in each item). We also used one reverse-worded item in each scale as an embedded attention check.

We report evidence for convergent validity by correlating self-efficacy and psychological cost with both measures of belonging, at both time points (pre/post to first semester), and for whole group plus subgroups. Finally, we explored the potential sensitivity of these scales to large-scale societal contexts that may have meaningfully impacted students' sense of belonging. For this, we investigated two potentially relevant societal events within the time frame of our data collection; the 2016 presidential election and the 2020 COVID-19 pandemic and subsequent societal responses.

4. Results

Evidence of the measure's reliability and validity are presented in four main results sections: internal consistency reliability evidence, respondent engagement validity evidence, convergent validity evidence, and sensitivity to societal contexts. For each of these, there are multiple independent strands of evidence, including both whole-group data as well as data disaggregated by subgroups of common interest to researchers focused on engineering education.

4.1 Internal Consistency Reliability Evidence

A standard metric for the reliability of a particular measure with a particular sample of respondents is the internal consistency reliability as represented by Cronbach's alpha. Typically in education research, a Cronbach alpha of 0.70 or higher is considered adequate for measurement quality purposes [78]. Table 1 presents the internal reliability alpha for each of the two measures, both by whole group and by subgroups.

The magnitudes of the Cronbach alphas in Table 1 which are all at least 0.82 or greater suggest that the sets of belonging items function together in a strongly consistent manner for first-year engineering students, including for the select subgroups investigated as well as the whole group.

4.2 Respondent Engagement Validity Evidence

Respondent engagement validity evidence leverages data that suggests that the survey takers are meaningfully responding to the particular items of the survey rather than being inattentive or simply

Table 1. Internal Consistency Reliability (Cronbach Alpha) for Both Belonging Measures, Including by Subgroups

	College Belonging		**Engineering Belonging**	
	Pre	**Post**	**Pre**	**Post**
Whole Group	0.83 (n = 3477)	0.84 (n = 2880)	0.86 (n = 1609)	0.88 (n = 1285)
Women	0.84 (n = 777)	0.84 (n = 699)	0.87 (n = 373)	0.88 (n = 335)
Men	0.83 (n = 2700)	0.85 (n = 2181)	0.85 (n = 1236)	0.87 (n = 950)
URG	0.85 (n = 506)	0.84 (n = 402)	0.86 (n = 276)	0.88 (n = 215)
Non-URG	0.82 (n = 2971)	0.84 (n = 2478)	0.86 (n = 1333)	0.89 (n = 1070)

Note. n = sample size, URG = underrepresented groups.

straightlining (marking the same rating for every item) as an efficiency measure to complete the survey quickly but without putting much thought into it. For our belonging measures, we present two independent pieces of evidence supporting conclusions that respondents overall were meaningfully engaged in reading and thinking about the specific questions.

4.2.1 Belonging in College vs. Belonging in Engineering

Although sense of belonging in college and sense of belonging in engineering are strongly correlated (see section below on *Convergent Validity Evidence*), results showed that the actual ratings of engineering students discriminated between these two constructs. Table 2 reports the belonging ratings (on a 4–20 scale, summing the four Likert items rated 1–5; see Appendix A for the instruments) for both college and engineering at the beginning of semester, including for the entire sample as well as for subsamples of interest. Table 2 also reports on a paired-samples t-test comparing those two ratings. Because the scale for engineering belonging was first administered in the 2019 cohort, results in Table 2 below only include cohorts 2019–2022.

Note that for every subgroup, their ratings for belonging in college were statistically higher than their ratings for belonging in engineering. The results comparing sense of belonging in college vs. engineering at the end of the semester (not reported in Table 2) showed the same pattern as for beginning of semester reported in Table 2. The effect sizes showed that the difference in this distinction between belonging in college vs. belonging in engineering was strongest for women, with a point estimate effect size of Cohen's $d = 0.59$. This can be interpreted to suggest that on the whole, women reported a much stronger sense of belonging in college compared to engineering, and that this difference, while present in all subgroups, was strongest for women. This discrimination in ratings between belonging in college vs. engineering served as a piece of respondent engagement validity evidence, indicating participants were thoughtfully reading and thinking about the questions, since it indicated that these respondents chose distinctly different ratings for each construct.

4.2.2 Embedded Attention Checks

The second aspect of respondent engagement validity evidence was the embedded attention check in the form of one of the four items in each measure being reverse-worded (see Appendix A). If students were straightlining or otherwise not reading the items carefully and thoughtfully, then one would expect the reverse-worded question to be rated similarly to the other positively-worded items because of inattention. However, when we reverse-coded that one item as we did prior to any subsequent analyses, the internal reliability of the set of 4 items for each of the two parallel belonging measures was quite high (see Table 1). And when the reverse-coded item was hypothetically removed from the reliability analysis for the whole group and for each sub-group, the resultant alphas did not change appreciably, varying between a reduction of 0.01 and 0.08. This is very similar to the alpha reduction that would have occurred if any of the other positively-worded items were to be removed instead, suggesting that reverse-coding the reverse-worded item brings the response patterns into strong agreement with the remaining items. This supports conclusions that students were attentively reading and responding to the actual wording of the items.

4.3 Convergent Validity Evidence

Convergent validity evidence was established from explorations of the two parallel belonging measures' correlations with other constructs either known or widely assumed to be closely related to it. For this study, the two related constructs of interest we explored were self-efficacy and psycho-

Table 2. Discrimination in Response Ratings for Belonging in College vs. Engineering

	Belonging in College Mean (SD)	**Belonging in Engineering Mean (SD)**	**p-value of difference College vs. Engineering**	**Cohen's d Effect size [95% CI[a]]**
Whole Group ($n = 1595$)	15.2 (3.6)	14.3 (3.8)	$p < 0.001$	$d = 0.27$ [0.22–0.32]
Women ($n = 371$)	14.8 (3.9)	12.6 (4.0)	$p < 0.001$	$d = 0.59$ [0.48–0.70]
Men ($n = 1224$)	15.3 (3.5)	14.8 (3.6)	$p < 0.001$	$d = 0.16$ [0.10–0.21]
URG ($n = 271$)	15.2 (3.6)	14.1 (3.8)	$p < 0.001$	$d = 0.33$ [0.21–0.45]
Non-URG ($n = 1324$)	15.2 (3.6)	14.4 (3.8)	$p < 0.001$	$d = 0.25$ [0.20–0.31]

[a] 95% CI = 95% Confidence Interval.

logical cost as detailed earlier. For each construct, we first explored each of the belonging construct measures' correlation whole group (all cohorts combined), and then separately by two different sets of subgroups (women/men; underrepresented group (URG)/non-URG) to explore convergent validity evidence of the measures for each subgroup.

4.3.1 Whole Group

Evidence for convergent validity of both parallel belonging measures in this study – belonging in college and belonging in engineering – was initially explored for the entire group of students. Data for eight cohorts was available for college belonging, and data from four of those cohorts was available for engineering belonging. Both measures of belonging were compared not only to each other at two different time points (at beginning of first semester and at end of first semester – labeled "Pre" and "Post" in tables below) but were also compared to measures of self-efficacy and psychological cost (see Table 3).

Note in Table 3 that nearly all correlations are stronger than 0.3, which Gignac and Szodorai [79] labeled as a large correlation relative effect size in comparison to the many effect sizes reported in education literature. Many of them are in fact quite a bit larger – over twice that magnitude in some cases. For the few correlations less than 0.3, they are all located in the cross-time points (Pre-Post) and are still greater than 0.2; a medium effect size. Additionally, the same-time point correlations (Pre-Pre and Post-Post – circled in Table 3) across all combinations of belonging measures with others tend to be at least slightly stronger than the cross-time point (Pre-Post) measures, which is an expected result since at any given time students most strongly responded in similar manners to the multiple measures than they did at differing times.

4.3.2 Disaggregated by Gender

Evidence for convergent validity of both parallel belonging measures in this study – belonging in college and belonging in engineering – was explored separately for men and women (see Table 4). This enables validity evidence to be generated for the use – and subsequent interpretations – by subgroup as well as whole group.

Note in Table 4 that nearly all correlations are stronger than 0.3, which Gignac and Szodorai [79] labeled as a large correlation relative effect size in comparison to the many effect sizes reported in education literature. For the few correlations less than 0.3, they are all located in the cross-time points (Pre-Post) and are still greater than 0.2; a medium effect size. Additionally, the same-time point correlations (Pre-Pre and Post-Post – circled in Table 4)

Table 3. Convergent Validity Correlations[a] for Whole Group: Belonging, Self-Efficacy, and Perceived Cost

		College Belonging		Engineering Belonging	
		Pre	Post	Pre	Post
College Belonging	Pre				
	Post	0.56***			
Engineer Belonging	Pre	0.58***	0.42***		
	Post	0.47***	0.67***	0.61***	
Self-Efficacy	Pre	0.39***	0.31***	0.49***	0.40***
	Post	0.23***	0.34***	0.25***	0.45***
Cost	Pre	-0.50***	-0.33***	-0.59***	-0.43***
	Post	-0.34***	-0.49***	-0.44***	-0.65***

same time points circled

Note. "*Same time points*" are measures of the same students Pre-Pre and Post-Post. For *college belonging* correlations, samples ranged between $1192 \leq n \leq 2880$ and for *engineering belonging* correlations, samples ranged between $1173 \leq n \leq 1595$ because of differing numbers of cohorts taking each measure and attrition pre to post.

[a] Interpretation of correlation relative effect size: small = 0.10, medium = 0.20, large = 0.30 [79].

*** $p < 0.001$.

Table 4. Convergent Validity Correlations[a] by Gender: Belonging, Self-Efficacy, and Perceived Cost

	College Belonging		Engineering Belonging		Self-Efficacy		Cost	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
College Belonging Pre		0.56***	0.60***	0.49***	0.40***	0.22***	-0.48***	-0.33***
College Belonging Post	0.55***		0.44***	0.72***	0.32***	0.34***	-0.33***	-0.51***
Engineer Belonging Pre	0.55***	0.39***		0.57***	0.47***	0.21***	-0.57***	-0.42***
Engineer Belonging Post	0.40***	0.59***	0.62***		0.41***	0.44***	-0.42***	-0.65***
Self-Efficacy Pre	0.36***	0.28***	0.53***	0.35***				
Self-Efficacy Post	0.24***	0.33***	0.32***	0.46***				
Cost Pre	-0.54***	-0.32***	-0.64***	-0.44***				
Cost Post	-0.34***	-0.44***	-0.43***	-0.64***				

Men subgroup above diagonal; same time points circled; Women subgroup below diagonal

Note. "*Same time points*" are measures of the same students Pre-Pre and Post-Post. For *college belonging* correlations, women samples ranged between $311 \leq n \leq 777$ and men samples ranged between $881 \leq n \leq 2626$. For *engineering belonging* correlations, women samples ranged between $302 \leq n \leq 373$ and men samples ranged between $879 \leq n \leq 1236$ because of differing numbers of cohorts taking each measure and attrition pre to post.
[a] Interpretation of correlation relative effect size: small = 0.10, medium = 0.20, large = 0.30 [79].
*** $p < 0.001$.

across all combinations of belonging measures with others tend to be at least slightly stronger than the cross-time point (Pre-Post) measures, which is an expected result since at any given time students most strongly responded in similar manners to the multiple measures than they did at differing times. Of most interest in terms of validity evidence for subgroups is that these same identical patterns of strength of construct correlations between belonging and other measures is present for both the women and men subgroups.

4.3.3 Disaggregated by Underrepresented Group (URG) Status

Evidence for convergent validity of both parallel belonging measures in this study – belonging in college and belonging in engineering – was explored separately for underrepresented groups in engineering (URG) status and well as non-URG (see Table 5). This enables validity evidence to be generated for the use – and subsequent interpretations – by these subgroups as well as whole group.

Note in Table 5 that nearly all correlations are stronger than 0.3, which Gignac and Szodorai [79] labeled as a large relative effect size in comparison to the many effect sizes reported in education literature. For the few correlations less than 0.3, they are all located in the cross-time points (Pre-Post) and are still greater than 0.2; a medium effect size. Additionally, the same-time point correlations (Pre-Pre and Post-Post – circled in Table 5) across all combinations of belonging measures with others tend to be at least slightly stronger than the cross-time point (Pre-Post) measures, which is an expected result since at any given time students most strongly responded in similar manners to the multiple measures than they did at differing times. Of most interest in terms of validity evidence of these scales for subgroups is that these same identical patterns of strength of construct correlations between belonging and other measures are present for both the URG and non-URG subgroups.

4.4 Sensitivity to Societal Contexts

In the time span of our data from 2015–2022, there were two large-scale, time-specific, society-wide contexts that may have influenced students' sense of belonging: the COVID-19 pandemic in 2020 and the 2016 presidential election. Both events affected United States' society in large-scale systematic ways that may have been relevant to individuals' perceived sense of belonging in specific ways, and our measures may have been sensitive enough to reveal any such effects.

For each of the two societal contexts, we hypothesized that in one case (COVID-19 pandemic) all of society may have been similarly affected, and in the other case (2016 presidential election) certain subgroups of students may have had systemic differences in experiences. These simi-

Table 5. Convergent Validity Correlations[a] by Underrepresented group (URG) Status: Belonging, Self-Efficacy, and Perceived Cost.

	College Belonging		Engineering Belonging		Self-Efficacy		Cost	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
College Belonging Pre		0.55***	0.58***	0.45***	0.40***	0.21***	-0.49***	-0.31***
College Belonging Post	0.60***		0.42***	0.66***	0.30***	0.34***	-0.33***	-0.49***
Engineer Belonging Pre	0.59***	0.46***		0.61***	0.49***	0.24***	-0.60***	-0.42***
Engineer Belonging Post	0.55***	0.73***	0.59***		0.39***	0.44***	-0.44***	-0.65***
Self-Efficacy Pre	0.39***	0.34***	0.49***	0.45***				
Self-Efficacy Post	0.33***	0.34***	0.34***	0.51***				
Cost Pre	-0.53***	-0.37***	-0.54***	-0.41***				
Cost Post	-0.47***	-0.52***	-0.52***	-0.67***				

non-URG subgroup above diagonal; same time points circled; URG subgroup below diagonal

Note. "*Same time points*" are measures of the same students Pre-Pre and Post-Post. For *college belonging* correlations, URG samples ranged between $190 \leq n \leq 506$ and non-URG samples ranged between $1002 \leq n \leq 2971$. For *engineering belonging* correlations, URG samples ranged between $185 \leq n \leq 271$ and non-URG samples ranged between $985 \leq n \leq 1324$ because of differing numbers of cohorts taking each measure and attrition pre to post.
[a] Interpretation of correlation relative effect size: small = 0.10, medium = 0.20, large = 0.30 [79].
*** $p < 0.001$.

larities and differences by subgroup may be reflected in their sense of belonging as first-year engineering students and show up as a signal in our measurements. It is most useful to have multiple years of data to establish overall trends to enable exploration of how these measures may reflect student internal states and to note discrepancies or differences in those trends due to these time-specific large-scale events. Thus, our validity evidence for this category relies only on the sense of belonging in college measure since the equivalent engineering measure was not administered until 2019, and thus there aren't enough years of data for the engineering measure to be productive in this exploration.

4.4.1 Evidence of Sensitivity of Measure to the COVID-19 Pandemic

As anyone who lived through it would recall, the COVID-19 pandemic greatly impacted nearly all aspects of society in a dramatic way and did so in a very time-specific manner. In the United States, the COVID-necessitated shutdown of much of normal societal operations and interactions happened in March 2020, and by the Fall 2020 school year most universities, including the one at the core of this study, had shifted relatively rapidly to mostly or exclusively remote teaching. For purposes of this study, the incoming engineering freshmen who responded to our surveys in August 2020 (Pre-semester; at the beginning of the semester) and in early December 2020 (Post-semester) are labeled the "COVID cohort" since they were all experiencing aspects of social isolation necessitated by the COVID pandemic. Because college sense of belonging is often closely related to social aspects of campus life, which are tied to engagement and interactions with faculty, staff, and students [24, 6],we explored if our sense of belonging measures were sensitive to potential impacts of the pandemic on sense of belonging.

Fig. 1 presents the college belonging scores of all students in cohorts 2015–2022. These belonging scores are on a scale of 4–20 by summing the four items rated on 1–5 Likert scale (see Appendix A for the measures), after recoding so that for all items, a higher rating represents a stronger sense of belonging. Each cohort student took the survey at the beginning of their first semester (Pre) and again at the end of first semester (Post).

As shown in Fig. 1, the magnitude of the drop in sense of belonging in college shows the greatest loss in the 2020 COVID year, with a statistically significant drop from pre-to-post ($p < 0.001$) using a paired samples t-test, and this drop has an effect size magnitude of Cohen's $d = 0.30$. There was also one prior year (2019) which also showed an overall statistically significant drop in sense of belonging

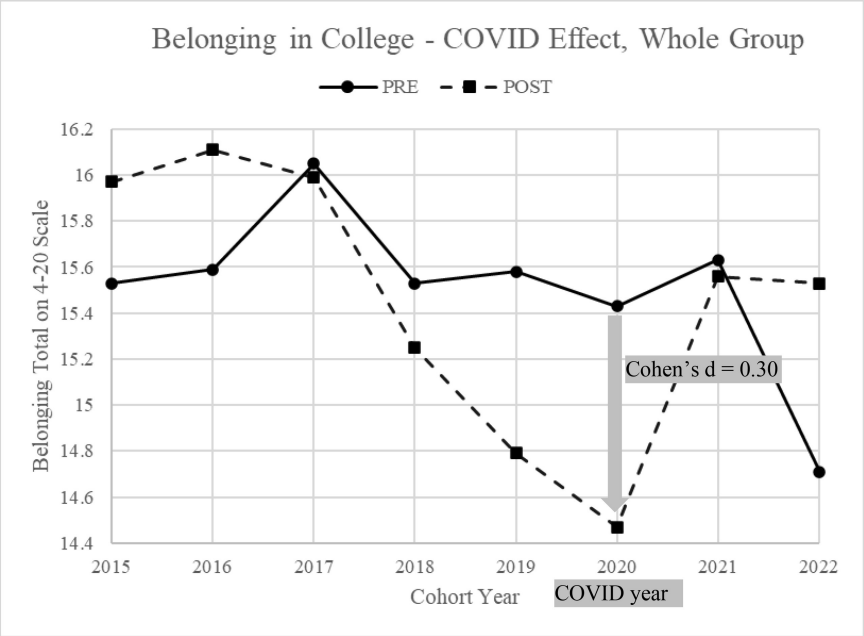

Fig. 1. Sensitivity of College Belonging Measure to COVID Impact in 2020 – the COVID Dip.

($p < 0.001$, $d = 0.23$) prior to the COVID year, but generally across the eight years of these data such a dramatic drop was the exception rather than the rule; in fact, in most years the post-belonging measure was either similar or stronger than the pre-measure except for the COVID year and 2019. Because the COVID year drop is the largest in magnitude, this suggests that the semester-long Fall 2020 experience of social isolation during the first year in college may have resulted in a substantially weaker sense of belonging by the end of that semester that applied widely across all engineering students.

Several studies have detailed the negative impact of COVID-19 to the mental health of college students. In Fletcher et al. [80], 59% of engineering students at a historically black college reported that being off campus during COVID-19 had negatively affected their sense of belonging to their college. Other studies point to high levels of mental health distress and inability to focus on academics [81] and decreased academic self-efficacy due to increased anxiety and mental stress [82].

In addition to the COVID year drop, of interest in these data is the reversal of the downward trend of reduction in sense of belonging across the first semester which culminated in the COVID year, and then recovered to a positive growth in sense of belonging in 2021. This may reflect the measurement's sensitivity to students' sense of isolation with resulting anxiety, stress and academic challenges of remote learning during COVID, and the subsequent reversal of that sense once the most dramatic pandemic social restrictions were lifted by fall 2022.

4.4.2 Evidence of Sensitivity of Measure to the 2016 Presidential Election

One notable feature of the 2016 US presidential election during the months prior to the November 2016 election and subsequent months post-election, was the high-profile and systematically regular rhetoric by candidate, and then-elected president, Donald Trump. These frequent episodes were well-covered in the daily news media, and ubiquitously on many social media platforms, and anyone in the US at that time would have been regularly exposed to this as part of the all-encompassing election coverage. This would be generally true no matter which news source – or even if not particularly attentive to any news source – an individual may have followed.

While some voting Americans did not react negatively to the 2016 election rhetoric, several qualitative studies suggested that the election rhetoric was met with distress and fear by many women, minoritized ethnic groups and members of the LGBTQ+ community [83–89]. These reactions suggested that the 2016 election may have also impacted members of these groups of people in terms of their feelings of fit (or belonging) within American society. Research by Block et al. [90] extended the earlier studies by quantifying people's expectations about how others in society will treat them, and to a lesser degree, how their self-concept fits within the broader American society. Their

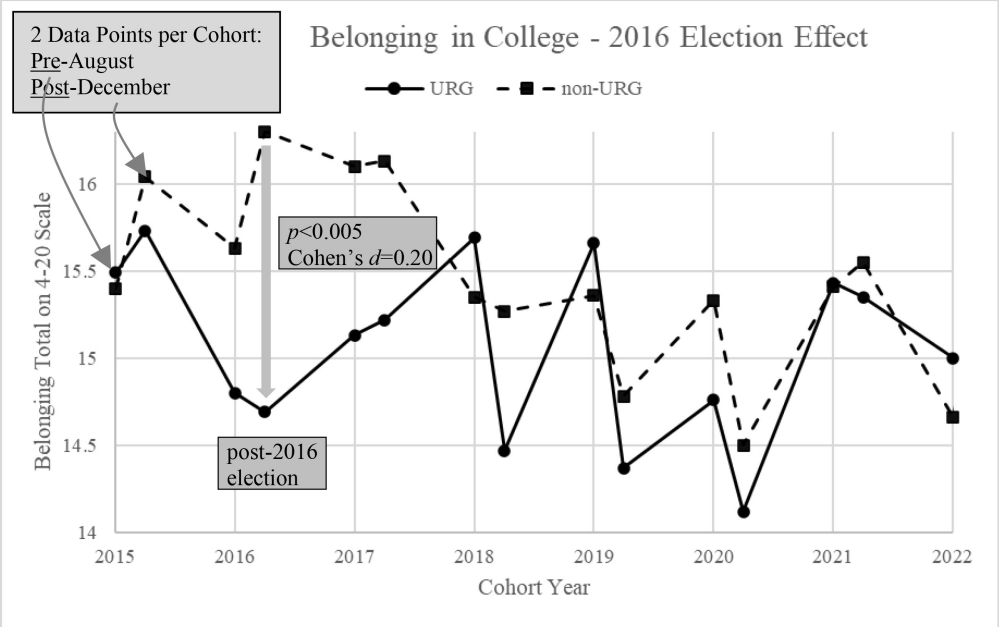

Fig. 2. Sensitivity of College Belonging Measure to Potential Belonging Differences in Underrepresented Groups in Engineering (URG) vs. non-URG due to Societal Context of 2016 Presidential Election

work confirmed that belonging, discrimination, and even physical threats were key concerns among women and minority group members because of the 2016 election. Studies have also shown similar findings for college students: underrepresented and marginalized college students felt anxiety and mental distress [84], and that the election experience had a negative impact on their sense of belonging in college for Latinx students [91].

Thus, we explored whether our incoming engineering students who identified as a member of an underrepresented group (URG) in engineering may have reflected that society-wide context in their sense of belonging differently from non-URG students. Many students identifying as a member of an URG may have subconsciously heard and possibly absorbed a message of unwelcome – or not belonging – as a subtext to the various negative rhetoric they were regularly exposed to as part of that national presidential election cycle. Fig. 2 documented sense of belonging in college – disaggregated by URG subgroups – for the eight cohorts of first-year engineering students in this study.

Fig. 2 presents two nearby data points for each year's cohort – the first is the Pre measure (beginning of semester – late August) and the second is the Post measure (end of semester – early December). Of the total of 16 comparisons, ONLY the two most immediately after the 2016 election (Post-2016 = December 2016, and Pre-2017 = August 2017) showed a statistically significant difference between URG and non-URG subgroups. The largest of these two is the Dec 2016 measurement point, immediately after the election results were determined the month prior. By 2018 and later any residual effect on URG students' sense of belonging potentially due to the election seems to have dissipated. As was shown for the whole group combined (see Fig. 1), Fig. 2 also reveals the COVID dip in sense of belonging for each subgroup (URG and non-URG) since the lowest point for each group is the post-2020 measure, after students experienced their first semester of college in a context of social isolation.

5. Discussion

This study documented the evidence for internal reliability and validity of two parsimonious sense of belonging scales used with first-year engineering students. Having validity evidence for a short 4-item scale can support researchers faced with the challenge of investigating this important topic, especially if the targeted participants are first-year engineering students who are often asked to respond to a relatively large number of survey items. Reliability and validity evidence for these two scales was presented in four distinctly different categories as reported in the *Results* section, and within those sections, there were also often multiple independent strands of evidence. Of particular importance to researchers who may be interested in studying sense of belonging in engineering for different subgroups of students such as men/women or underrepresented groups, this validity evidence reported by subgroups strongly suggested that the validity of these measures was equally strong for

those subgroups as for the whole group of first-time, first-year engineering students.

Among those results of measurement sensitivity by subgroup, the results in Table 2 showed that women tended to have a lower sense of belonging in engineering than men, whereas the same was not true for sense of belonging in college. This is substantial evidence that although the two scales are parallel they measure distinctly different senses of belonging; college and engineering. We therefore suggest that researchers would be able to use these scales according to whichever constructs they are interested in measuring. It seems likely that if someone were to study a college discipline other than engineering, e.g., physics or mathematics, it may be possible to modify the scale with those labels and still retain the validity of the measurement.

Within the strand of validity evidence of sensitivity to broad societal contexts, our scales captured differential sense of belonging impacts for URG compared to non-URG due to the 2016 presidential election rhetoric. It also captured negative societal impacts (which often directly connect with sense of belonging) for all students due to the COVID-19 pandemic effects in 2020. This strand of evidence is distinctly different from the other strands off evidence and the results encourage that this measure is sensitive to lived experiences, which is of importance to researchers trying to understand the effects of societal or personal contexts on sense of belonging.

6. Conclusions

This paper showed through multiple independent strands of validity evidence that scales intentionally designed to be of minimum length validly captured the complex concept of sense of belonging. Given the anticipated survey load of studies of the many facets of interest when researching first-year retention, limiting the belonging survey to four items permits a wider array of other survey items without substantially impacting potential survey fatigue or straightlining. Although one piece of validity evidence on its own might not be very strong, the different sources of validity evidence reported in this study collectively provided strong evidence for being able to extract valid interpretations from our two parallel parsimonious scales. Because the evidence included students making clear distinctions between college and engineering, that also provided confidence that future minor modifications to target different disciplines may be likewise valid.

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Appendix A

Belonging in College & Belonging in Engineering Measures

Belonging in College

The following questions ask you about your perceptions of your belonging in college. Please respond honestly.

Please indicate how true each of the following statements is.

	Not at all true	Slightly true	Somewhat true	Mostly true	Completely true
Sometimes I worry that I do not belong in college.	○	○	○	○	○
I am anxious about whether I fit in at college.	○	○	○	○	○
I feel confident that I belong in college.	○	○	○	○	○
When I face difficulties in college, I wonder if I really fit in.	○	○	○	○	○

Belonging in Engineering

The following questions ask you about your perceptions of your belonging in engineering. Please respond honestly.

Please indicate how true each of the following statements is.

	Not at all true	Slightly true	Somewhat true	Mostly true	Completely true
Sometimes I worry that I do not belong in engineering.	○	○	○	○	○
I am anxious about whether I fit in at an engineering school.	○	○	○	○	○
I feel confident that I belong in engineering.	○	○	○	○	○
When I face difficulties in engineering, I wonder if I really fit in.	○	○	○	○	○

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