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Enabling Multi-Dimensional Measurement of Student Engagement in Engineering Learning Environments*

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Engineering student engagement is linked to belonging and persistence, which have been shown to influence graduation rates. Little is known about the ways in which engineering engagement is influenced by peers and faculty, motivation, satisfaction, and belonging in a learning setting. This research describes the approach used to develop the items to measure post-secondary students' engineering engagement in their learning environment. Having an instrument that assesses engineering student engagement relative to their disposition toward their academic discipline, themselves, other students, and faculty will extend the research base on engineering student learning and retention and answer specific calls to examine these factors. We used several statistical techniques including exploratory and confirmatory factor analyses (n = 976) to explore the reliability and validity of the engagement subscales. Exploratory and confirmatory factor analyses of the data indicated that the instrument best fits a six-factor model. The factors are: Major Satisfaction, Academic Discipline Belonging, Major Valuing, Achievement Striving, Peer Interaction, and Positive Faculty Relationship. The consistency of the observed inter-factor correlations strengthens the validity of the PosSE Survey as an instrument that measures different facets of affective engagement.

Keywords: engagement; persistence; survey development; confirmatory factor analysis

1. Introduction & literature review

The lack of meaningful student engagement portends ill-prepared college graduates or increasing numbers of college dropouts, which could limit the capacity to meet future demands for qualified scientists and engineers. To support engineering career needs of the future and retain students in engineering disciplines, more resources are being focused on initiatives that promote enriching educational experiences and enhance student engagement, especially among traditionally underrepresented student groups. To understand factors that support historically underrepresented student persistence, it is important to examine what works specifically for different groups of students [1]. Some reports have estimated that nearly half of students who declare a science, technology, math or engineering (STEM)-related major leave STEM fields before the fourth year of their college degree programs [2, 3] and in the second year for engineering students [4]. Attrition from STEM fields seems particularly pronounced among underrepresented groups such as ethnic minorities and females [3, 5]. Attrition rates in engineering remain disturbingly high, at 57% according to Ohland, Sheppard, Lichtenstein, Eris, Chachra and Layton [4] despite investments in retention research and efforts to translate findings into practice at all levels of education.

Literature strongly supports the need to examine factors related to engagement in learning environments (e.g., in the classroom) [6, 7]. While research efforts have resulted in the development of instruments that assess multiple facets of engagement [8, 9], current instruments fall short in one way or another. Measures of school connectedness as a form of affective engagement are limited at best and non-existent at worst in current instruments. Both the Student Engagement Instrument (SEI) developed by Appleton and colleagues and the National Survey of Student Engagement (NSSE) has items assessing some indicators of school connectedness as a form of affective engagement. Academic Pathways of People Learning Engineering Survey (APPLES) measures satisfaction with instruction and frequency of interactions with instructors as measures of engagement [10, 11]. Such instruments range from a few items measuring student affective engagement subsumed within a broader inventory, to those developed to assess a broad spectrum of engagement indicators. No

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instrument measures affective engagement as comprehensively as described in the literature. Therefore, current instruments cannot support research answering the calls from engineering education researchers described above. Given the influence of school connectedness [12, 13], we believe an instrument that assesses student affective engagement relative to school connectedness would be a notable contribution to the literature.

Further, measuring engagement is fraught with issues related to variations in the definitions and measures of student engagement [14]. To clarify what the instrument measures, we clearly describe our particular definition and operationalization of engagement. In the next section, we explain affective engagement as forms of connectedness to school and persons in school and the relationship between affective engagement and the forms of connectedness measured by the instrument (i.e., belonging, valuing, satisfaction, academic striving and interacting with peers and faculty).

2. Connectedness as a form of affective engagement

Using Finn's participation-identification model [15], we argue that behavioral engagement moderates academic achievement and affective engagement, and, in this context, is a form of connectedness. Continued participation in desirable learning activities increases the likelihood of academic success and improved sense of connectedness, or how well students connect with a learning community [16]. Conversely, failing to participate in learning activities and with the learning community diminishes a student's likelihood of achieving academic success, and can erode his/her sense of connectedness or bonding with his/her learning community. The model portrays dropping out from school as a logical outgrowth of prolonged dysfunctional involvement with persons associated with school and school itself.

Identification, referred to as connectedness in this study, is the affective component of involvement that describes a student's sense of significance, or inclusion, in school [16, 17]. Continued participation in school and classroom activities often gets rewarded with success, which reinforces sense of connectedness with the learning community. Connectedness embodies students' need for belonging and sense of value. Students' sense of connectedness is also reflected in affective behaviors such as satisfaction and achievement striving, and engagement with others in their learning community [16, 18]. These constructs are briefly reviewed in the section below.

Need for Belonging—Having a sense of belonging describes a student's perception of acceptance, inclusion, and support within the school's social environment [19]. The need to belong derives from a psychological need for social acceptance within a domain, and having that need met strengthens the motivation to strive for continued acceptance within the domain [20]. Research has demonstrated the significance of social and academic connections to academic achievement [21]. Tinto [22] posits that the sense of fit within, and the ability to integrate into, an academic culture would impact both student achievement and academic persistence. Lacking that sense of belonging often indicates disaffection or disengagement with school: emotionally detached students often show signs of cognitive and behavioral disengagement with learning activities [22–24].

Valuing—Value describes the relative importance attached to something [25]. It could involve feelings of personal importance that evolve from having a sense of fulfilment or satisfaction with school tasks, or a sense of practical importance students associate with school and learning because they appreciate its utility in achieving some present or future goals [18]. The expectancy-value theory of achievement motivation suggests that perceived inherent value influences student achievement behaviors, such as the task they choose, and their persistence on task [26].

Connectedness is feeling-based and is more of an affective construct just as its constituents (belonging and valuing) are affective. School connectedness has a significant impact on achievement behaviors and learning performance. Apart from value and belonging however, feeling connected with school is also reflected in students' academic satisfaction, achievement striving, and interactions with others—especially peers and faculty—in school. Students find learning-related tasks valuable and feel belonging in school when they have a deep sense of personal satisfaction with school. For instance, students who lack a sense of fit within their academic domain tend to be dissatisfied with their educational experience, are less cognitively engaged with learning, and are less emotionally invested in their academic achievements [23]. Similarly, the more satisfied students are with school and their learning experiences, the more engaged they tend to be, suggesting that satisfaction by itself is indicative of affective engagement in school.

Similarly, connectedness is also reflected in students' attitude towards others within their learning community, and its accepted customs. To remain in good academic standing is customarily expected of students who aspire to remain accepted in school or within their academic community. The need for social acceptance influences achievement striving, the determination to succeed that compels them to engage in behaviors that promote performance—in students [27]. On the contrary, students who feel less connected with school soon find it needless to conform to such school norms, see their learning experiences as less valuable, and feel dissatisfied with school. Also, students who lack the drive for academic success are not inclined to seek study help from their peers and faculty [28].

Peer interaction is pertinent to connectedness and an enriching learning experience because students who are actively engaged with their peers also feel a deeper sense of school connectedness [23]. In the same vain, positive student-faculty interaction has a prominent impact on learning experience, academic persistence, and achievement [29, 30]. Peer interaction and student-faculty relations key moderators of emotional and academic support [30]. By engaging with peers, the learner is able to work collaboratively with others and share knowledge, thus deepening understanding of difficult concepts while learning from others [31]. Such relationships strengthen the bond of connection that students feel, as well as their attitude, towards school and learning.

3. Purpose of this study

Despite abundant examples of factors related to attrition and that support engagement in higher education, more can be done to enhance the undergraduate engineering experience in ways that improve learning, retain more students and reduce the barriers faced particularly by students underrepresented in engineering. The sense of connection engineering students feel towards college or university substantively influences their attitude toward learning and others in their learning community and, consequently, their persistence. Connection to school is a measure of affective engagement that bears out in at least five ways for engineering students: (i) their sense of belonging in engineering school; (ii) the value they attach to engineering school and learning; (iii) engineering students' satisfaction with educational experience; (iv) their achievement striving in engineering; and (v) in their interactions with peers and faculty that promote feelings of belonging in their discipline (see Fig. 1). The instrument does not directly measure engagement while learning in classroom settings, but instead assumes that the factors measured do propagate through to the classroom. We also discussed the link among these indicators of affective connection, other forms of engagement behaviors, and academic achievement.

Since its inception, the Postsecondary Student Engagement (PosSE) Survey has undergone multiple efforts to establish its face and content validities. The present study reviews these previous validity efforts and reports on an effort to document the construct validity and evidence towards reliability of subscales of the instrument.

4. Methods

4.1 Participants

Data for the study were obtained from a total of 976 undergraduate science, technology, engineering, and mathematics students who responded to the Postsecondary Student Engagement (PosSE) Survey. An overwhelming majority of the participants (n = 825) were undergraduate engineering students. Participants were undergraduate students across predominately white institutions located in southern and mid-Atlantic states in the United States. The institutions selected for sampling were ones where a significant number of engineering

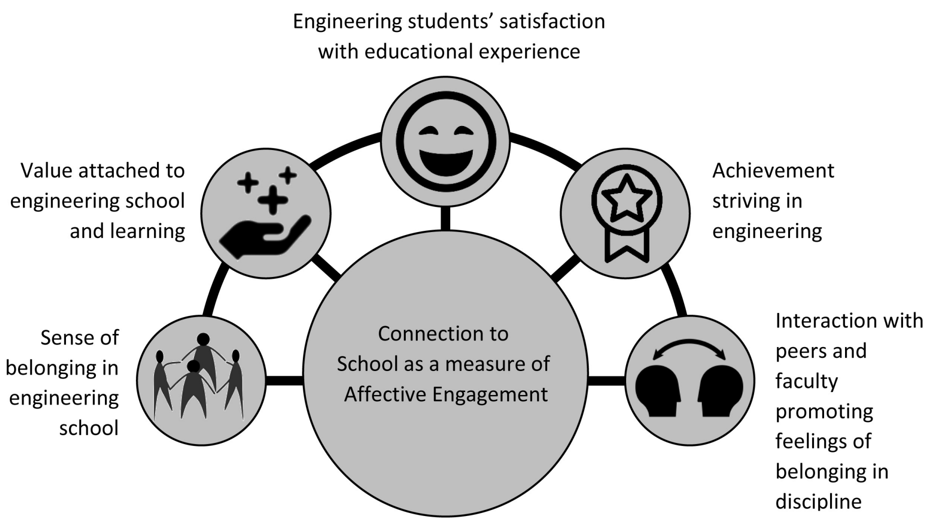

Fig. 1. Measures of Connection to School.

Table 1. Factors of the PosSE Survey

Factor	Conceptual Name	No. of Items	Loading Range	Reliability (Cronbach's)
1	Major Satisfaction	5	0.71 to 0.52	0.87
2	Academic Discipline Belonging	4	0.85 to 0.48	0.82
3	Academic Discipline to Career Link	2	0.46 to 0.60	0.72
4	Major Valuing	3	0.99 to 0.53	0.75
5	Achievement Striving	5	0.82 to 0.49	0.78
6	Peer Interaction	4	0.83 to 0.43	0.75
7	Positive Faculty Relationship	3	0.85 to 0.57	0.78

degrees are awarded to women and underrepresented ethnic groups, which ensured our sampling included underrepresented groups in engineering [32]. This purposeful sampling method would maximally serve our goal of exploring affective engagement for engineering undergraduates and especially underrepresented groups. Moreover, the large sample size (N>1000) and high subject to item ratios (>20:1 ratio; 26 items) would be enough to ensure the stability of estimates with power of 0.80 or greater [33, 34].

4.2 The instrument

Development of the Postsecondary Student Engagement (PosSE) Survey proceeded in three phases as described below.

Phase I: Item development. The PosSE Survey assesses engineering students' affective engagement. Development of the engagement items involved a literature review including review of relevant instruments, web searches, a Q-Study, a panel of experts and, finally, think-aloud sessions to determine face validity [35]. The item development process involved adapting items from existing instruments, administering items to a development sample, evaluating the items, and optimizing the scale length [36, 37].

Phase II: Pilot study. During pilot testing of the survey, data from 133 participants were analyzed using Exploratory Factor Analysis (EFA) to reduce or refine the items on the survey and to examine the preliminary structure of the items [37]. Results from the EFA suggested an underlying structure of seven factors that explained over 69% of the variances (see Table 1). Several of the original 27 survey items were revised to improve content validity. One survey item was removed to improve internal reliability; thus, the current instrument contains 26 items.

Phase III: Exploratory validating study. The current study reports the third phase of the development and validation of the PosSE Survey. In this phase, we explored the structure of the final 26-item survey using a larger sample drawn from postsecondary institutions located in southern and mid-Atlantic states with a predominantly White student population. Both an EFA and a Confirmatory Factor Analysis (CFA) were conducted to further replicate and confirm the structure of the items in measuring involvement outcomes. After deleting cases with completely missing values on all survey items and excluding students in non-STEM degree programs, 976 valid responses—with 875 being undergraduate engineering students—were available for analysis. Table 2 shows the demographic distribution of the participants whose responses were included in the final analysis.

4.3 Data analysis

To conduct the validation analyses, the full sample was randomly split into two subsamples. The first subsample (dataset 1) was used for ongoing development of the instrument and item selection while the other subsample (dataset 2) was used to replicate the results and provide further valuable information [38]. An EFA and reliability analysis were conducted on the first dataset to examine the structure of the scale in order to implement any modifications deemed empirically and theoretically justified. Then a CFA was conducted on dataset 2 to replicate and confirm the model identified in the EFA. Lastly,

Table 2. Participant Characteristics (N = 976)

Characteristics	Number of students	Percent
Gender		
Male	518	53.1%
Female	445	45.6%
Other or Not reported	13	1.3%
Race		
Asian	100	10.2%
Black	118	12.1%
Hispanic	128	13.1%
White	664	68.0%
Other races	46	4.7%
Classification		
First year	255	26.1%
Sophomore	177	18.1%
Junior	253	25.9%
Senior	229	23.5%
Fifth year and beyond	62	6.4%
Major		
Science	120	12.3%
Technology	24	2.5%
Engineering	825	84.5%
Mathematics	7	0.7%

internal consistency reliability evidence, Cronbach's alpha of each subscale, and item discriminatory analyses were computed.

4.3.1 *Exploratory factor analysis*

Exploratory factor analysis was first used to examine the preliminary structure and construct validity of the PosSE Survey. An instrument is deemed to have construct validity if it measures what it actually claims to be measuring [39]. EFA provides construct validity evidence by determining the number and nature of common factors needed to account for the pattern of correlations among the measured variables, which results in a more parsimonious conceptual understanding of a set of measured variables [40]. The results of EFA also offer a better understanding of the structure of correlations among the measured variables, which can inform decisions to revise items to improve reliability and content validity. Prior to the analysis, the Kaiser-Meyer-Olkin (KMO) and Bartlett tests were examined to assess whether the data were amenable to the Principal Component Analysis (PCA) procedures. The KMO was 0.79, which meets Kaiser's "middling" criteria and suggests the items were adequate for factor analysis. The Bartlett test was significant ($p < 0.05$), indicating that the correlation matrix is not an identity matrix and is factorable [41].

The EFA procedure includes extraction, rotation, and interpretation of the factors. Maximum likelihood was used as an extraction method. We selected an oblique solution (i.e., direct oblimin) in the rotation step, since our factors ought to be theoretically correlated, although we did not know how at the time. The number of factors on a scale are determined based on the eigenvalues, scree plot, and conceptual meaning of the items in the extraction procedure. Factors with eigenvalues greater than 1 were extracted [42], and items with a factor loading greater than 0.4 were retained; a factor loading of 0.40 or above is considered to be meaningful [43]. The factors were extracted as dimensions of engineering student engagement.

4.3.2 *Confirmatory factor analysis*

Confirmatory factor analysis is conducted to examine the factor structure of the latent factors when investigating construct validity [44]. The CFA assists in the reduction of measurement error and allows for the comparison of alternatively proposed models at the latent factor level [44]. Conducting CFA adds a level of statistical precision and can assist in the development of abbreviated forms of an instrument or confirmation of its possible subdomains [44]. Based on CFA findings, observed variables are examined to determine if their factor loadings are significant and appropriately placed.

Besides the significance level of each parameter, Stevens [45] proposed a table of critical values against which loadings can be compared. He recommended values greater than 0.162 for sample sizes over 1000. Items with loadings of 0.40 or above were considered for inclusion in the subscales and Cronbach's alpha values of 0.6 and above for each full scale were considered acceptable. Once overall fit of the models is established, construct validity, error variance, indicator reliability, Cronbach's alpha, and construct reliability are assessed. Assessment of construct validity is based on the standardized factor loadings, which is a measure of the variance that is accounted for by the latent variables. Construct validity is ascribed based on the extent to which an indicator converges or shares in a single construct. An indicator has high validity when its factor loading value is high and significant. The indicator reliability, which measures the variance in each measured variable explained by the underlying latent variable, was assessed by the square of the standardized factor loadings. Cronbach's alpha was used to measure internal consistency and reliability.

5. Results

5.1 *Exploratory factor analysis*

First, the EFA was conducted on the 26 items of the survey using dataset 1 ($n = 488$). We wanted the fewest number of factors that explained the largest amount of variation in the data. Our EFA analysis indicated that six factors best explained the covariation matrix and about 72.25% of the variances observed within the dataset. All items displayed a clear and strong fit with each factor except one item, "I feel like a real part of my current academic discipline." This item was cross-loaded on two factors: Academic Discipline Belonging and Achievement Striving, factor loadings for each were below 0.40. Moreover, the two items related to Perceived Fit with Career were not loaded together. One item, "My eventual career will directly relate to a job in my academic discipline," was loaded on Major Satisfaction, with a loading of 0.45. However, the theoretical meaning of this item was focused more on the academic discipline but not major. The other item, "In the future, I will not have a career that requires me to have skills of my academic discipline," was loaded on Academic Discipline Belonging, but with a low factor loading (.34). The authors made decisions about whether to retain items with cross-loadings based on whether they could determine which factor the item best fit. When the item did not have a clear fit with any one factor, the item was deleted. As a result, these three items were not retained due to cross-loadings and their lack of a clear fit with any one factor on which

Table 3. Exploratory Factor Analysis Results

Item	Factor loading	Factor/Subscale	Cronbach's α
Overall, I am happy with the major I've chosen.	0.680	Major Satisfaction	0.864
I don't intend to change my major from current major to another major.	0.493		
I am enthusiastic about my major.	0.787		
I think I will be very happy to spend the rest of my career in my current major.	0.713		
My major is interesting to me.	0.799		
I do not feel like "part of the family" in my academic discipline. (Reversed)	–0.813	Academic Discipline Belonging	0.901
I do not feel "emotionally attached" to my academic discipline. (Reversed)	–0.728		
I do not feel a strong sense of "belonging" to my academic discipline. (Reversed)	–0.891		
Success in my major at school is very valuable to me.	–0.939	Major Valuing	0.870
It matters to me how well I do in my major at school.	–0.845		
Being good at my major is an important part of who I am.	–0.531		
I excel at identifying opportunities.	0.737	Achievement Striving	0.816
If I see something I don't like, I fix it.	0.604		
If I believe in an idea, no obstacle will prevent me from making it happen.	0.722		
I love being a champion for my ideas, even against others' opposition.	0.637		
I am constantly on the lookout for new ways to improve my life.	0.494		
I discuss career issues with peers.	0.837	Peer Interaction	0.856
I discuss academic issues with peers.	0.843		
I discuss social issues with peers.	0.771		
I discuss cultural issues with peers.	0.546		
The instructors in my program respect me.	–0.892	Positive Faculty Relationship	0.848
I am satisfied with the faculty in my major.	–0.709		
I am treated with as much respect by faculty as other students in my program.	–0.781		

they cross-loaded. Table 3 shows the EFA results based on the retained 23 items.

We calculated internal reliability coefficients for each original subscale in the sample (n = 488). Cronbach's alphas of all but one subscale was above 0.8, which is considered reliable [46, 47]. Moreover, we analyzed items related to each subscale. We noticed that although the subscale Academic Discipline Belonging had strong internal reliabilities (α = 0.854), the highlighted item, "I feel like a real part of my current academic discipline," was poorly correlated to the other items related to Academic Discipline Belonging. Deleting this item will further improve the internal reliability of the subscale. Perceived Fit with Career had the lowest coefficient (α = 0.601), perhaps because two of its items, "In the future, I will not have a career that requires me to have skills of my academic discipline" and "My eventual career will directly relate to a job in my academic discipline," were not strongly correlated with each other.

5.2 *Confirmatory factor analysis*

We conducted a confirmatory factor analysis using the remaining sample (n = 488) to validate the EFA results. A measurement model was constructed based on the retained 23 items. The fit of the measurement model identified in the EFA with the confirmatory factor analysis was less than ideal: $\chi^2(215, N = 488) = 809.07$, $p < 0.05$: the goodness-of-fit index (GFI) was 0.88, and the adjusted goodness-of-fit (AGFI) index was 0.85; the comparative fit index (CFI) was 0.96; the root-mean-square error of approximation (RMSEA) was 0.071; the standardized root mean square error of approximation (SRMR) was 0.054. A large modification index (MI) suggested that three pairs of indicators were highly correlated. As suggested by the modification index, a revised model was estimated by releasing the covariance of three pairs of indicators. The systematic variance of the three pairs of indicators were allowed to be correlated with each other. Then the model fit was much improved: $\chi^2(212, N = 488) = 490.85$, $p < 0.05$; GFI = 0.92, AGFI = 0.90; CFI = 0.98; RMSEA = 0.052; and SRMR = 0.048.

As seen in Table 4, each of the items on their respective factors had generally moderate or high pattern coefficients with some variability (range of loadings = 0.55 to 0.94), and all were statistically significant. The statistical test of each parameter was formed by dividing the parameter estimate by the standard error of that estimate. An alpha level of 0.05 was employed. An extracted variance of greater than 0.50 indicates that the validity of both the subscale and the individual variable is high [48]. The extracted variance estimate of Academic Discipline Belonging and Positive Faculty Relationship were high (over 0.70). For Achievement Striving, the estimates were slightly lower than 0.50. However, it is important to note that this variance extracted estimate test is very conservative. Given the significant factor loadings and high reliabilities,

Table 4. Standardized Loading, Reliability, and Validity of the Final Measurement Model

Subscales and indicators	Standardized loading	t	Reliability	Variance extracted estimate
Major Satisfaction			0.87	0.57
Overall, I am happy with the major I've chosen.	0.79	–	0.63	
I don't intend to change my major from current major to another major.	0.55	14.79	0.30	
I am enthusiastic about my major.	0.84	20.00	0.71	
I think I will be very happy to spend the rest of my career in my current major.	0.79	18.53	0.62	
My major is interesting to me.	0.77	18.12	0.60	
Academic Discipline Belonging			0.88	0.71
I do not feel like "part of the family" in my academic discipline. (Reversed)	0.82	–	0.68	
I do not feel "emotionally attached" to my academic discipline. (Reversed)	0.82	20.47	0.68	
I do not feel a strong sense of "belonging" to my academic discipline. (Reversed)	0.88	22.11	0.78	
Major Valuing			0.89	0.65
Success in my major at school is very valuable to me.	0.76	–	0.57	
It matters to me how well I do in my major at school.	0.74	28.76	0.55	
Being good at my major is an important part of who I am.	0.91	13.87	0.83	
Achievement Striving			0.80	0.46
I excel at identifying opportunities.	0.72	–	0.52	
If I see something I don't like, I fix it.	0.67	12.90	0.45	
If I believe in an idea, no obstacle will prevent me from making it happen.	0.71	13.54	0.50	
I love being a champion for my ideas, even against others' opposition.	0.65	12.56	0.42	
I am constantly on the lookout for new ways to improve my life.	0.61	11.84	0.37	
Peer Interaction			0.88	0.62
I discuss career issues with peers.	0.83	–	0.69	
I discuss academic issues with peers.	0.94	22.37	0.89	
I discuss social issues with peers.	0.73	18.09	0.53	
I discuss cultural issues with peers.	0.62	14.57	0.38	
Positive Faculty Relationship			0.87	0.71
The instructors in my program respect me.	0.92	–	0.84	
I am satisfied with the faculty in my major.	0.72	18.83	0.52	
I am treated with as much respect by faculty as other students in my program.	0.88	24.69	0.77	

the subscale was still meaningfully measured by the items.

5.3 *Internal reliability and item discrimination analyses*

All the analyses in this section were conducted using the full sample (n = 976). Factor scores were calculated using the regression method for each engagement subscale prior to examining the descriptive statistics and intercorrelations among them. The summary of descriptive statistics and correlations are shown in Table 5. The six subscales had significant correlations with each other, and the inter-correlations among them ranged from 0.23 to 0.71 (see Table 5). Specifically, Major Satisfaction was strongly correlated with Academic Discipline Belonging and Major Valuing. In addition, the internal consistency reliability (Cronbach's alpha) were estimated for each of the six factors (see Table 5). Reliability coefficients for all subscales were

Table 5. Descriptive statistics and Correlations for Subscales

					Correlations				
Subscales	Cronbach's α	Mean	S.D.	Skew	Academic Discipline Belonging	Major Valuing	Achieve-ment Striving	Peer Inter-action	Positive Faculty Relationship
Major Satisfaction	0.87	3.34	0.53	–0.62	0.71*	0.55*	0.42*	0.23*	0.54*
Academic Discipline Belonging	0.89	2.97	0.75	–0.34		0.49*	0.30*	0.27*	0.55*
Major Valuing	0.88	3.37	0.54	–0.43			0.44*	0.29*	0.33*
Achievement Striving	0.81	3.06	0.55	0.14				0.41*	0.34*
Peer Interaction	0.87	3.15	0.59	–0.22					0.28*
Positive Faculty Relationship	0.86	3.14	0.59	–0.49					

* $p < 0.05$.

Table 6. Empirical Item Analysis Results

Factor	Factor/Subscale Name	Items Mean Range	Items Discrimination Range
1	Major Satisfaction	3.20 to 3.49	0.59 to 0.70
2	Academic Discipline Belonging	2.94 to 3.03	0.80 to 0.84
3	Major Valuing	3.29 to 3.45	0.59 to 0.64
4	Achievement Striving	2.93 to 3.34	0.60 to 0.71
5	Peer Interaction	3.02 to 3.24	0.65 to 0.78
6	Positive Faculty Relationship	3.10 to 3.22	0.60 to 0.70

high, ranging from 0.81 to 0.89. Compared to results in the pilot study, the internal consistency reliability of all measured subscales was increased.

Additionally, each item was subjected to an empirical item analysis to assess quality (see Table 6). In general, the discrimination indices for the scale suggested that the items may discriminate between persons of low and high levels of each factor. However, the lower discriminating items may not predict total scores as well. That is, item performance will not differ systematically for students with low or high total scores.

6. Discussion

The purpose of this study was to examine the psychometric properties of the engagement subscales measured by the PosSE Survey. An initial pilot study with 133 participants reduced the PosSE Survey to a 26-item, 7-factor instrument. The current iteration in the development and validation of the PosSE Survey was intended to reexamine our initial findings and to improve on our earlier efforts to validate the instruments using a larger sample size. Both EFA and CFA analyses were conducted on two datasets derived from 976 participants. Our EFA of PosSE Survey data of 488 participants indicated that the instrument best fits a 23-item 6-factor model. Items on the Academic Discipline to Career Link factor did not strongly correlate to each other, the internal reliability coefficients were low (α = 0.601) for this subscale; hence, they were not included in the new instrument. The CFA conducted on a second dataset of 488 participated supported the six-factor model that resulted from our initial EFA. The 23 items on the survey cleanly loaded onto the six factors, with the factor loadings of all items exceeding 0.5. Additionally, the internal reliability of the factors on the instrument was promising: Cronbach's alpha of reliability coefficient ranged between 0.80 and 0.90. Overall, the results support the idea that connectedness as a form of affective engagement is multidimensional and complex [16] in the six sub-dimensions. We attribute this to the dimensions of affective engagement that are critically dependent on learners' beliefs and attitudes toward their academic pursuits (e.g., satisfactions, values, interest) or their relationship to school, and others in school (e.g., belonging, relationships with peers and instructors; [12, 13]). The results indicate that students can recognize and respond to items assessing the extent to their connectedness with the learning community and how they associated with school-related activities as indicated by the engineering career factor.

Moreover, the inter-correlation observed among factors was also consistent with the literature. Academic Discipline Belonging showed a high positive correlation with Major Satisfaction (r = 0.71), and moderate positive correlations with Major Valuing and Student-Faculty Relationship (0.49 and 0.55 respectively). In reference to motivational theories, it is expected that students who have a high sense of belonging within their academic community would also show increased sense of satisfaction and valuing with their major [27, 28]. Similarly, students who feel belonging within their academic community would be more motivated to strive to attain expected standards of achievement [21, 49]. We also observed a similar pattern of correlations between Academic Discipline Belonging and students' interaction with others: Peer Interaction and Student-faculty Relationship, 0.27 and 0.55 respectively. The inter-correlations observed among other factors on the instruments are consistent with the literature, showing positive correlations between different indicators of students' affective engagement [23, 29]. For example, students' achievement striving to academic success also showed moderate positive correlations with Major Valuing, Major Satisfaction and Peer Interaction (0.44, 0.42 and 0.41 respectively). Students who are more motivated to strive to attain expected standards of achievement show increased major satisfaction, valuing, and importance attached to their major [28]. Similarly, students who have a strong aspiration to high standards of achievement also interacted more with their peers in discussing academic, career, or cultural issues [27]. The consistency of the observed inter-factor correlations strengthens the case for the content validity of PosSE Survey as an instrument poised to measure different facets of affective engagement.

The present study focuses on measures of affective engagement which denotes students' emotional response to learning, which can include anxiety, interest, boredom, and belonging [12, 14, 50, 51]. This study and instrument are particularly important to engineering educators' ability to assess departmental culture and many interactions that influence engineering students' affective engagement. The culture within engineering departments has been described as a "chilly climate," which refers to the negative, unfavorable educational atmosphere that surrounds students' interaction with faculty and peers [52]. Academic departments that express these unfavorable environments have been shown to decrease student engagement and increase student attrition [53]. An instrument measuring affective engagement of engineering students will provide feedback to faculty and administrators on what students are experiencing, for instance, while in the classroom and interacting with peers and faculty. Specifically, lacking a sense of academic discipline belonging often indicates disaffection or disengagement with school, resulting in emotionally detached students who may show signs of cognitive and behavioral disengagement with learning activities, which eventually results in student attrition [23, 24, 54].

Alternatively, cultivating positive associations in the classroom has been suggested to help students persist and sustain a sense of resilience and affective engagement [14, 55, 56]. The field of engineering depends on engineers who not only are knowledgeable in core sciences and mathematics, but also are astute and adaptable to emergent issues and are able to manage the socio-economic challenges of the future. To equip future engineers with these skills, the educational experiences for engineering students need to be well-rounded and must prepare these future engineers to take on leadership roles in interdisciplinary challenges. Students who are positively engaged in educational activities develop lifelong learning skills that ensure total personal development [57]. Based on this research and by using data from the PosSE Survey, faculty and administrators who educate engineers can increase academic discipline belonging, gain a better understanding and promote student interactions among peers and strengthening faculty relationships.

6.1 Limitations and future direction

Although the results of this study yielded a conceptually meaningful six-factor model of student engagement dimensions, several limitations exist. One limitation of the study pertains to the selected sample. The sample comprised students who came from five comprehensive, public doctoral universities located in southern and mid-Atlantic states in the United States. Though similar, this select sample may possibly affect the replicability of the findings in another sample. Another factor that limits this study is the sample size of participants who completed the PosSE Survey. Although our sample size is enough for us to conduct the exploratory as well as replicable analysis by splitting the total sample into two parts; a larger sample would allow us to cross-validate the factor model and further investigate the subscales of student engagement from the PosSE Survey.

Approaches to assessing student engagement include teacher ratings of students, observations, interviews, and students' self-reports [8]. Similar to other engagement instruments, the PosSE survey relies on self-reported data. However, self-reports are particularly informative because they tap into latent traits that are not directly observable by the researcher. For example, while researchers or teachers can make subjective inferences about students' cognitive or affective engagement, such inferences may also be biased by presumed norms that differ from students' realities [8, 58]. Many self-report instruments have been designed to measure different dimensions of student engagement. Engagement self-report measures range from subscales measuring engagement within larger inventories (e.g., in the Motivated Strategies for Learning Questionnaire [MSLQ], [59]) to those assessing specific or multiple types of engagement indicators (e.g., the National Survey of Student Engagement [NSSE] and the School Engagement Measure [SEM]).

Although a majority of respondents were students of engineering majors, items on the survey were framed to allow usage across multiple majors with the thought that the instrument may be useful to measuring non-engineering students' affective engagement. The affective engagement of students in majors other than engineering should be studied in the future to determine what, if any, are the differences in students' affective engagement between and among students from different academic disciplines. Future research on student engagement could also examine the test-retest reliability and further demonstrate the convergent and divergent validity of the PosSE Survey. Convergent validity is demonstrated by the strength of the relationship between the scores obtained from two different instruments assessing related subscales, such as major satisfaction or major commitment. Continued examination of the validity of student engagement will help to further establish its construct validity.

7. Conclusion

As previous literature indicates, engineering students' affective engagement relative to school connectedness is linked to a myriad of positive student outcomes, notably increased persistence. In a time when calls for a larger, more diversified, and better prepared engineering workforce, having an instrument to robustly measure undergraduate engineering student affective engagement was missing. Developing such an instrument is a notable contribution to the body of research on engineering student persistence and the nuanced, affective engagement engineering students experience with faculty and peers. Having a better understanding of especially underrepresented students' affective engagement and disengagement will allow engineering education stakeholders to successfully implement and bolster initiatives such as the Engineer of 2020 and the ABET criteria for all engineering students.

The extensive instrument development process described above resulted in a conceptually meaningful 23-item, 6-factor inventory of student engagement dimensions that researchers can use across various domains. The factors include: Major Satisfaction, Academic Discipline Belonging, Major Valuing, Achievement Striving, Peer Interaction, and Positive Faculty Relationship. Notably, the inter-factor correlations were consistent with previous literature and, as such, strengthen the legitimacy of the PosSE Survey as a tool to measure different aspects of affective engagement.

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