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Evaluating The Fairness Of The Undergraduate Supports Survey: A DIF Analysis Of Gender And Year-In-School

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EVALUATING THE FAIRNESS OF THE UNDERGRADUATE SUPPORTS SURVEY: A DIF ANALYSIS OF GENDER AND YEAR-IN-SCHOOL

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ABSTRACT

It is well established that access to social supports is essential for engineering students' persistence and yet access to supports varies across groups. Understanding the differential supports inherent in students' social networks and then working to provide additional needed supports can help the field of engineering education become more inclusive of all students. Our work contributes to this effort by examing the reliability and fairness of a social capital instrument, the *Undergraduate Supports Survey* (USS). We examined the extent to which two scales were reliable across ability levels (level of social capital), gender groups and year-in-school. We conducted two item response theory (IRT) models using a graded

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response model and performed differential item functioning (DIF) tests to detect item differences in gender and year-in-school. Our results indicate that most items have acceptable to good item discrimination and difficulty. DIF analysis shows that multiple items report DIF across gender groups in the *Expressive Support scale* in favor of women and nonbinary engineering students. DIF analysis shows that year-in-school has little to no effect on items, with only one DIF item. Therefore, engineering educators can use the USS confidently to examine expressive and instrumental social capital in undergraduates across year-in-school. Our work can be used by the engineering education research community to identify and address differences in students' access to support. We recommend that the engineering education community works to be explicit in their expressive and instrumental support. Future work will explore the measurement invariance in *Expressive Support* items across gender.

Introduction

Social relationships are essential for undergraduate students' success in engineering. The relationships that comprise social support networks come in multiple forms, such as close relationships (strong ties) with friends and family that help students with personal issues and more distant relationships (weak ties) with classmates, faculty, and advisors that help students with academic and career issues (Martin et al. 2020). Both types of relationships have been shown to improve student outcomes in undergraduate engineering, such as improving students' success in the classroom, their persistence to a degree, and their ties to professional skill development (Brush 2013; Campbell-Montalvo et al. 2022; Dika and Martin 2018). Yet access to support is *not equal* among students. Students with identities that have been historically minoritized in engineering have greater difficulties acquiring needed support and utilizing their social networks to be successful in higher education (Skvoretz et al. 2020). Additionally, students who experienced multiple years of the COVID-19 pandemic during higher education report fewer supports and social networks than peers (Douglas et al. 2022).

A present challenge for researchers and educators wishing to facilitate engineering student success is how to fairly and reliably measure the ways in which various students are supported by people in their networks—this can be operationalized as social capital. Social capital refers to the current or potential resources and supports one receives from their relationships or social network (Lin 1999; 2008). Specifically, social capital emphasizes the access to resources by the individual (called the ego), through people in their social network (called alters). In the case of higher education, students access academic and career-related resources, information and support from a variety of alters, including faculty, academic support staff, peers, and family (Martin et al. 2020; Skvoretz et al. 2020). Lin posits that there are three factors impacting the volume of social capital available to the ego: network locations, structural positions, and purposes of action (Lin 2008). The ego's access to resources is dependent on the alter's structural position, the position or authority the alter has, and the alter's network locations, such as specific characteristics of the ego-actor relationship. *Purposes of action*, the type of support the alter can provide to the ego, can be broken into two categories, expressive and instrumental supports. Essentially, instrumental actions are for obtaining new resources, while expressive actions are for maintaining resources. Expressive supports impact the "physical health, mental health and life satisfaction" of the individual and often require a mutual understanding of the need for support (Lin 2002, 4). Instrumental supports seek gains in resources, often moving the individual towards a goal.

Social capital instruments tend to measure various aspects of students' social supports, such as network characteristics (e.g., density, strength of relationships) and types of support (Gentry et al., 2023). However, these instruments have little to no evidence of validity, including little evidence of reliability (that is, little evidence that the questions in the instrument are internally consistent and fair across groups) (Chen and Starobin 2019). If the engineering education community is to become inclusive of *all* students and support them in being successful in the field, it is important to establish reliable and fair social capital measurement across groups, such as gender and year in school.

In this paper, we aim to contribute to the reliability evidence for the *Undergraduate Supports Survey* (USS), a social capital instrument that enables educators to measure the supports present in engineering students' social networks. We asked the following research questions: To what extent are the USS scales for Expressive Supports and Instrumental Supports reliable across ability levels (for undergraduate engineering students in the U.S.); to what extent are the *Expressive Supports scale* and the *Instrumental Supports scale* reliable for these students across gender groups and year in school?

Methodology

Instrument

The *Undergraduate Support Survey* (USS) (initially developed by Martin, Gipson, and Miller 2011) measures the expressive and instrumental social capital available to engineering students' through their social networks. The USS is theoretically supported by Lin's Network Theory of Social Capital and utilizes a combined name and resource generator to assess social capital available from weak and strong ties (2008). Scores for the *Expressive* and *Instrumental Supports* scales range from zero alters to provide a resource to five alters to provide a resource.
Douglas et al. (2023) performed a validation study of the USS and reported reliability coefficient alphas above 0.7 and 4 factors with factor loadings that ranged from 0.51 to 0.85. The combined validity evidence showed that USS can be used to measure undergraduate students' expressive and instrumental social capital.

Setting and Participants

We distributed the USS to undergraduate engineering students at 13 institutions in April, 2022. We selected the institutions using a probabilistic stratified sampling strategy to strive for equal representation of students from different types of institutions (Blair and Blair 2014). Across the 13 institutions, we collected a total of 2,246 responses.

We performed minor data cleaning and preprocessing to ensure data quality. The data cleaning included screening the survey for completion rate. We deleted all responses with less than a 50% completion rate— a total of 658 responses in this round of data cleaning. We also included a filter question in the survey and asked participants to choose "Not at all" as a response. We excluded responses that did not pass the filter question from the dataset for further data analysis. Using filter questions, we eliminated 354 responses. After these two rounds of data cleaning, the cleaned dataset contained 1,234 participants. Among these participants, seven did not fill out their year in program (what we are terming their “cohort”). As we were examining USS item reliability and sensitivity for students of various demographic groups, including gender and cohort, we only excluded these seven responses with missing cohort information from analysis when we were looking at the comparison between cohorts. In other words, for the DIF analysis on gender, we used the entire cleaned dataset (n = 1,234), and for the DIF analysis on cohorts, we excluded the seven responses (n = 1,227). Table 1 contains the demographic information for participants in the cleaned dataset (n = 1,234).

Table 1. Participant Demographic Information

	n	%
Gender		
Men	678	55
Women	522	42
Other	34	3
Cohort		
First year	317	26
Second year	239	19
Third year	305	25
Fourth year	273	22
Fifth year and above	93	8

Note. Other gender includes students self-identified as “nonbinary”, “other”, and “N/A” as their gender.

Item Response Theory Methods

We performed an item response theory (IRT) analysis on USS expressive and instrumental scales to examine the item reliability and sensitivity. In classical test theory, item statistics are dependent on the sample, hence the difficulty of the items is associated with the ability of the student (Reeve 2002). Whereas with item response theory, item and sample parameters are “invariant” meaning that an item’s difficulty or sample’s ability will not impact the performance of the item (Ostini and Nering 2006). This is particularly salient when examining an instrument's reliability across students’ abilities, where reliability and instrument sensitivity is important. We utilized Samejima’s (1997) graded response model to estimate parameters for ordinal, polytomous scales. The two-parameter item response theory model approximates the likelihood of a respondent selecting that response at a given trait level using:

$$P_{ik}(\theta)=\frac{e^{a_i(\theta-b_{ik})}}{1+e^{a_i(\theta-b_{ik})}} \qquad (1).$$

where $P_{ik}(\theta)$ is the probability that a respondent with the latent trait (θ) selects a response option k or higher for item i (where i is the resource the alter provides). The discrimination parameter (a_i) represents the slope of the response curve, and the threshold, or difficulty, parameter (b_i) indicates the 0.5 likelihood of the respondent choosing the response immediately above or below k. In the case of this instrument, k is from zero to five, zero meaning no mentor provided that support and five meaning five mentors provided that support.

We examined 21 items for differential item functioning (DIF) across gender (e.g., women, men, and nonbinary) and year-in-school (e.g., first, second, third, fourth, and fifth year and above) using the Generalized Mantel-Haenszel statistical test with the *difR* package (Magis et al. 2010). DIF is a well-established method to evaluate if items perform differently for groups of students across the same level of ability, in this case social capital (Magis et al. 2010). Generalize Mantel-Haenszel is preferred for polytomous data and is proven to have significantly lower type I error than other DIF methods (Magis et al. 2010; Kabasakal et al. 2014). Since Mantel-Haenszel is a comparison of two groups, we conducted two gender comparisons, men and women and women and nonbinary students. We selected women as the reference group since their reported levels of expressive and instrumental social capital are higher than men and nonbinary students. For year-in-school, we grouped first and second years into a "new to university" student cohort since literature shows that first and second-year students impacted by the pandemic have had fewer opportunities to develop social capital (Douglas et al. 2022).

Results

We performed two graded response models using the standard expectation maximization algorithm with fixed quadrature. We deemed the two IRT models as having an acceptable fit based on the goodness of fit indices of the confirmatory factor analysis models specified in Douglas et al. (2023). Confirmatory factor analysis goodness of fit indices can be utilized to assess model fit for IRT models, as the model fit parameters are similar (Albert Maydeu-Olivares 2005; Alberto Maydeu-Olivares et al., 2011).

Item Discrimination and Difficulty

We found discrimination and difficulty parameters for all items in each scale. Discrimination values are judged based on Baker's (2001) rating system, where items can have little to very high discrimination. Items in this study have moderate (a_i = 0.65-1.34), high (a_i = 1.35-1.69) or very high ($a_i > 1.7$) discrimination. Difficulty values (b_1-b_5) should range from [-4,4] and be evenly distributed around 0, indicating an appropriate level of difficulty across all student's levels of social capital. Tables 2 and 3 show the mean, standard deviation, discrimination, and difficulty parameters for items in the *Expressive Supports and Instrumental Supports* scales.

The *Expressive Supports and Instrumental Supports* scales have high discrimination parameters (a_i), indicating the instrument can be used to differentiate between students based on levels of social capital. In the *Expressive Supports* scale, all items were very discriminating, with 13 items having high to very high discrimination parameters. Two items are candidates for revision due to having moderate levels of discrimination (12.6 and 12.8). The *Instrumental Supports* scale discrimination parameters are highly discriminating, with four items having very high discrimination and two items (12.4 and 13.1) having high discrimination.

Table 2. Expressive Social Capital Scale

	M	*SD*	a_i	b_1	b_2	b_3	b_4	b_5
12.1: challenges me to be my personal best	2.15	1.51	1.69	-1.50	-0.35	0.46	1.12	1.94
12.2: checks on my progress	1.90	1.44	2.02	-1.26	-0.14	0.64	1.32	2.01
12.3: discusses school, academic and career topics	2.34	1.55	1.77	-1.73	-0.46	0.28	0.92	1.61
12.5: encourages me about my studies	2.05	1.52	2.08	-1.20	-0.25	0.45	1.09	1.85
12.6: is a mentor	1.20	1.32	1.12	-0.47	0.73	1.72	2.67	3.85
12.8: supports me with other resources	1.50	1.47	1.36	-0.82	0.28	1.11	1.85	2.64
14.1: [discussed] Your mental or emotional health	1.46	1.40	2.44	-0.62	0.22	0.93	1.57	2.13
14.2: [discussed] Your physical health?	1.18	1.28	2.04	-0.38	0.51	1.29	1.94	2.73
14.3: [discussed] Disappoints you've had	1.38	1.40	2.68	-0.50	0.29	0.94	1.58	2.10
14.4: [discussed] Difficulties you've faced	1.97	1.61	3.05	-0.91	-0.13	0.46	1.00	1.49
15.1: Made an effort to stay in touch (contact you if it has been a while)	1.58	1.45	2.65	-0.63	0.08	0.80	1.41	2.01
15.2: Ask you how classes were going	2.19	1.57	3.13	-1.14	-0.30	0.32	0.86	1.42
15.3: Encouraged you to keep going when you struggled	1.88	1.57	3.12	-0.84	-0.05	0.53	1.07	1.57
15.4: Asked about your levels of stress	1.28	1.33	2.61	-0.46	0.38	1.07	1.70	2.24
15.5: Initiated conversation with you	2.08	1.65	2.87	-0.93	-0.22	0.37	0.91	1.44

Difficulty parameters (b_i) for the *Expressive and Instrumental Supports* items indicate that approximately half of the items have moderate to high levels of difficulty and may not accurately measure students with low levels of social capital. Items in both scales demonstrate a floor effect, negatively skewed difficulty parameters, meaning the center difficulty parameter (b_3) is shifted higher than zero; this indicates that students must have already high levels of social capital to be able to select that an alter provided a resource. Items lacking an evenly distributed *b* parameter range may poorly capture ranges in students' social capital, since items are only able to capture students with high social capital ability. *Expressive Support* items 12.6, 14.1, 14.3, and 15.4 all have negatively skewed b parameters. All but one Instrumental Supports scale item (13.2) has shifted *b* parameters.

Table 3. Instrumental Social Capital Scale

	M	*SD*	a_i	b_1	b_2	b_3	b_4	b_5
12.4: helps me with course selection	1.11	1.08	1.51	-0.67	0.83	1.96	2.72	3.79
12.7: suggests networking opportunities	1.06	1.22	2.28	-0.23	0.71	1.44	2.09	2.65
13.1: tries to involve me in extracurricular activities	1.16	1.27	1.36	-0.37	0.70	1.58	2.59	3.55
13.2: gives me advice on academic and/or career options	1.98	1.47	2.02	-1.32	-0.16	0.59	1.29	1.87
13.3: suggests job or graduate school opportunities	1.19	1.25	2.31	-0.38	0.50	1.27	2.02	2.60
13.4: introduces me to people in their professional network	0.70	1.03	1.87	0.27	1.19	1.95	2.79	3.60

DIF analysis

We conducted three DIF analyses for the *Expressive* and *Instrumental Supports* scales. DIF items that with both statistically significant and having substantial effect size should be reviewed to improve item functioning. Substantial DIF is considered as effect sizes in the moderate ($1 \leq |\Delta MH| \leq 1.5$) to large ($|\Delta MH| \geq 1.5$) ETS delta scale range (Holland and Thayer 1986). Effect sizes below ($|\Delta MH| \leq 1$) are considered negligible and not needed to be further analyzed.

The *Expressive Supports* scale reported the largest number of items with DIF. Six items have significant DIF between men and women, however only four had substantial effect sizes, items 12.2, 14.1, 14.4 and 15.5. Three of the four items favored women over men, whereas item 12.2 favored men. Items 12.3, 14.4, and 15.5 had substantial DIF between women and nonbinary engineering students, favoring nonbinary engineering students. DIF analysis of nonbinary students should be examined carefully, as the small sample of nonbinary students may impact the power of the DIF analysis (Lai et al., 2005); despite the small effect size, these items should be reviewed for DIF. We found no DIF between student year-in-school cohorts.

We found the *Instrumental Supports Scale* to be adequately fair across gender and year in school, with only two items reporting DIF. Across gender, item 13.2 had significant but unsubstantial DIF favoring men over women. No DIF was found between nonbinary students and women. Across year-in-school, only one item, 13.4, had substantial DIF in favor of third, fourth, and fifth-year and above students.

Conclusions, Limitations, and Implications

We utilized IRT and DIF analysis to answer the two research questions, finding the *Expressive* and *Instrumental Support scales* to be reliable across levels of social capital and fair in assessing social capital across gender and year in school cohort. Our results indicate that the items are able to sensitively capture variance in students' social capital but may be overly difficult, resulting in less reliable assessment for students with low levels of social capital. DIF analysis showed that the *Expressive Supports* scale has multiple items that favor women and nonbinary engineering students, whereas the *Instrumental Supports scale* has little to no DIF.

To address the high-difficulty parameters of the *Instrumental Supports* scale, we propose revising items to make what is considered accessing a resource more explicit. For example, a faculty member introducing a student to a colleague might not seem like networking to a first and second-year student, although the faculty member would recognize it as such. This difference in interpretation could be a potential explanation for the DIF in *Instrumental Supports* item 13.4.

A potential explanation of the DIF seen in the *Expressive Supports* scale could be explained by the access to specific examples of the expressive support, particularly by those who are minoritized in engineering (women and nonbinary students). The prevalence of gender-specific engineering organizations focused on well-being and retention may play a role in making expressive supports explicit to those students. Douglas et al. (2023) found that men in engineering have fewer alters providing expressive supports, potentially related to being in organizations that may not focus on well-being. Our work confirms the need for engineering education community members to provide explicit expressive support to *all* engineering students.

One limitation of this study lies in the method selected; DIF analysis is not ideal for examining fairness between more than two groups and when sample sizes are uneven. We have utilized methods that will result in the best power and error management for our sample sizes, but future work should examine fairness by utilizing multi-group confirmatory factor analysis or ordinal logistic regression. Specifically, future work should explore measurement invariance for gender groups across expressive and instrumental supports.

An important implication of our work for the international engineering education community is the opportunity to intentionally provide instrumental resources to students with whom we interact. For example, engineering instructors could make announcements about undergraduate research opportunities in their department or student organization meetings during class. These types of instrumental supports are small actions that can make a large difference in students' social capital access. Another important implication of our work lies in the utility of the USS for engineering education researchers. Our work has demonstrated that researchers can confidently use the USS survey to examine expressive and instrumental social capital in engineering undergraduates across year-in-school.

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