Validity and Reliability Evidence for a Novel Instrument Measuring Graduate Students' Mental Health Experiences as a Module for the Healthy Minds Study

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Introduction

This paper describes validity and reliability evidence for the Graduate Student Module (GSM), a survey instrument developed as an optional module for institutions participating in the Healthy Minds Study (HMS), a large-scale, annual survey of college and university students' mental health and wellbeing. The HMS is administered annually by The Healthy Minds Network [1], [2]. Previously, we reported our development process and initial validity evidence for the 35-item draft GSM measure to ASEE [3]. Here, we present the quantitative results of the pilot implementation of the GSM survey, yielding the latent factor structure of its engineering-culture-related items and subscale reliability estimates. The GSM, and other instruments used in the HMS, can be used by participating institutions or researchers conducting secondary analyses to better understand the reality and causes of mental health related phenomena and to develop proactive interventions supporting students [1], [2].

The development of the GSM measure was motivated by what has been described as a mental health crisis [4] for university students, including graduate students and engineering students. Graduate students develop mental health disorders and report mental health concerns broadly, including in engineering [5-7]. Consequences of these mental wellbeing issues include decreased retention, especially among PhD students [8], [9], impacts on academic performance [10], and low satisfaction with graduate student experiences in academia [11]. A key factor identified across the literature on graduate student wellbeing is the impact of stressors and chronic stress on mental health and persistence [8], [10-14] The GSM seeks to identify top stress factors impacting graduate students.

Studies suggest that engineering students engage in help-seeking behaviors for mental-health-related concerns less frequently compared with their non-engineering peers [5], [15]. Furthermore, the wellbeing of graduate engineering students is understudied compared to the body of research investigating undergraduate engineers [14]. Existing national surveys of wellbeing, like the HMS, often do not differentiate between graduate and undergraduate populations [2], [5], and do not account for factors apparent in broad fields such as engineering, which has its own disciplinary culture (described in [16]-[18]). Thus, we sought to develop a measure addressing these gaps, with the overarching question in our broader study of, *what factors are needed to assess the range of engineering graduate students' mental health experiences?*

The Healthy Minds Study

The Healthy Minds Study, administered by the Healthy Minds Network, is a large-scale, population-level annual survey of postsecondary students that has collected responses from over 935,000 students at over 675 institutions [1], [2]. In addition to including measures of mental health experiences and help-seeking behaviors administered at all institutions in each HMS survey year, universities and colleges that administer the HMS can choose to collect data from elective modules, comprised of validated surveys related to other wellbeing topics [1], [2]. We developed the GSM to be an elective module for future HMS administration by colleges and universities interested in investigating graduate student experiences.

Datasets from the HMS are available to researchers conducting secondary data analyses. Recent examples of published research investigating HMS data as secondary analyses include comparisons of HMS participants' mental wellbeing by academic discipline (including comparisons to engineering [19]), explorations of differences due to sociocultural background (e.g., [20]-[21]), and clarifications of relationships between specific mental wellbeing constructs measured across the survey, including by elective modules (e.g., [22]). Of particular interest to the engineering education community are studies that conduct population-level analyses of differences among engineering students (e.g., [23]).

Methods

This paper describes the determination of latent factors for a portion of the GSM related to engineering culture (comprising $n = 17$ items from the 35 developed), using exploratory factor analysis (EFA) techniques on responses from a pilot implementation of the GSM module. We analyzed GSM data collected as part of the 2025 HMS administration at a single institution ($N = 782$), providing construct validity. After determining the factor structure of the GSM, we computed internal consistency reliability estimates for each defined subscale and conducted additional validity checks on some other GSM items.

Pilot Data Collection

A pilot administration of the GSM was conducted at a single, large Midwestern R1 university during the spring of 2025. Participants were randomly selected by the HMS team to participate in the study and were roughly representative of the focal institution by gender, racial identity, and academic discipline. Of the $N = 782$ graduate student participants, $n = 290$ were in STEM disciplines, and specifically, $n = 156$ participants were engineering graduate students. Participants in the HMS study consent to allow researchers access to deidentified bulk data. At this stage of construct development, we did not analyze responses to the module's demographic items.

Design of the GSM

We have previously reported an in-depth description of the design of the GSM measure and initial validity testing [3]. To briefly summarize key points from that prior report on the GSM development, we wrote the items in the GSM measure by synthesizing a broad literature comprising research on engineering graduate student wellbeing, including by reviewing existing surveys related to (graduate or undergraduate) student mental wellbeing and engineering culture, resulting in a 35-item draft survey. A particular focus was given to research and the advising relationship [9], [10], [24]. The GSM was grounded in theories of engineering culture [16]-[18] and in Bronfenbrenner's bioecological systems theory [25]. This survey was refined through cognitive interviews [26] to reduce errors arising from interpretation and to provide evidence of content and face validity for the GSM [26]-[27].

In our previous work [3], we presented evidence of item-level validity and reliability. This paper provides construct-level inferences on the validity and reliability of the GSM.

The final GSM draft module consisted of four parts: first, four demographic items specific to graduate students were to be added to the HMS survey. These items will be evaluated in the context of other demographics to provide validity and reliability evidence for the full GSM administration and are not discussed further in this paper.

Next, the GSM consists of 31 Likert-type items related to graduate program experiences. We divided these items into three groups related to (1) **mental health norms** in graduate programs, including cultural perceptions in engineering, norms related to self-care and wellbeing, and personal life and balance stressors (17 items); (2) **academic stressors** related to graduate coursework, milestones, and academic career progress (7 items); and (3) **research-related experiences** (e.g., research advisor and research-group; 7 items).

The 17 GSM **mental health norms** items were assessed by endorsement of a 7-point Likert-type scale ranging from "1=strongly disagree" to "7=strongly agree", with an additional "N/A" response option. Example mental health norm items include: "I feel pressure to sacrifice my sleep to complete tasks as a grad student" and "I feel like I am being made to compete with and/or being compared to my peers". Four of the 17 items were reverse-worded as an attention check. The underlying latent factor structure of these 17 items was assessed using an EFA approach. These items were particularly based on prior research on engineering culture [16-18].

The 7 GSM **academic stressors** items were assessed twice each, first by a rating of the severity of the experience of the stressor represented by each item on a 7-point Likert-type scale ranging from "significantly negative experience" to "significantly positive experience", with an additional response option of "N/A". Participants who did not indicate "N/A" were then given a second, 8-point Likert-type scale rating the frequency of experiencing each stressor, from "1=Never" to "8=Multiple times a day". The initial prompt for the academic stressors items was: "Please rate the type of emotional experience each of the following have been for you during your graduate (grad) program, on average, from significantly negative to significantly positive," and example items include: "Securing a job post-graduation" and "Presenting on my research (e.g., research group meetings, conference, talk, etc.)". As these items are not intended to form a single construct, they were not included in the EFA analysis. However, correlations between the severity and frequency responses of each item were calculated as a validity check.

The 7 GSM **research-related experiences** items were assessed by endorsement of a 7-point Likert-type scale ranging from "strongly disagree" to "7=strongly agree", with an additional "N/A" response option. Example items include: "Knowing what I know now, I would choose to work with my advisor again" and "I feel supported by my research group". Due to an implementation error during the HMS administration of the GSM survey, approximately half of the pilot study respondents received an incorrect form of the response scale to these 7 advisor-related items. Thus, we omitted these items from the EFA procedure to avoid potentially confounding the interpretation of the EFA results. This error is further discussed in the Limitations and the Conclusions and Future Work sections. The correct form of these items was collected from a subset of n = 267 participants.

Some GSM items were reverse worded as an attention check, where higher scores indicated more positive experiences. Before analyses, the response scales were flipped for parity among all items.

Exploratory Factor Analysis
We determined the suitability of the mental health norm items for EFA analysis using Bartlett's test of sphericity and the Kaiser-Meyer-Olkin test [28]. In the absence of a theoretical justification for treating latent factors as perfectly orthogonal constructs, given the likely interrelationships among different cultural assumptions and stressors, we used an oblimin rotation and an ordinary least squares estimation method [29]. We considered latent factors strong when they exhibited eigenvalues > 1. Conservative guidance on EFA techniques suggests at least 500 participants and 10 per item [30], which our sample size meets.

We determined item retention by following multiple, stepwise iterative EFA approaches, as outlined in Author et al., [30]. *A priori*, we hypothesized that the 17 items might divide into four factors of 3-5 items apiece related to dimensions of culture defined by Godfrey and Parker, which influenced the design of these items, or that the items might divide by topic (e.g., items about peers, items about stressors, items about norms). However, we used Scree plots and the parallel analysis technique to determine the number of factors at each iteration in this approach [29-30]. These techniques sometimes diverged in suggested number of factors, in which case we created multiple EFA models with each suggested number of factors, and then compared eigenvalues resulting from at each iterative step. Cutoffs for item retention on factor loadings were for loadings to be > 0.32 for determining under-loading items, and no two loadings be > 0.3 for determining cross-loading items [29]-[30]. However, in our final model, we allowed some cross-loading given the theoretical closeness of the factors under the umbrella of mental wellbeing and stress-related phenomena.

Reliability Analyses
We estimated evidence for the reliability of the instrument using two internal consistency measures: Cronbach's alpha and McDonald's omega [31]. We tested these for new latent factors found for the mental health norm items,

As we were unable to include the 7 advisor-related items in the EFA procedure, we treated them as a separate subscale corresponding to a single common latent factor to obtain a reliability estimate. We present two separate reliability calculations using the erroneous and correct response scales.

Results and Discussion

EFA results
The 17 mental health norm items were determined to be sufficiently factorable (KMO = 0.78; Bartlett's test of sphericity is significant with p-value ~=0.0, $\chi^2 = 1738.2$ on 136 degrees of freedom).

An iterative EFA procedure following multiple item retention strategies yielded agreement to a two-factor solution with a total of 12 items. One item, "If you think grad school is too hard, you aren't cut out for it", cross-loaded into both factors and is tabulated below with both. Table 1 presents the factor structure, with factor loadings and eigenvalues. Some items cross-load onto multiple factors (refer to the discussion below in the Reliability of Scales section).

Table 1. GSM Mental Health Norm EFA Results

Factor Number (and eigenvalue)	Item Text	Loading
Factor 1 (λ = 1.968)	I have a life outside of grad school (for example, maintaining friendships and relationships, participating in hobbies, cooking, exercising, etc.)	0.32
	If you think grad school is too hard, you aren't cut out for it	0.38
	I feel like I am being made to compete with and/or being compared to my peers	0.49
	I feel like I don't belong in my graduate school program	0.66
	I conform to values, norms, and/or behaviors I don't believe in to "fit in" my program	0.62
	I feel behind in life compared to peers my age (e.g., financially, lifestyle, etc.) because I chose to pursue a graduate degree	0.41
	Knowing what I know now, I would choose to pursue grad school again	0.42
	Most grad students I know are making good progress in their degree program	0.32
Factor 2 (λ = 1.372)	I feel pressure to sacrifice my sleep to complete tasks as a grad student	0.33
	I think grad school is unnecessarily difficult	0.51
	If you think grad school is too hard, you aren't cut out for it	-0.30
	Grad students are relaxed	0.65
	The successful grad students I know have a healthy work-life balance	5.7

The largest latent factor contains items such as, "I feel like I am being made to compete with and/or being compared to my peers" and "I feel like I don't belong in my graduate school program". We have labeled this factor ***Graduate Peer Relationships***. The items are all related to peer relationships, though some are related to peer support, while others are related to peer competition.

The second latent factor contains items such as "I think grad school is unnecessarily difficult" and "I feel pressure to sacrifice my sleep to complete tasks as a grad student." We have labeled this latent factor ***Graduate Engineering Stress Culture***, as its items are closely related to descriptions of engineering culture and workload demands [16-18].

Items that were excluded included an item related to financial pressures: "I worry about how I will pay for my degree and/or related living expenses while in grad school", an item with the text "Being the best is very important to me", and two items about peer relationships: "I would help a peer in my program even if there was no immediate or direct benefit for me" and "I am more likely to try and stay connected with peers I feel are as smart or smarter than myself." We believe that given that these items did not load well onto the ***Graduate Peer Relationships*** scale, they should thus be disregarded.

We propose a heuristic for scoring these items: sum the items and divide the sum by the number of items in each subscale, allowing the subscales to be directly compared on the same response scale.

Reliability of Scales

We calculated the reliability of each GSM culture latent factor using both Cronbach's α and McDonald's ω. These results suggest that the ***Graduate Peer Relationships*** exhibits acceptable internal consistency, while the ***Graduate Engineering Stress Culture*** subscale exhibits lower internal consistency. However, the entire measure also exhibits improved reliability compared to its subscales as a general factor. Thus, we recommend that the measure be used as a single subscale or two smaller factors at any researchers' discretion. The interpretation of the general factor is one that identifies endorsement of engineering stress cultural norms, with two significant inner themes.

Table 2. Reliability of the GSM Mental Health Norms Scale and Subscales

Measure	Cronbach's α	McDonald's ω_{total}
Graduate Engineering Stress Culture	0.70	0.75
Graduate Peer Relationships	0.57	0.65
Entire GSM Mental Health Norms (12 items)	0.75	0.79

For the research-related experiences items, reliability estimates were calculated using the subset of participants who responded after the error in the response scale of these items was corrected (n=267). These items performed well, with Cronbach's α of 0.92 and McDonald's ω_{total} of 0.95.

Our theoretical backing for the GSM items features elements of both personal appraisals, socializing, and cultural norms of engineering, which coincide with more or less distal elements of Bronfenbrenner's bioecological theory [25]; one possible explanation for the EFA best fit structure of two factors loosely fitting inside a more general factor may concern peer relationships being more distal than inwardly-held cultural appraisals. Our items were initially generated with intention to align with more or less distal cultural elements and to align to one of four cultural factors identified in Godfrey & Parker's depiction of engineering culture: "An Engineering Way of Thinking," "An Engineering Way of Doing," "Being an Engineer", and "Relationships" [16]. The final factor structure is more compact than the initial number of elements we intended, which may also explain the inconsistency in internal structure when breaking down the measure.

Tests of the Academic Stressors Items

The seven GSM items related to academic stressors should not represent a measure of a single construct, as they measure stressors of different types. However, given the overlap of topics (experience of a stressor) in the items, we tested the internal consistency of these items on the severity and frequency response scales. We also tested item-level correlations between the severity and frequency response scales for each stressor, expecting at least moderately strong correlations between them (anticipating that more seriously experienced stressors would occur more frequently). These correlations were moderate and significant ($p<0.05$) with an average correlation between response scales of 0.45.

Treated as a factor, the severity items perform comparably compared to the other scales (Cronbach's α of 0.86 and McDonald's ω_{total} of 0.78). The frequency items were internally consistent despite the inconsistency of the severity items (Cronbach's α of 0.89 and McDonald's ω_{total} of 0.92). This evidence suggests that these items, which pertain to a common phenomenon (stress), may be cautiously treated as a factor when measuring overall experiences with many stressors.

Limitations and Future Work

The primary limitation in this work is that the pilot GSM administration was conducted at a single institution, limiting the transferability of its results. Additionally, fairness testing is useful to check the performance of measures across diverse groups.

An implementation error in the research-related items limited our ability to test them as part of the EFA model. However, these items displayed very high internal consistency. Thus, we will test the items as a single factor in confirmatory factor analyses.

To address these issues, our next step will be to administer the entire 35-item GSM as an opt-in module in the HMS study. We will conduct analyses of the GSM alongside the other suite of items in the HMS. Our planned reliability and validity analyses will include confirmatory factor analysis to test the resulting factor structure and correlation testing with other existing HMS modules to ensure discriminant and convergent reliability with related and unrelated measures [32]. These next steps will explicitly address the single-institution limitations and allow for confirmatory testing of the GSM-Advisor subscale without its response scale error. We will also test for consistency across similar groups by racial, gender, and other sociocultural identities and confirm that mean differences between subgroups by identity match expectations described in the critical quantitative literature on engineering culture [33], including by testing the GSM among other measures.

In addition, there are additional factors that contribute to the ***Graduate Engineering Stress Culture*** that should be explored. Although one of the four demographic items developed asks information about funding sources, financial stressors were not included as part of the ***Graduate Engineering Stress Culture*** subset. There is potential to develop more or include other measures of stressors for doctoral engineering students (e.g., such as those developed in [34]). Future work will also investigate the magnitude of respondents' experiences of different subfactors within the GSM to investigate differences in light of the instruments' theoretical frameworks [16], [25].

Conclusions

Our main findings from this work are the validity and reliability evidence presented above for the final, modified form of the GSM survey instrument. EFA results suggest that this instrument is best represented by two latent factors, which we have labeled Graduate Engineering Stress

Culture and Graduate Peer Relationships, or by a general factor describing culture with both dimensions. While work is forthcoming to finalize the validity, reliability, and fairness of this measure and fully characterize it, the GSM is ready for adoption as an elective module by universities and colleges participating in the HMS.

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