Confirmatory evidence for a survey of skill and attitude development on engineering teams

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***Abstract*—This research-to-practice paper describes an ongoing project that 1) seeks to gather validity evidence for a survey of engineering student teaming attitudes and skills and 2) identifies what skills and attitudes engineering students develop over time and to what degree. Teamwork is an essential skill for engineering students. The skill's effectiveness has been studied extensively, but little work has been done that explores the learning of teamwork as a set of malleable skills and attitudes. Our project seeks to develop and test a survey of engineering skills and attitudes to understand how students' teamwork skills develop over time. In our prior work, we conducted an exploratory factor analysis (EFA) of our items using half of our data and identified the existence of 16 factors. This work sought to use the second half of our data to gather confirmatory evidence. Of our 16 initial factors, we found that 15 passed our secondary validity evidence checks. Our findings indicate that we have a strong survey of skills and attitudes that we can use to begin our work of understanding how engineering students' skill and attitude development happens over time. Our future work will engage in this longitudinal effort.**

Keywords—teamwork, noncognitive and affective factors, confirmatory factor analysis

I. Introduction

Teamwork is an essential part of a student's engineering education. As encapsulated in ABET's Criterion 5, teamwork infers that engineering programs must provide students with, "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" [1]. In view of this criterion, engineering educators have utilized a variety of methods for both addressing this educational objective and assessing the success of their endeavors. The majority of teamwork assessment strategies typically consist of post-hoc surveys, given at the end of a particular teamwork experience, and are intended to allow students to reflect on their team's ability to operate successfully given the constraints of the project imposed upon them. Such post-hoc surveys are inherently limited in their ability to proactively address the common issues that may arise in team environments, such as slacker teammates, and incidents of conflict or bias, because they are completed only after aforementioned events have unfolded. Additionally, post-hoc surveys are limited in their scope. For example, a post-hoc survey only addresses work done on a specific project team, and does not easily address issues such as continuous improvement in teamwork skills or attitudes towards teamwork, both of which are integral to engineering formation. As a solution to this problem, a collection of studies have been conducted which focus not on post-hoc evaluation, but on continuous development of teamwork skills (CDTS) including [2]-[5]. By and large, these studies have utilized the Comprehensive Assessment of Team Member Effectiveness (CATME) developed by Laughry et al. [6]. CATME is designed to evaluate peer experiences in specific teams, with assessments based on reflection and situationally dependent teamwork experiences. As such, it is difficult to attribute changes in individual student teamwork skills as due to personal growth unless students work on the same teams over a longer period of time (long enough to enable multiple assessments). Therefore, it is of interest to develop an instrument of teamwork skill development that is independent of team context. Such an instrument could, theoretically, be used longitudinally over multiple semesters to assess the broader teamwork skill development of engineering students, as well as their overall attitude towards teamwork and team environments.

We are engaging in work that 1) seeks to gather validity evidence for a survey of engineering student teaming attitudes and skills and 2) identifies what skills and attitudes engineering students develop over time and to what degree. Our prior study [7], and this one, are in effort to meet our first goal. In our initial study [7], an exploratory factor analysis (EFA) was conducted on numerous teamwork attitude and skill factors, with the goal of being able to develop an instrument capable of detecting longitudinal changes. We found that most of the question items responded well, with only one set of factor set needing to be removed in order to maintain statistical reliability (Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism).

However, EFA is only the first step in the survey development process; the next step is to confirm this factor structure using confirmatory factor analysis (CFA). CFA is critical to assessing an instrument's ongoing applicability. Therefore, in this research article, we wish to answer the following research question (RQ): *What confirmatory evidence is there for our framework of teamwork attitudes and skills?*

II. Background

The choices for survey items used in our previous work [7] are based upon a framework of engineering teamwork that draws from multiple sources, with the explicit aim of defining what it means to "function effectively on a team," by "provid[ing] leadership," "creat[ing] a collaborative and inclusive environment," and "establish[ing] goals, plan[ing] tasks, and meet[ing] objectives." [1] Each factor is described below, alongside descriptions of how we measure each component and what sources these items derive from. We also provide a synopsis of our initial validity evidence from our prior study [7].

A. Providing Leadership

Our definition of *providing leadership* draws heavily from the work of Anderson & Sun [8], Northouse [9], and Schell [10]. In their work on leadership styles, Anderson & Sun describe six styles of leadership, out of which we have identified three styles that are of particular importance for engineering students to develop: participative, servant, and delegative leadership styles. These leadership styles are identified as the most-important due to their emphasis on communication, trust, autonomy, and growth mindset [10]. In participative leadership, which is also called democratic leadership, each team member is involved in decision-making for the team [9]. Next, in delegative leadership, a team leader gives over responsibility for particular tasks to individual team members, allowing each team member to utilize their unique experiences to accomplish the task at hand. Finally, in servant leadership, the leader aids in developing the skills of their teammates, putting the team's needs before their own [9]. Below we briefly describe some of the constructs we are using to help outline "providing leadership" on an engineering team:

1) Leadership

We included a shortened form of Wielkiewicz's [11] 28-item, two-factor scale to make up our leadership assay. Our version consisted of 15 items that we felt should map onto two factors (as in [11]). The EFA results for Leadership were strong and fit into two factors as expected: hierarchical thinking and systemic thinking. Six total items loaded onto hierarchical thinking resulting in strong reliability ($\alpha = 0.87$) [7]. Similarly, five total items loaded onto systemic thinking with also exceptional reliability ($\alpha = 0.78$) [7]. The final Tucker-Lewis Index (TLI) of this model was 0.90 with a Root Mean Square Error of Approximation (RMSEA) of 0.07 [7].

2) Patience

Patience is important for students on engineering teams to have, given they must deal with difficult situations and difficult teammates. Patience inherently informs students' leadership capability. Our inclusion of patience as a category is also justified by numerous students' mentions of patience in our qualitative work that is happening in parallel with this quantitative instrument development. The patience category includes a three-factor, 11-item scale from Schnitker [12] which covers interpersonal patience, life hardships patience, and daily hassles patience. At the time of our EFA, this scale did not yet have evidence of validity with engineering students and as such, this was tested by our study. The patient-related items resulted in two successful factors composed of seven total items. The first factor was interpersonal patience (consisting of five items). Interpersonal patience describes one's patience working with other people ($\alpha = 0.8$) [7]. The second factor was life patience (consisting of two items), which describes one's patience with life events outside of teamwork, such as traffic or waiting in lines ($\alpha = 0.59$) [7]. Within the context of our EFA, interpersonal patience performed much better than life patience, which is understandable given our population's age range. The final TLI of this model was 0.91 with a RMSEA of 0.09 [7].

3) Mindfulness

Brown and Ryan posit that students who are more mindful are more likely to be successful in light of challenges [13]. The challenges encountered by team leaders are many, and include things like coordination of team member activities, communication, and overcoming team conflicts. As such, we included in our EFA a single-factor, 4-item scale from Scheidt et al. [14-15] which, based upon their work, has strong validity evidence with engineering students. Each of the four mindfulness items loaded onto a single factor (which we term Mindfulness) with strong reliability ($\alpha = 0.81$) [7]. The final TLI of this model was 0.97 with a RMSEA of 0.08.[7]

4) Mindset

Students who have a mindset that is more growth-aligned are more likely to believe that intelligence can be developed rather than stay fixed [16]. As such, having a growth mindset could benefit a leader, who challenges their teammates to grow within the context of a project, rather than to stick to what they are already good at. Thus, in our EFA we included a two-factor, 8-item scale, also from Scheidt et al. [14-15] that similarly already has strong validity evidence with engineering students. Their later work [15] found that these factors might be better represented as a single factor, so we tested both. The results were that all eight mindset items successfully loaded onto two factors with four items each (termed Fixed and Growth Mindset). Each factor had very strong reliability ($\alpha = 0.86$; $\alpha = 0.9$; respectively) [7]. Note, we are also aware of confirmatory issues discussed by Scheidt et al. [15]. Thus, we did try and test Mindset as a single factor and had little luck in an exploratory format. Part of the present study includes a confirmation of this finding (below). The final TLI of this model was 0.94 with a RMSEA of 0.11.[7]

B. Creating A Collaborative and Inclusive Environment

We define an inclusive environment as consisting of a highly engaging space wherein there is mutual trust, support, and respect for each team member and their personhood [17]. Factors that support trust and respect include the acknowledgment of implicit bias [18], understanding microaggressions [19-20], and fostering a sense of belonging through open communication [21-22]. Another area that contributes to inclusion is one's non-cognitive development [23] which includes factors such as sense of belonging [24], development of engineering identity [25-26], one's purpose and meaning, their motivation [27-28], mindset [16], and skills like self-control [29], patience [12], and mindfulness [30].

As such, in addition to the factors of *patience*, *mindfulness*, and *mindset*, described above, factors that may contribute to a collaborative and inclusive environment are:

1) Self-Control

We posited that students with strong senses of self-control, specifically the ability to manage restraint and impulsivity, worked better on teams [29]. We included a two-factor, 8-item scale from Scheidt et al. [14-15] that already has strong validity evidence with engineering students. The items cover both impulsivity and restraint. In the EFA, five of the eight items loaded onto two factors of self-control. The first factor, Impulsivity, had only three items load onto it resulting in weaker reliability than the other constructs (α = 0.56) [7]. In contrast, restraint had two items load onto it with stronger reliability than Impulsivity (α = 0.72) [7]. The final TLI of this model was 1.00 with a RMSEA of 0.00 [7].

2) Team Inclusion

Team inclusion can be influenced by feelings of comfort or, conversely, discrimination. As such, we included several items based on these topics in addition to a general team inclusion assay. Unlike the other question banks above, however, these scales remain unpublished. Each of these scales were first developed and tested unsuccessfully by Kirn & Colleagues at the University of Nevada (please refer to Bridgers project). More about this work may be found in existing literature by Rodriguez-Simmonds et al [31], and Langus et al [32-33]. Despite these drawbacks, there is (unpublished) initial validity evidence (EFA) for the items we have included. Thus, we expect to use this work to gather further evidence for the scale's use.

Team Inclusion. Seven of our 14 total team inclusion items loaded onto a single factor, Team Awareness, with strong reliability (α = 0.86) [7]. The final TLI of this model was 0.80 with a RMSEA of 0.16 [7].

Comfort. Out of our comfort items, only three items which were related to faculty loaded onto a single factor, termed Faculty Inclusion. This factor has strong reliability (α = 0.81) [7]. As such we are very interested in the confirmatory work (below) which will aid us in determining whether the factor performs similarly, or is correlated to, the Faculty Caring factor (below). The final TLI of this model was 0.90 with a RMSEA of 0.14 [7].

Discrimination. To account for the broad scope of discriminatory behaviors, we adapted and included five items across five different identity-axes (race/ethnicity, gender, sexual orientation, (dis)ability, and socioeconomic status) from Bahnson et al's [34] work on discrimination amongst engineering graduate student experiences. Discrimination performed better than expected; out of the 25 total items, 22 items loaded across two factors: Faculty Inclusion and Peer Inclusion. These factors both had strong reliability (α = 0.98; α = 0.96; respectively) [7]. We are very interested in how peer inclusion relates to team inclusion, and how faculty inclusion relates to both comfort factors described above. The final TLI of this model was 0.66 with a RMSEA of 0.22 [7].

3) Belonging & Faculty Caring

Belonging in particular is an essential human need that has been identified as one of the key predictors of student success [24]. Hoffman et al. also suggest belonging is highly correlated with Faculty Caring [24]. We considered whether these two factors, either independently or considered together, could influence teaming. We included a single-factor 7-item scale of belonging from Scheidt et al. [14-15] that already has strong validity evidence with engineering students. We likewise included a two-factor 13-item scale of faculty caring that includes both comfort with faculty and empathetic faculty understanding from the same author.

Belonging. Seven items related to belonging loaded onto a single factor (termed Belonging) with strong reliability (α = 0.93).[7] The final TLI of this model was 0.84 with a RMSEA of 0.22 [7].

Faculty Caring. Eleven of the 13 items for faculty caring loaded successfully across the two constructs that were expected based on [14-15]: Empathetic Faculty Understanding and Comfort With Faculty. Each of these constructs resulted in strong reliability (α = 0.85; α = 0.86; respectively), with the final TLI of this model being 0.94 with a RMSEA of 0.22 [7].

4) Meaning & Purpose

Based in part on our parallel qualitative work, we wondered whether students with a stronger sense of meaning and purpose within their engineering team (and more broadly as an engineer, see Engineering Identity below) are more likely to be successful on a team. Meaning & purpose in life is one of many important constructs of "thriving" considered by Scheidt et al. [14-15] and refers to one's sense they have meaning and purpose to their life long-term [13]. We included a single-factor, 3-item scale of meaning & purpose from Scheidt et al. [14-15] with strong validity evidence with engineering students. The three meaning and purpose items loaded onto a single factor (Meaning & Purpose) with strong reliability (α = 0.9); unfortunately, TLI and RMSEA could not be computed for this model because of its size [7].

5) Engineering Identity

Like motivation, meaning & purpose, students who have stronger beliefs about their personal identity as engineers are more likely to be successful in academic contexts [25]; this likely has to do with the interrelatedness of identity and motivation [35]. As such, we included a three-factor, 12-item scale from Scheidt et al. [14-15] that already has strong validity evidence with engineering students for identity. Twelve of the 14 total chosen items loaded successfully across the three expected constructs from Scheidt's work: Performance-Competence, Interest, and Recognition. Each of these constructs resulted in strong reliability (α = 0.87; α = 0.89; α = 0.83; respectively), with the final TLI of this model being 0.96 with a RMSEA of 0.06 [7].

6) Team Gratitude

It was found by Renshaw and Bolognino [36] that students with a strong sense of gratitude are more likely to feel capable and supported. We wondered, in part based on our parallel qualitative work, if gratitude towards one's team may be indicative of feelings of capability and support by one's team. Thus, we adapted a single 6-item factor from Scheidt et al.[14-15] that already has strong validity evidence with engineering students with respect to gratitude. The individual items were modified to refer to one's team and instructor of the team, rather than to others in general.

Team Gratitude performed well: across our six items, all items loaded onto a Gratitude Towards Teaming factor with exceptional reliability (α = 0.91); the final TLI of this model was 0.89 with a RMSEA of 0.17 [7].

C. Establishing Goals, Planning Tasks, and Meeting Objectives Through Effective Communication

Communication is essential for a team to establish goals, plan and execute tasks and meet objectives [37-8]. Effective communication is a hallmark of effective teamwork [39], and consists of both intra-team communication (i.e., listening and responding to feedback from one's own team members) and external communication (i.e., interacting with other project groups or with superiors such as instructors). Communication covers not only verbal and written communication, but also the ability to collaboratively make decisions and resolve team conflicts. Additionally, it is also important for teams to be able to disseminate information clearly - both among themselves and among wider audiences. As such, factors that encompass effective communication are patience, self-control and:

1) Team Conflict & Contributions (22 items)

Similar to the Team Inclusion scales, the scales related to Team Conflict and Contributions, remain unpublished, and were first developed and tested unsuccessfully by Kirn & Colleagues at the University of Nevada, Reno (please refer to Bridgers project). More about this work can be found in their work [31-33]. Luckily, like the Team Inclusion scales, there is initial validity evidence for the included items (i.e. EFA) and we expect to use this work to gather further evidence for the scale's use.

Team Conflict. Initially, we were not sure how Team Conflict items would load, so our EFA was indeed exploratory. It was found that six of the 12 total items loaded onto two separate factors: Team Frustration and Conflict Resolution. Team Frustration describes arguments and conflicts relating to the team project, in particular, conflicts related to roles and splitting of work. This factor had strong reliability ($\alpha = 0.79$) [7]. The second factor, Conflict Resolution, included two opposingly loading factors (one negative and one positive) which described the resolution of conflicts either by the team members themselves or by the instructor. This second factor had weaker reliability than the first ($\alpha = 0.57$), with a final TLI of 0.97 and RMSEA of 0.06 [7].

Team Contributions. This factor was likewise exploratory for us. It was found that eight of the items loaded successfully across three factors, namely: Team Time Management, Attendance, and Contribution Difficulties. As it turned out, Team Time Management was among the strongest factors from the entire EFA study, with a strong reliability ($\alpha = 0.83$) [7] and containing four items. The next strongest was attendance, which had a reliability of ($\alpha = 0.7$) [7], but strange loadings across two items. We hypothesize that this factor will break down in confirmatory work (below). Finally contribution difficulties had the weakest reliability, with ($\alpha = 0.59$) [7]. As such, we also hypothesize that this factor will break down throughout confirmatory work. The final TLI of this model was 0.93 with a RMSEA of 0.08 [7].

2) Self-Control

Finally, it was posited that students with strong senses of self-control, in particular the ability to manage both restraint and impulsivity, worked better on teams [29]. In terms of communication and task management, self-control (restraint) and impulsivity can positively(negatively) affect the products or deliverables of teamwork and can potentially lead to conflict. Thus, we included a two-factor, 8-item scale from Scheidt et al. [14-15] that like all of their previously mentioned scales, has strong validity evidence with engineering students. Five of the eight total items loaded onto the two expected factors of self control. The first factor, Impulsivity, had three items load onto it, unfortunately resulting in weaker reliability than most of our other constructs ($\alpha = 0.56$) [7]. In contrast, restraint, which had two items load onto it, had stronger reliability ($\alpha = 0.72$) [7]. The final TLI of this model was 1.00 with a RMSEA of 0.00 [7].

III. METHODOLOGY

1) Survey Administration and Data Collection

In the summer/fall of 2023, we developed and administered our pilot survey of engineering teaming attitudes and skills at two mid-Atlantic institutions. The survey was administered via Qualtrics across over a dozen courses serving students in their first-through-fourth years. A total of n=606 students completed the survey. A breakdown of the demographics of this sample can be found below in Table 1. Half of this initial data set was used for our initial EFA work [7] while the other half was used for confirmatory work presented here.

TABLE I. DEMOGRAPHICS OF OUR SAMPLE

Group	***Count***	***%***
Race/Ethnicity		
American Indian or Alaskan Native	19	3.1
Asian	73	12.0
Black	35	5.8
Biracial/Multiracial	16	2.6
Hispanic	85	14.0
International	≤ 5	≤ 1.0
Middle Eastern or North African	26	4.3
Hawaiian Islander or Pacific Islander	≤ 5	≤ 1.0
White	295	48.7
Another Race	14	2.3
Gender		
Woman	130	21.5
Cisgender	52	8.6
Man	344	56.8
Transgender	≤ 5	≤ 1.0
Agender	≤ 5	≤ 1.0
Another Gender	≤ 5	≤ 1.0
Non-Binary	6	≤ 1.0
Sexual Orientation		
Heterosexual/Straight	411	67.8
Homosexual/Gay/Lesbian	10	1.7
Bisexual	43	7.1
Pansexual	15	2.5
Asexual	≤ 5	≤ 1.0
Another Sexuality	8	1.3
Identifies with a disability		
Yes	78	12.9
No	393	64.9
Identifies as neurodivergent		
Yes	167	27.6
No	307	50.7

NOTE: Given opportunity for multi-select, percentages will not add up to 100%.
NOTE: Sample sizes ≤ 5 are redacted to protect our participants.
NOTE: Disability and neurodivergence were collected as broader categorizations but coerced down into Yes/No in this table to protect participants.

2) Data Analysis

We used Confirmatory Factor Analysis (CFA) to check our survey data for evidence of stronger validity. Specifically, we checked whether the factor structures identified in our initial EFA work [7] held up on the second half our data. CFA was conducted using the programming language R in RStudio [40]. Amongst testing, we used a maximum likelihood estimator with a Satorra-Bentler correction to correct for non-normality [41], [42]. We also used a Weighted Least Squares robust Means robust Variance (WLSMV) estimator. Following testing, we examined global and component fit of our models. To check for global fit, we ensured our models met the following criteria agreed upon in literature [43]: Composite Fit Index (CFI > 0.9), Tucker-Lewis Index or Non-Normal Fit Index (TLI/NNFI > 0.9), Root Mean Square Error of Approximation (RMSEA < 0.06; upper tail < 0.08), and Standardized Root Mean Squared (SRMR < 0.08). To check for component fit, we ensured our models met the following criteria: the loadings for each measure were less than 0.632 (Squared Standardized Loadings; SSL > 0.4) and significant ($p < 0.05$), Average Variance Extracted (AVE > 0.5), Composite Reliability (CR > 0.7), and Cronbach's α (α > 0.7) [44-46]. All factors were checked for validity evidence separately and together (one singular model).

IV. RESULTS

Our models had mostly good fit. There were, however, exceptions. First was Self-Control which fell apart (e.g., fell out of the factor structure) completely in testing. Similar issues with the factor have been discussed by Scheidt and colleagues [15]. Second was Motivation – Value which also fell apart in testing. When it came to Team Conflict, Team Frustration worked well, but Conflict Resolution did not. Based on our prior EFA loadings, we expected this possibility. Finally, for Team Contribution, only Team Time Management remained; Attendance and Contribution Difficulties fell apart; again this outcome was something we expected was possible based on our EFA. Other factors remained. In certain factors, RMSEA requirements were violated, but not by a concerning amount (values were still under a higher threshold of 0.10 [43]). A summary of our CFA results for the models is shown in Table 2. Atop individual model fit, our combined model also performed tremendously well meeting the following global fit indices: CFI = 0.971, TLI/NNFI = 0.969, RMSEA = 0.012 (Upper = 0.019), SRMR = 0.050. Overall, regarding our research question, these findings point to strong validity evidence with most remaining factors.

TABLE II. CFA RESULTS. PROBLEMATIC FIGURES OF RMSEA ARE ITALICIZED AND PROBLEMATIC ITEMS ALTOGETHER ARE SHOWN REMOVED.

	Max r^2	**Global Fit**				**Component Fit**			
		CFI	***TLI***	***RMSEA***	***SRMR***	***SSL > 0.4?***	***AVE***	***CR***	***α***
Belonging	0.814	0.969	0.939	***0.095***	0.024	✓	0.754	0.937	0.939
Comfort - Faculty Inclusion	0.897	1.000	1.000	0.000	0.000	✓	0.755	0.902	0.900
Engineering Identity – Performance/Competence	0.786	0.975	0.966	0.039	0.035	✓	0.673	0.890	0.900
Engineering Identity – Interest	0.885					✓	0.815	0.928	0.922
Engineering Identity – Recognition	0.753					✓	0.606	0.848	0.860
Faculty Caring – Empathetic Faculty Understanding	0.688	0.988	0.983	0.034	0.033	✓	0.547	0.828	0.827
Faculty Caring – Comfort with Faculty	0.639					✓	0.615	0.862	0.864
Faculty Inclusion – Race/Ethnicity	0.906	0.976	0.967	0.026	0.044	✓	0.867	0.944	0.955
Faculty Inclusion – Gender	0.891					✓	0.866	0.949	0.950
Faculty Inclusion – (Dis)Ability	0.937					✓	0.845	0.942	0.942
Leadership – Hierarchical Thinking	0.668	0.957	0.931	***0.067***	0.043	✓	0.574	0.795	0.807
Leadership – Systemic Thinking	0.671					✓	0.605	0.861	0.856
Meaning & Purpose	0.895	1.000	1.000	0.000	0.000	✓	0.828	0.935	0.934
Mindfulness	0.703	1.000	1.023	0.000	0.006	✓	0.629	0.870	0.868
Mindset – Fixed	0.755	0.970	0.951	0.052	0.026	✓	0.608	0.861	0.857
Mindset – Growth	0.763					✓	0.689	0.868	0.869
Motivation – Connectedness	0.629	0.935	0.917	0.056	0.052	✓	0.512	0.677	0.674
Motivation – Expectancy	0.762					✓	0.704	0.914	0.924
Motivation – Instrumentality	0.817					✓	0.698	0.871	0.869
Motivation – Perceptions of Future	0.701					✓	0.636	0.874	0.872
Motivation – Value	-					X	-	-	-
Patience – Interpersonal	0.697	0.961	0.927	***0.077***	0.037	✓	0.562	0.835	0.836
Patience – Life	0.581					✓	0.501	0.659	0.648
Self-Control – Impulsivity	-	-	-	-	-	X	-	-	-
Self-Control – Restraint	-					X	-	-	-
Team Conflict – Conflict Resolution	-	1.000	1.000	0.000	0.000	X	-	-	-
Team Conflict – Team Frustration	0.949					✓	0.689	0.868	0.862
Team Contribution – Attendance	-	1.000	1.000	0.000	0.000	X	-	-	-
Team Contribution – Contribution Difficulties	-					X	-	-	-
Team Contribution – Team Time Management	0.674					✓	0.549	0.783	0.777
Team Gratitude	0.720	0.982	0.970	0.055	0.035	✓	0.628	0.904	0.909
Team Inclusion – Team Awareness	0.640	0.983	0.971	0.044	0.031	✓	0.509	0.860	0.858

V. Discussion, Implications, and Future Work

We sought to gather further validity evidence for our survey of engineering teaming skills and attitudes with the intention that, if validity evidence was present, we could safely move forward with longitudinal work. Our CFA resulted in a number of our factors performing quite well meeting stringent criteria. Revisiting our initial RQ, *What confirmatory evidence is there for our framework of teamwork attitudes and skills?*, we find that there is strong evidence for most factors, and limited evidence for others related to specific teamwork actions such as attendance and contribution difficulties. A triangulation of these results points to evidence that we may need to look further to identify specific teamwork actions and activities that may be linked to the skills and attitudes we are interested so we can full capture the holistic nature of teamwork activities. Part of this investigation may include further validity work to create and test items. We have already begun this work through our parallel, unpublished, qualitative work. Through this work, we are identifying through students' eyes what the causes of teamwork difficulty are and what skills and attitudes they think are most important. We can use these qualitative findings to further guide our efforts. Once we have determined what new factors need to be created and tested, our next steps will be to administer such a survey to a larger student audience over a longitudinal period. In the meantime, this study shows that we have reasonable evidence for a number of our initial factors.

VI. Limitations

The primary limitation we see to this work is our limited sample size and its limitations to our two-institution context. Similarly, our predominantly White and male sample further complicates these limitations. Further validity work is necessary to see if factors continue to perform as well across other populations and contexts.

References

[1] "Criteria for Accrediting Engineering Programs, 2024-2025."Accreditation Board for Engineering & Technology (ABET). https://www.abet.org/accreditation/accreditation-criteria/criteria-foraccrediting-engineering-programs-2024-2025/ (accessed May 13, 2024).

[2] P. Polly, J-L. Yang, N. Jones, T. Thai, A. Luo, C. Herbert, T. Lewis, R. Vickery, A. Richardson, and S. Schibeci, "The Teacher-Student Journey: Program-Wide Teamwork Skills Development and Evaluation in the Medical Sciences," *The International Journal of Assessment and Evaluation,* vol. 24, no.1, pp.1-24, Jan. 2018.

[3] M.Z., Farland, D. E. Beck, "Collaborative Learning Teams to Longitudinally Teach and Assess Teamwork Behaviors and Attitudes," *American Journal of Pharmaceutical Education*, vol.83, no.9, pp. 7255, Nov. 2019.

[4] S. Wei, C. Zhou, and M. W. Ohland, "Longitudinal Effects of Team-Based Training on Students' Peer Rating Quality," presented at the 2021 ASEE Virtual Annual Conference, Jul. 19-26, 2021.

[5] S. H. Pee, K. L. Chue, "Longitudinal teamwork measurement in Singapore Polytechnic: Initial steps and findings," in *Transforming education & strengthening society: Conference proceedings,* Nanyang Technological University, National Institute of Education (Singapore), 2022, pp 36-47.

[6] M.L. Loughry, M.W. Ohland, and D.D. Moore, "Development of a theory-based assessment of team member effectiveness," *Educational and Psychological Measurement,* vol. 67, pp. 505-524.

[7] J. C. Major and R. Cimino, "Initial validity evidence for a survey of skill and attitude development on engineering teams," presented at the 2024 ASEE Annual Conference & Exposition, Jun 23-26, 2024.

[8] M.H. Anderson, P.Y.T Sun, "Reviewing leadership styles: Overlaps and the need for a new 'full-range' theory," *International Journal of Management Reviews,* vol. 19, no. 1, pp. 76-96.

[9] P. G. Northouse, Leadership: Theory and Practice (7th ed.). SAGE Publications, 2016.

[10] W.J. Schell, B.E. Hughes, B. Tallman, E. Annand, R.M. Beigel, and M.B. Kwapisz, "Exploring the Relationship Between Students' Engineering Identity and Leadership Self-Efficacy," presented at the 2019 ASEE Annual Conference & Exposition, Jun. 16-19, 2019.

[11] R. M. Wielkiewicz, "The leadership attitudes and beliefs scale: An instrument for evaluating college students' thinking about leadership and organizations," *J. Coll. Stud. Dev.*, vol. 41, no. 3, pp. 335–347, 2000.

[12] S.A. Schnitker, "An examination of patience and well-being," *Journal of Positive Psychology,* vol.7, no. 4, pp.263-280.

[13] K.W. Brown, R.M. Ryan, "The benefits of being present: Mindfulness and its role in psychological well-being," *Journal of Personality and Social Psychology,* vol. 84, no. 4, pp.822–848.

[14] M. Scheidt, A. Godwin, R. Senkpeil, J.S. Ge, J. Chen, B.P. Self, J.M. Widmann, and E.J. Berger, "Validity evidence for the SUCCESS survey: Measuring non-cognitive and affective traits of engineering and computing students," presented at the 2018 American Society for Engineering Education Annual Conference & Exposition, Jun. 24-27, 2018.

[15] M. Scheidt, A. Godwin, J. Chen, J. Ge, B. P. Self, J. M. Widmann, J. C. Major, & E. J. Berger, "Validity evidence for the SUCCESS survey: Measuring non-cognitive and affective traits of engineering and computing students (Part II)," presented at the 2019 Frontiers in Education Conference, Oct. 16-19, 2019.

[16] C.S. Dweck, Mindset: The new psychology of success. Penguin Random House, 2007.

[17] F. Miller, J. Katz, Safe enough to soar: accelerating trust, inclusion, and collaboration in the workplace. Berrett-Koehler Publishers, 2018.

[18] S. Isaac, N. Kotluk, R. Tormey, "Educating Engineering Students to Address Bias and Discrimination Within Their Project Teams," *Science and Engineering Ethics,* vol. 29, art. 6.

[19] J.Y. Kim, A. Meister, "Microaggressions, Interrupted: The Experience and Effects of Gender Microaggressions for Women in STEM," *Journal of Business Ethics,* vol. 185, no. 3, pp. 513-531.

[20] S. Masta, D. Dickerson, A.L. Pawley, and M.W. Ohland, "The Minimization of Microaggressions in Engineering Education," in *2022 CoNECD (Collaborative Network for Engineering & Computing Diversity),* New Orleans, LA, 2022.

[21] M.G. Sedgwick, O. Yonge, "'We're it', 'we're a team', 'we're family' means a sense of belonging," Rural Remote Health, vol. 8, no. 3, art.1021.

[22] J. Campbell, L. Klotz, "Work in Progress: A Framework for an Improv Intervention to Increase Psychological Safety and Sense of Belonging on Student Engineering Design Teams," presented at the 2021 ASEE Virtual Annual Conference, Jul. 19-26, 2021.

[23] M.S. Khine, S. Areepattamannil, Non-cognitive Skills and Factors in Educational Attainment. Sense Publishers, 2016.

[24] M. Hoffman, J. Richmond, J. Morrow, and K. Salomone, "Investigating "sense of belonging" in first-year college students," *Journal of College Student Retention: Research, Theory & Practice*, vol. 4, no. 3, pp. 227–256.

[25] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice. *Journal of Engineering Education*, vol.105, no.2, pp. 312–340.

[26] S. L. Rodriguez, C. Lu, M. Bartlett, "Engineering Identity Development: A Review of the Higher Education Literature," *International Journal of Education in Mathematics Science and Technology*, vol. 6, no. 3, pp. 254-265.

[27] D. F. Shell, J. Husman, “Control, motivation, affect, and strategic self-regulation in the college classroom: A multidimensional phenomenon,” *Journal of Educational Psychology*, vol. 100, no. 2, pp. 443–459.

[28] A. Kirn, L. Benson, “Engineering students’ perceptions of the future: Exploratory instrument development,” in the 2015 American Society for Engineering Education Annual Conference & Exposition, Jun. 14-17, 2015, Seattle, WA.

[29] P.W. Maloney, M.J. Grawitch and L.K. Barber, “The multi-factor structure of the Brief Self-Control Scale: Discriminant validity of restraint and impulsivity, “*J. Res. Pers.*, vol. 46, no. 1, pp. 111–115.

[30] N.T. Van Dam, M. Earleywine, and A. Borders, “Measuring mindfulness? An item response theory analysis of Mindful Attention Awareness Scale,” *Pers. Individ. Dif.*, vol. *49*, no. 7, pp. 805–810.

[31] H.E. Rodriguez-Simmonds, N.S. Pearson, B.P. Jackson, T.C. Langus, J.C. Major, A. Kirn, and A. Godwin, “Interpersonal interactions that foster inclusion: Building supports for diversity in engineering teams,” presented at the 2018 American Society for Engineering Education Annual Conference & Exposition, Jun. 24-27, 2018.

[32] T. C. Langus, N. S. Pearson, J. C. Major, A. Godwin, & A. Kirn, “WIP: How traumatic events help shape social exclusion in engineering teams,” presented at the 2019 Frontiers in Education Conference, Oct. 16-19, 2019.

[33] T.C. Langus, N.S. Pearson, J.C. Major, A. Godwin, and A. Kirn, “WIP: How traumatic events help shape social exclusion in engineering teams,” presented at the 2019 ASEE Annual Conference & Exposition, Jun. 16-19, 2019.

[34] M. Bahnson, E.C. Hope, D. Satterfield, M. Wyer, and A. Kirn, “Development and Initial Validation of the Discrimination in Engineering Graduate Education (DEGrE) Scale,” *Journal of Diversity in Higher Education*.

[35] A. Godwin, A. Kirn, “Identity- based motivation: Connections between first-year students’ engineering role identities and future-time perspectives,” *Journal of Engineering Education*, vol. 109, no. 3, pp.362–383.

[36] T.L. Renshaw, S. J. Bolognino, “The college student subjective wellbeing questionnaire: A brief, multidimensional measure of undergraduate's covitality,” *Journal of Happiness Studies*, vol. 17, no. 2, pp. 463-484.

[37] E. Shafipour Yourdshahi, M. A. do Carmo Alves, A. Varma, L. Soriano Marcolino, J. Ueyama, and P. Angelov, “On-line estimators for ad-hoc task execution: learning types and parameters of teammates for effective teamwork,” *Autonomous Agents and Multi-Agent Systems*, vol. 36, no. 2.

[38] J.D. Murphy, Courage to execute: What elite U.S. military units can teach business about leadership and team performance. John Wiley & Sons, Incorporation. 2014.

[39] C. Tenopir, D.W. King, Communication Patterns of Engineers. Piscataway, NJ: IEEE Press, 2004.

[40] RStudio Team, “RStudio: Integrated development for R.” RStudio, Inc., Boston, MA, 2015. [Online]. Available: http://www.rstudio.com/

[41] C. K. Enders, “The impact of nonnormality on full information maximum-likelihood estimation for structural equation models with missing data,” *Psychol. Methods*, vol. 6, no.4, pp. 352–370, 2001.

[42] A. Beauducel and P. Yorck Herzberg, “Structural equation modeling on the performanceof maximum likelihood versus means and variance adjusted weighted least squares estimation in CFA,” *Struct. Equ. Model.*, vol. 13, no. 2, pp. 186–203, 2009.

[43] T. A. Brown, *Confirmatory Factor Analysis for Applied Research*, Second. New York, NY: The Guilford Press, 2015.

[44] C. Fornell and D. F. Larcker, “Evaluating structural equation models with unobservable variables and measurement error,” *J. Mark. Res.*, vol. 18, no. 1, pp. 39–50, 1981.

[45] F. Lord and M. Novick, *Statistical theories of mental test scores*. Reading, MA: Addison-Wesley, 1968.

[46] D. T. Campbell and D. W. Fiske, “Convergent and discriminant validation by the multitrait-multimethod matrix,” *Psychol. Bull.*, vol. 56, no. 2, 1959.