Instrument Development: Measuring Undergraduate Students' Perceived Support in STEM

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***Abstract*—This work-in-progress paper presents emerging results from a research study aiming to develop and gather validity evidence for an instrument that can be used by college administrators and student-support practitioners to assess the magnitude of undergraduate students' perceived institutional support received in science, technology, engineering, and mathematics (STEM). Our goal is to provide stakeholders with a validated tool to diagnose areas of strength and opportunities to better support students, particularly those from underserved populations. Over the past year, we have engaged in a systematic process of instrument development. We began by developing a prototype based on the newly developed Model of Co-Curricular Support (MCCS). We refined it by reviewing existing literature and instruments germane to student support, and soliciting stakeholder feedback. During the spring of 2018, we distributed the instrument to STEM undergraduate students at three U.S. institutions. In this paper, we report our process of instrument development and preliminary results. These results will inform the next revision of our instrument, ultimately providing the STEM education community with novel and theory-based ways to measure students' perceptions of support in STEM.**

Keywords—student support, retention, diversity, inclusion

I. Introduction

Colleges allocate considerable human, physical, and financial resources to support undergraduate STEM students, particularly gender, racial, and ethnic minorities who are severely underrepresented in certain disciplines. Our project seeks to help colleges improve their returns on these investments by developing and validating an instrument to assess the magnitude of support provided to undergraduate students in STEM. Such an instrument is important because it will help STEM educators and college administrators: (1) assess local environments; (2) monitor progress as it relates to supporting students, and (3) provide data-driven evidence for tailoring interventions to the unmet needs of target populations.

Whereas student-support practitioners have traditionally focused on the impact of individual interventions (e.g., [1]–[3]), our project involves a radically different approach. Rather than focusing on specific interventions, our instrument will enable colleges to take a more holistic look across their portfolio of support offerings to identify support that students do and do not receive, and how access to support varies across subpopulations. It is important to rethink student support in STEM because the need to support a diverse population of undergraduate students will only amplify in importance, according to U.S. demographic projections. The purpose of this work-in-progress is to document our progress to date.

II. Model of Co-Curricular Support

Theories on student retention traditionally focus on attrition at the institutional level (e.g., [4], [5]), but efforts to address student retention in STEM (e.g., mentoring programs or living-learning communities) are commonly implemented at the college level (e.g., [6]–[8]). To bridge this divide across student-retention theory and STEM student-support practice, we are grounding the development of our instrument in the recently developed model of co-curricular support (MCCS), which focuses on assisting both practitioners and researchers [9], [10]. Based on a four-institution study of STEM student support efforts, the MCCS repurposes Tinto's model of institutional departure [5]—an oft-cited student-retention model—for the college level, specifically focusing on the use of co-curricular support in STEM. In evaluating a STEM learning environment, the MCCS [9], [10] suggests that it is necessary to consider the academic, social, and professional (i.e., discipline-specific career path) systems within a college (e.g., College of Engineering or College of Science) as well as the overarching university context in which the college is embedded.

The model illustrates how students that receive co-curricular support benefit when receiving various elements of institutional support. Whereas Tinto's model explains how a student's interactions with the academic and social systems could influence student retention at an institutional level, the MCCS explains how a student's interactions with academic, social, and professional systems could influence a student's success more broadly in an undergraduate STEM degree program. Systematically conceptualizing the learning environment using the MCCS serves as a foundation for better understanding how to build institutional capacity for supporting undergraduate students in STEM, shifting focus from individual attributes.

This work was supported through funding by the National Science Foundation under an EAGER Grant No. (1704350). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

According to the MCCS, elements of institutional support are the essential experiences that students get from interventions (i.e., what you would see if you observed participation) [9], [10]. The benefit of looking at student support through this lens is that these elements provide a way to deconstruct *student support* and identify the underlying experiences that should be facilitated. For example, instead of investigating the impact of peer mentoring programs—which are not often identical—this lens allows us to investigate the extent to which students receive the support institutions aim to provide via peer mentoring programs without limiting our investigation to a particular source. The MCCS outlines six elements of institutional support: academic performance, faculty/staff interactions, extracurricular involvement, peer-group interactions, professional development, and additional circumstances. Details on these dimensions can be found in Lee and Matusovich [9]. Though these elements of support are conceptualized in the MCCS, a method for measuring them does not exist currently.

III. Instrument Development

The aim of this exploratory research is to develop and collect validity evidence for an instrument grounded in the MCCS that can be used to assess the magnitude of institutional support effectively provided to undergraduate students in STEM. To develop the instrument, we have currently engaged in five rounds of development.

Because the purpose of the project was to identify institutional support as it pertains to underrepresented and underserved populations in STEM, we aimed to achieve maximum variation within the 38 students included during the initial phases of the project, paying close attention to representation across engineering and science disciplines, gender identity, race/ethnicity, and transfer student status. The research team recruited a diverse group of students at University 1 and University 2 via purposive sampling. Participants were compensated $15-20, depending on the round of data collection and commensurate with the time commitment required. The specific number of interviewees/ participants per institution was determined based on the availability of students meeting our selection criteria. However, to ensure institutional representation, at least 10 students from both institutions were selected. Each step of this process is further discussed in the following sections.

A. Theoretical Construct Development

Initially, we developed the questions on the instrument based on the MCCS, which was developed from a multi-site case study of student support practitioners and students involved in six different students support centers serving engineering and science students at four U.S. universities [9, 10]. Student support centers are common providers of assistance for undergraduate students, especially those from underrepresented groups (e.g., Women in Engineering and Minority in Engineering Programs). We use the theoretical MCCS to support the development of items in each of the six dimensions of student support. In addition to leveraging the constructs of the MCCS, we also leveraged responses collected from students via open-ended surveys during the development of the model related to each element of institutional support. This round of instrument development allowed us to develop a set of items that covered the full set of theoretical dimensions of student support and write items that were informed by students' word choice. Both of these practices began to establish content and face validity for the instrument [11].

B. Review of Existing Instruments

Once we had an initial prototype of the instrument, we reviewed existing instruments related to our purpose. To accomplish this, it was necessary to develop questions that would capture the extent to which students were involved in a wide range of programs, activities, or services; and demographic information more inclusive than typically used in education research. We identified and reviewed a pool of instruments from multiple locations, identifying questions and sections in those instruments that were applicable to this project as well design components that needed to be considered as we collected feedback from various stakeholders. The following instruments were reviewed:

- University of Washington Pre-testing Protocol (Project to Assess Climate in Engineering [PACE], Version 9), 2007 [12]
- PACE Survey, 2011 [13]
- Education & Training (E&T) Evaluation Form, 2011 [14]
- University of Washington Center for Workforce Development PEERS Survey Instrument, 2013 [15]
- Professional Engineering Pathways Study (PEPS) Survey, 2016 [16]
- Human Relations Facilitation (HRF) Process Interview, Intake & Demographics, 2017 [17]
- The Engineering Majors Survey, 2017 [18]
- Virginia Tech College of Engineering Report, 2017 [19]

The questions included in the demographics section were developed by focusing on the sub-populations of particular interest for this project. The first step was to clarify which student populations our instrument needed to identify. Questions to capture aspects of student diversity such as gender identity, race and ethnicity, socioeconomic status, academic major, GPA, transfer student status, and international student status were identified. These questions were also gathered from a variety of sources, including the instruments listed above, the U.S. Department of Education standards, data collection and instrument development conference proceedings [20] [21], and other samples of demographic questions [22].

C. Advisory Board Feedback

Upon developing an initial set of items, we sent the instrument to the project advisory board consisting of three scholars with expertise in both qualitative and quantitative research as well as student support, workforce development, and diversity in STEM. Based on the feedback from these practitioners and education research experts, we modified the instrument items for the next round of piloting. Our institutional partners also offered recommendations regarding existing instruments to review, as discussed in section B.

D. Focus Groups

During the fall of 2017, we conducted four focus groups, each including four to six undergraduate science and engineering students for a total of 16 participants (12 from University 1 and four from University 2). We intentionally gathered information from a wide variety of students, including 11 women and five men from across the undergraduate years and in different engineering and science degree programs. In this round, we did not collect any other self-identified demographic information. For the first round, we focused on identifying high-level issues with the instrument (i.e., the applicability of the questions and answers) and students' initial reactions. During the focus groups, students were asked to reflect on their experiences in their undergraduate degree programs and indicate whether each item was relevant to their experience. Students were also asked if there were other experiences that provided support for them as undergraduates that were not captured in the instrument. We also prompted students to give feedback on the construction and wording of the instrument to identify any potentially confusing or poorly worded items. Based on student feedback, we added new items to the instrument and revised items for clarity.

E. Cognitive Interviews and Administrator Feedback Forms

After focus groups, we conducted cognitive interviews with eight science and engineering undergraduate students [26]. Six of the students were in engineering programs and two were in science programs. Two of these students identified as sophomores, two as juniors, three as seniors, and one as a sixth year. Three of these students identified as Black/African American, one as South Asian, one as East Asian, and three as white. Five of the students were from University 1 and three were from University 2. During the interviews, students were asked to complete the questions, one section at a time, and "think aloud" about their interpretation of each item and how they were connecting it to their experience. The interview protocol asked students how they interpreted the questions on the survey, making sure students' interpretations and the researchers' interpretations aligned.

Unlike the focus groups, these "think aloud" interviews had few interruptions from the interviewer unless the interviewee stopped thinking aloud. If the interviewee did stop thinking aloud, the interviewer prompted him/her about what they were thinking and allowed the student to continue taking the survey. At the end of each section, the interviewer debriefed the interviewee on the content of the section and gathered any additional input about the clarity and content of the survey from the students. This information was used to revise items on the survey that were unclear or had a wide difference in interpretation. This step allowed us to ensure that students were interpreting the questions as intended and provided additional evidence for the face validity of the survey [11].

During this stage of instrument development, we also got feedback from eight administrators that work with STEM students at various institutions. In addition to a copy of the instrument, each administrator was provided with a feedback form that focused on comprehension, question format, institutional appropriateness, length, and instrument use.

F. Research Group Feedback

Our last phase of instrument development involved feedback from the engineering education graduate students in the research group of the PIs and Senior Personnel on the project. These students were included because of their expertise related to survey development and implementation, education research, and various underrepresented groups. This step was conducted to catch grammatical errors and elicit input from another group of engineering education researchers. Fourteen graduate engineering students provided feedback during this step; ten students from University 1 and four students from University 2. Eight students identified as women, five as men, and one as genderqueer or non-binary, transgender. Four students identified as Black/African American, one as Mexican, one as Hispanic or Latino/a, one as East Asian, six as white, and one student chose not to answer the race/ethnicity question.

G. Finalized Pilot Instrument

The final instrument consisted of eight sections: academic support, faculty-interaction support, extracurricular support, peer-interaction support, professional-development support, additional support, student involvement, and demographics.

On the support sections, students were asked their level of agreement to several statements on an anchored numeric scale from 1 - "Completely Disagree" to 5 - "Completely Agree." Students were also given an option of "Does Not Apply to Me." Table I provides an example question for each section of the instrument section.

The student involvement section captured students' self-reported involvement in student organizations, co-ops and internships, study abroad, learning communities, and other out-of-class experiences that may have provided opportunities for the perceived supports captured in earlier sections.

The demographics section asked information about students' degree programs, year in university, parent's level of education, citizenship status, if students identified as a part of the LGBTQ+ community, if they identified as a student with a disability (regardless of accommodation), gender identity, and race/ethnicity. These items were developed from the research team's experience in higher education instruments and the development of more inclusive demographic questions [24].

IV. Spring 2018 Instrument Pilot Deployment

After the extensive instrument development process, we sent a live link via Qualtrics™ software [25] and IRB approved recruiting scripts to the project partners at University 1, University 2, and University 3. These partners are program directors for several different ESSCs at each institution and agreed to send the instrument to all participants in their program either via mailing list or personal emails. As of draft submission, the survey is still open and data collection is ongoing.

A. *Institutional Contexts*

The three institutions included in the initial piloting of the instrument represent three public, research-intensive, land-grant universities. Each of these universities is a predominately white institution. This context is particularly useful for exploring the experiences of STEM students from underrepresented and underserved group. These institutions also enroll a large number of engineers each year (~2,000 at University 1, ~2,300 at University 2 and ~1200 at University 3), so the opportunity to survey a larger sample representative of the engineering student population nationally for this pilot could be achieved.

TABLE I. EXAMPLES OF ITEMS ON DEVELOPED INSTRUMENT

Section	Number of Items	Sample Question(s)
Academic Support	12	"I had access to a physical place to study or work on academic assignments on campus."
Faculty-Interaction Support	13	"I had the opportunity to get to know STEM instructors on a personal level."
Extracurricular Support	14	"I had opportunities to participate in out-of-class activities that fit within my schedule."
Peer-Interaction Support	18	"I met STEM students who were experiencing struggles similar to those I experienced."
Professional Development Support	21	"I had opportunities to network with professionals in my field."
Additional Support	16	"I have received information about scholarship opportunities that apply to me" "I have received assistance from disability services."
Student Involvement	16	Self-reported involvement in student organizations, co-ops and internships, study abroad, learning communities, and other learning experiences that may have provided opportunities for the perceived supports captured in earlier sections.
Demographics	9	Degree programs, year in university, parent's level of education, citizenship status, if students identified as a part of the LGBTQ+ community, if they identified as a student with a disability (regardless of accommodation), gender identity, and race/ethnicity.

B. *Participants*

As of April 2018, approximately 700 students have completed the survey: 598 from University 1, 51 from University 2, and 123 from University 3. Of those students, 414 identified as women, 283 identified as men, seven identified as genderqueer or non-binary, five as transgender, and three as agender. Six of the respondents chose "gender not listed," while 11 preferred not to answer.

While a majority of students who participated in the survey identified as White, there were several varied student demographics. Out of the 722 students, nine identified as American Indian or Alaska Native, 31 as Black or African American, 40 as Hispanic or Latino, 46 as South Asian (e.g., Indian, Pakistani, Bangladeshi, Sri Lankan, etc.), 62 as East Asian (e.g., Chinese, Korean, Japanese, etc.), 25 as Southeast Asian (e.g., Thai, Vietnamese, Burmese, etc.), 22 as Middle Eastern or North African, nine as Native Hawaiian or other Pacific Islander, 544 as White, and eleven as another race/ethnicity. Iranian, Hungarian, Afghan, and "prefer not to answer" were among the specified responses for those who chose "another race/ethnicity."

V. FUTURE WORK

The data collected will provide an opportunity to test the validity of our developed instrument. We plan to test our pilot data for construct validity using a minimum residuals exploratory factor analysis and correlation analyses. A minimum residuals exploratory factor analysis is robust, even for badly behaved matrices over a maximum likelihood approach [26].

These results will inform the next revision of our instrument as well as provide the engineering and computing education community with novel and theory based ways to measure students' perceptions of support in STEM. Student-retention theories traditionally focus on institutional retention even though efforts to support STEM students occur at the college level. This larger study will bridge this gap between research and practice by developing an instrument focused on supporting and retaining minoritized students in STEM. Rather than prescribing specific interventions that may not work in every context, our study will help prioritize the elements of institutional support that should appear somewhere in a college's suite of support efforts.

Once we have completed the piloting of our instrument, we plan to distribute the instrument to a broader set of students. Our target sample for this part of the research is 2,000 students, so we will survey 8,000 students based on a 25% anticipated response rate. We will use incentives and our campus contacts to ensure we reach a diverse and adequate sample to reach the response total necessary for statistical analyses. Following data collection, we will use confirmatory factor analysis to continue establishing construct validity and report on the stability of constructs emerging from our piloting on a new student sample, which will also include students from institutions beyond the institutions reported in this paper. We will also investigate differences across these constructs by subpopulations of students.

ACKNOWLEDGMENT

The authors would like to thank their research teams at Virginia Tech, GUIDE Research Group and the DEEP Lab, and Purdue University, STRIDE. We would also like to thank the anonymous participants for their involvement in the research.

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