2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #39328

Board 395: Testing the Performance of Outcome Measures for LGBTQ STEM Students and Their Peers

Dr. Bryce E. Hughes, Montana State University, Bozeman

Bryce E. Hughes is an Associate Professor in Adult and Higher Education at Montana State University. His research interests encompass diversity and equity in engineering education, with a focus on LGBTQ students. He was recently awarded an NSF CAREER grant to study the experiences of LGBTQ undergraduates in STEM fields. He holds a Ph.D. in education from the University of California, Los Angeles, an M.A. in student development administration from Seattle University, and a B.S. in general engineering from Gonzaga University.

Sidrah MGWatson

CAREER: Testing the Performance of Outcome Measures for LGBTQ STEM Students and their Peers

Abstract

The purpose of this NSF CAREER project is to explore the participation of LGBTQ students in STEM fields. LGBTQ students leave engineering and other STEM majors and careers at higher rates than their heterosexual, cisgender peers, and the climate within these fields is a contributing factor to this difference in attrition. In order to develop a diverse engineering workforce and adequately prepare the next generation of engineers and other STEM professionals, engineering educators and departments must address inequities such as these to ensure broad participation.

This purpose of this poster is to highlight progress toward meeting the first research aim of the overall project, to examine the social networks and related STEM outcomes of LGBTQ students. The project comprises three primary research aims, which also include future work comparing STEM degree completion rates between LGBTQ students and their cisgender, heterosexual peers, and exploring the intersection of STEM discipline-based identity (e.g., engineering identity, science identity) with sexual and gender identity. This project stands to improve our understanding of how to broaden participation in engineering and other STEM fields by pursuing robust research efforts that illuminate the ways sexual and gender identity shape trajectories into, through, and out of STEM.

Over the past year of the project, we have accomplished developing and administering a survey to college students nationally. We administered the survey at two universities in Spring 2022 followed by a third in Fall 2022, and administration will conclude at two more in Spring 2023.The survey itself uses an egocentric social network analysis approach to gather data on the characteristics of a subset of students' social networks, measures of several affective outcomes known to lead to academic persistence, and data on students' college experiences and personal demographics. For this poster, we present our work testing how well the outcome measures performed in the survey instrument.

Overall, our dataset as collected to date includes 404 students who completed the survey. Of these students, over half were women (58.2%), about a quarter were men (28.1%), and 8.9% were nonbinary, genderqueer, or gender nonconforming. In terms of sexual identity, 38.8% of were heterosexual, 30.1% were bisexual or pansexual, 14.4% were gay or lesbian, and 6.5% were asexual. Our survey measured three affective outcomes: sense of belonging in one's major, commitment to one's major, and science and engineering identity. Reliability testing and factor analysis demonstrated that our data performed well in replicating the factor structure of our measures, and content validity testing demonstrated these measures related as expected with other variables in the dataset.

Introduction

Engineering, along with other STEM fields, remains slow to design learning environments that support minoritized students and their interests in or talents for STEM work. This troublesome diversity issue takes shape through participation barriers that filter out promising contributions to solving some of society's most complex problems [1]. Importantly, people from minoritized backgrounds broaden the variety of perspectives working on these pressing issues and the STEM workforce benefits from their participation [2]. Newer lines of research are revealing how sexual orientation and different gender identities shape participation in STEM [3], adding to the importance of understanding and counteracting the impact of minoritization in STEM.

Project Overview

The overall purpose of the NSF-funded CAREER project from which this work is drawn is to explore the participation of LGBTQ students in STEM fields. Research shows that LGBTQ students are more likely to leave STEM majors than their peers [4, 5], which is a result of how they experience the climate in STEM. This project explores how LGBTQ students develop and achieve different affective and behavioral outcomes associated with success in a STEM field to see how sexual and gender identity may shape their academic and professional trajectories.

Research Aims

Three specific research aims define the scope of our project's study. This paper focuses on the first research aim which tests how characteristics of students' social networks predict development of affective outcomes known to promote persistence in a STEM major. The second research aim extends previous work on STEM retention to see if LGBTQ students graduate with STEM degrees at different rates than their peers. The third aim then explores how LGBTQ students experience STEM identity and envision future possible selves as part of the STEM workforce.

The first research aim is a social network analysis of students' networks to see how characteristics of those networks might predict students' achievement of specific affective outcomes known to promote persistence in a STEM major. Social network analysis measures and represents the set of relationships constituting an actor's social context and the influence of that context on an actor's behavioral and attitudinal outcomes [6]. For this study, we selected an egocentric approach that captures a somewhat representative subset of an individual's social network to test the relationship between characteristics of that network and outcomes achieved by a set of individuals. In the survey, we prompted students to identify six members of their social networks—three people that provide them the most academic support and three people that provide them the most personal support. Students were then prompted for information about these individuals and the relationship the participant has with them as well as measures of different affective outcomes, college experiences, and demographic characteristics.

Last year we presented our work developing the survey instrument used to collect data for this study and reported on data collected from two institutions. Since then, we administered the survey at three institutions in 2022—two in the spring, and one in the fall—and we will be administering the survey at two more institutions in spring 2023. These five institutions are somewhat similar in focus and mission, as they are all research universities, but they are geographically diverse as each one is located in the Northwest, the Southwest, the Southeast, the Northeast, and the Midwest regions in the United States. From the three institutions where we have administered the survey, we assembled a sample of approximately 400 students.

Student Outcomes

Our focus in this paper is on the three outcome measures we gathered in our survey. These measures include a sense of belonging in one's major, science and engineering identity, and commitment to one's major. Each of these outcomes has been shown to predict retention in or completion of a STEM degree [7-9], serving as important intermediate outcomes along a student's trajectory toward that longer term goal. Here, we will define each of these outcomes and how they are measured, followed by the steps we took to test how well our surveys performed in measuring each of these outcomes.

Sense of belonging

Sense of belonging reflects the extent to which a student feels they are a part of a specific community of interest. We adapted our measure of sense of belonging from one developed by Hurtado and Carter to understand sense of belonging in Latinx college students [10], grounded in social psychological research on social cohesion [11]. The assumption is that sense of belonging reflects the extent to which students can claim memberships in multiple social identity groups simultaneously: for Hurtado and Carter, this meant being Latinx and a member of one's college community; in this study, this means being LGBTQ and being a STEM student. This outcome is measured using a three-item factor adapted from Hurtado and Carter's measure [10], which continues to be used by the Higher Education Research Institute in their annual surveys.

Commitment to a STEM major

Commitment to a STEM major indicates students' intentions to continue in their chosen major as well as their assessment that their selected major is the right major for them. This measure was adapted from Davidson, Beck, and Milligan's measure used to assess students' commitment to the university in which they were enrolled [12]. This measure is grounded in Ajzen's theory of planned behavior which asserts that intermediate to acting in a specific manner people first develop and express an intent to do so [13]. Many cross-sectional or short-term studies on college students that are unable to follow students to longer-term outcomes like degree completion use intent to persist as a proxy for this later outcome as a result. This variable is measured using a three-item factor asking students their intent to reenroll in the same major the following academic year, to complete a degree in that major, and that their chosen major is the right one for them.

Science and engineering (STEM) identity

Finally, science and engineering (STEM) identity demonstrates the extent to which students see themselves as science and/or engineering people. Identity has emerged as a central construct within science and engineering education research to understand students' underlying psychological motivation to pursue science or engineering degrees [14]. Identity has also become an important analytic lens to understand how one's multiple social identities shape their trajectory into and through STEM [15]. For this study, we used and adapted Godwin's measure of engineering identity to capture both engineering and science identity, which parses engineering identity into three dimensions [16]: performance and competence in engineering, interest in engineering, and recognition as an engineering person.

Methods

For this study, we began with tested, validated measures of the three outcomes of interest as a starting point to claim the validity and reliability of our data. However, because we made minor modifications, and we are using these measures with a specific set of students, we took several steps to test how well our data appears to perform in measuring the underlying constructs of interest. We employed descriptive techniques to better understand the distribution and variability of the data within our sample, exploratory factor analysis (with promax rotation) to test whether our data can reproduce the same factor structure as the measures we are using, and bivariate techniques to assess construct validity to determine if the three constructs associate with other variables in the dataset in expected ways [17]. For the purposes of this paper, we used listwise deletion in running these analyses [18], which means the sample sizes for each factor differ slightly based on the number of complete cases, but the sample sizes do not differ by more than 3 cases.

Results

Overall, the data collected from this sample performed well in terms of testing how our measures capture the underlying factors and constructs that our instrument purported to measure. For sense of belonging, all three items loaded onto the factor well (with all loadings higher than .7), and the reliability coefficient was high as well, α=8775. The three items used to measure commitment to one's major also loaded onto the respective factor (all loadings were higher than .6) with good reliability, α=.7693.

STEM identity was tested using its respective component dimensions of interest, recognition as a scientist or engineer, and competence/performance. Interest and recognition both performed well. Interest in one's field loaded onto a single factor (with factor loadings all exceeding .8), with a reliability of α=.9091. Recognition as a science person also loaded onto a single factor with factor loadings all exceeding .8 and a reliability of α=.9235, as did recognition as an engineering person, factor loadings exceeding .8 and reliability of α=.9462.

Competence/performance generally performed well, except for the rotated factor solution. Of the five items that composed competence in one's field, four had unrotated factor loadings that exceeded .7 and one was higher than .5. The reliability for competence was also good at α=.8633. The rotated factor solution hinted at these five items loading onto two factors, with three of the items loading onto one at higher than .5, but the other two not performing terribly well only loading onto the second factor higher than .3.

Further, one of the items, confidence in understanding my field outside of class, appeared to cross load onto the factors, loading onto factor one at .39 and factor two at .40. The item, others ask me for help in my field, performed the worst in terms of how little it loaded onto either factor (factor 1, .26; factor 2, .36). Since the unrotated factor loadings did exceed generally accepted minimum cutoffs for factor loadings (.4), and the reliability was reasonably high, we proceeded to compute the composite scores for competence from the unrotated loadings for the purposes of testing here. We plan to revisit this factor after we complete administration of the survey.

We then ran several tests to see if these composite factors performed as would be hypothesized in bivariate tests with other variables in our dataset. The descriptive statistics for all the composite factors are provided in Table 1. There is some variation among the variables in terms of the ranges, with regard to interpreting the means and standard deviations, as the factor scores were computed as a weighted sum of the values from the individual items, weighted by factor loading. This summary table helps offer context for understanding the bivariate tests we performed to see if our variables performed as we would expect.

Table 1. Summary statistics for all computed factors

	N	Mean	Std. Dev.	Min	Max
Sense of belonging in field	402	8.839	2.45	2.461	12.304
Commitment to major	401	9.787	1.65	2.155	10.774
Interest in field	402	11.579	2.11	2.592	12.962
Recognition as science person	404	9.883	3.15	2.642	13.211
Recognition as engineering person	403	6.434	3.71	2.750	13.750
Competence in field	401	15.928	2.61	3.754	18.769

Sense of belonging in one's field was compared on the basis of membership in major-related student organization. Those who indicated they had been a member scored higher (M=3.80) than those who had not (M=3.53), t(400)=-2.54, p<.05. Commitment to one's major was also compared on the same basis; students who had been involved with a major-related student organization scored higher (M=10.00) on commitment to their major than those who had not (M=9.54), t(399)=-2.78, p<.01. The correlation between sense of belonging in one's field and commitment to one's major was r=.348, p<.001, which is significant but small.

We tested interest by comparing whether interest in one's field differed on the basis of participating in undergraduate research, membership in a major-related organization, and attending a professional conference. In all three cases, the relationship was not significant: t(400)=-1.36, t(400)=-.063, and t(400)=-1.37, respectively, all p>.05. Interest in one's field did correlate significantly with sense of belonging in one's field and commitment to one's major, at r=.485, p<.001, and r=.382, p<.001, respectively. It's not too surprising that the item may not have related to the specific experiences tested as the item is constructed to refer to "field" broadly across STEM and non-STEM majors, but the relationship with the other two measures is encouraging.

Recognition as a scientist and as an engineer were both compared between STEM and non-STEM majors. Unsurprisingly, STEM majors scored higher on recognition as a scientist (M=11.23) than non-STEM majors (7.23), t(402)=-15.09, p<.001. STEM majors also scored higher on recognition as an engineer (M=7.28) than non-STEM majors (4.78), t(401)=-6.71, p<.001. When disaggregated by fields of majors, engineering students scored far higher (M=12.14) than students in any other major categories, with math and computer science majors scoring the second highest (M=8.60). This item appeared to perform exactly as anticipated based on these comparisons.

Finally, competence/performance, computed from the unrotated factor solution, was tested using two different experiences that we hypothesized may predict differing levels of perceived competence among students in their chosen fields. Competence did not differ between students who had participated in undergraduate research (M=16.09) and those who had not (M=15.84), $t(399)=-0.92$, $p>.05$. Competence only marginally differed between students who had attended a professional conference (M=16.32) and those who had not (M=15.80), $t(399)=-1.71$, $p<.10$. Further analysis of our data and the completion of survey administration will allow us the full opportunity to explore what might be different about the competence dimension of STEM identity regarding its performance with our data compared to other variables.

Future Work

After completing our analysis with the final social network analysis data set, we will turn our focus to the second research aim. This aim will test, using merged longitudinal data sets provided by (HERI) and (Clearinghouse), if LGBTQ students graduate with STEM degrees at different rates than their peers withing particular fields such as Engineering. This summer we will also commence the third research aim exploring STEM discipline-based identity as experienced by LGBTQ students by developing interview protocols for this qualitative phase.

Acknowledgments
This material is based upon work supported by the National Science Foundation under Grant No. 2046233. 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.

References

[1] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, D.C.: The National Academies Press, 2011.

[2] S. E. Page, *The difference: How the power of diversity creates better groups, firms, schools, and societies*. Princeton, NJ: Princeton University Press (in English), 2008.

[3] E. A. Cech and T. J. Waidzunas, "Systemic inequalities for LGBTQ professionals in STEM," *Science Advances,* vol. 7, no. 3, 2021, doi: 10.1126/sciadv.abe0933.

[4] B. E. Hughes, "Coming out in STEM: Factors affecting retention of sexual minority STEM students," *Science Advances,* vol. 4, no. 3, 2018, doi: 10.1126/sciadv.aao6373.

[5] J. Maloy, M. B. Kwapisz, and B. E. Hughes, "Factors influencing retention of transgender and gender nonconforming students in undergraduate STEM majors," *CBE—Life Sciences Education,* vol. 21, no. 1, 2022, doi: 10.1187/cbe.21-05-0136.

[6] C. McCarty, M. J. Lubbers, R. Vacca, and J. L. Molina, *Conducting personal network research: A practical guide* (Methodology in the social sciences). New York, NY: The Guilford Press, 2019, p. pages cm.

[7] B. E. Hughes and S. Kothari, "Don't be too political: Depoliticization, sexual orientation, and undergraduate STEM major persistence," *J. Homosex.,* pp. 1-28, 2021, doi: 10.1080/00918369.2021.1996101.

[8] C. Riegle-Crumb, M. Peng, and T. Russo-Tait, "Committed to STEM? Examining factors that predict occupational commitment among Asian and White female students completing STEM US postsecondary programs," *Sex Roles,* vol. 82, no. 1, pp. 102-116, 2020.

[9] B. E. Hughes, W. J. Schell, B. Tallman, R. Beigel, E. Annand, and M. Kwapisz, "Do I Think I'm an Engineer? Understanding the Impact of Engineering Identity on Retention," in *ASEE Annual Conference and Exposition*, Tampa, Florida, 2019/06/15 2019: ASEE Conferences. [Online]. Available: https://peer.asee.org/32674. [Online]. Available: https://peer.asee.org/32674

[10] S. Hurtado and D. F. Carter, "Effects of college transition and perceptions of the campus racial climate on Latino college students' sense of belonging," *Sociology of Education,* vol. 70, no. 4, pp. 324-345, 1997, doi: 10.2307/2673270.

[11] K. A. Bollen and R. H. Hoyle, "Perceived cohesion: A conceptual and empirical examination," (in English), *Soc Forces,* vol. 69, no. 2, pp. 479-504, Dec 1990, doi: 10.1093/sf/69.2.479.

[12] W. B. Davidson, H. P. Beck, and M. Milligan, "The College Persistence Questionnaire: Development and validation of an instrument that predicts student attrition," *J. Coll. Stud. Dev.,* vol. 50, no. 4, pp. 373-390, 2009, doi: 10.1353/csd.0.0079.

[13] I. Ajzen, "The theory of planned behavior," in *Handbook of Theories of Social Psychology*, vol. 1, P. A. M. V. Lange, A. W. Kruglanski, and E. T. Higgins Eds. Thousand Oaks, CA: SAGE, 2011, pp. 438-459.

[14] H. B. Carlone and A. C. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *J. Res. Sci. Teach.,* vol. 44, no. 8, pp. 1187-1218, 2007, doi: 10.1002/tea.20237.

[15] A. D. Patrick and M. Borrego, "A review of the literature relevant to engineering identity," in *American Society for Engineering Education (ASEE) Annual Conference & Exposition.*, New Orleans LA, 2016, pp. 26-29.
[16] A. Godwin, "The development of a measure of engineering identity," presented at the ASEE Annual Conference and Exposition, New Orleans, Louisiana, 2016/06/26, 2016. [Online]. Available: https://peer.asee.org/26122.
[17] G. E. Mills and L. R. Gay, *Educational research: Competencies for analysis and applications*. New York, NY: Pearson (in English), 2019.
[18] P. D. Allison, *Missing data series: Quantitative applications in the social sciences*, Kindle Edition ed. Thousand Oaks, CA: Sage, 2002.