WIP: STEM culture from faculty perspectives: How faculty see climate in STEM and its effect on the sense of belonging of traditionally / historically excluded students

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***Abstract*—This research-to-practice WIP shares preliminary findings about faculty contributions to cultivating an inclusive culture for students from traditionally/ historically excluded groups within the STEM field. Faculty perspectives about STEM culture correlate to traditionally/historically excluded students' sense of belonging and retention in STEM disciplines [1]. As a result, the "chilly" climate in STEM decreases the sense of belonging in STEM for traditionally/historically excluded students' [2]. These findings from the study demonstrate faculty perception of inclusion and their perception of the inclusivity of STEM culture. STEM faculty have a substantial role in educating future professionals. The following research questions were used to guide the study: (1) How do faculty perceive STEM culture? (2) How do faculty describe the relationship between STEM culture and students' experiences? (3) What characteristics of STEM culture do faculty believe affect traditionally/historically excluded students' sense of belonging?**

The data shared in this article is derived from a larger study that used interviewers and group level assessment to explore STEM climate and culture at two white universities in a large city in the United States. Faculty represented in this study were in the Mathematics and Biomedical Engineering departments. Findings demonstrated how faculty see STEM culture in colleges and universities, and its effect on traditionally excluded students and their sense of belonging. Faculty shared their experiences, opinions, and observations about how STEM culture creates barriers for students, such as a lack of representation, support, and sense of belonging. Moreover, faculty suggested strategies and approaches to promote a more inclusive environment for diverse students. Participants recommended strategies from the study consisted of pre-courses for mathematics and science, professional development opportunities, increasing representation of faculty from traditionally/historically excluded groups, and facilitating intentional social opportunities within academic programs.

Keywords— STEM, culture, faculty, undergraduate students' underrepresentation, sense of belonging, diversity.

I. LITERATURE AND BACKGROUND

Faculty are significant contributors to campus STEM culture and the development of students' perception of the much larger STEM climate. Existing research on underrepresented students' sense of belonging and retention in STEM has centered on students' experiences of the STEM campus climate [3]. Furthermore, faculty interactions can influence how students from diverse backgrounds interact with the campus and STEM courses—among peers and with the learning materials. Faculty affect how welcoming (or unwelcoming) the STEM environment is, which in turn affects students' STEM persistence [4], [5], [6] [7], including developing an interest in graduate school and STEM careers [8].

To promote a sense of belonging for students, O'Leary [6] indicates that faculty devised different course grading strategies, while Goering [9] stresses the need for faculty to be aware of students' academic backgrounds. Moreover, students have confidence in the ability of faculty to support them through their studies by creating an empowering environment [10]. However, faculty's perceptions of student, particular stereotypical beliefs about students 'performance creates a low sense of belonging, leading to poor academic performance [11], [12], [13] and isolation [14]. This is consistent with a study that found that underrepresented STEM students who engage in community and small-group mentorship programs develop self-confidence and positive working relationships with peers and faculty [15]. Students with a keen sense of belonging easily

access information necessary to locate opportunities and resources to be academically and socially successful [16].

II. Theory

To understand the relationship between campus climate and STEM culture, we used Strayhorn's [17] sense of belonging theoretical framework. Sense of belonging refers to a student's perception of the campus social support system, which creates the feeling of being accepted and valued in any setting within the campus [17]. Besides dependence on social identities, other elements of Strayhorn's model relevant to our understanding of traditionally/historically excluded students include satisfaction of need and the motives that drive behavior change.

III. Methodology

This paper aims to describe the effect of faculty perceptions of students' performance and capabilities in STEM at a university located in an urban city in the United States. We used semi-structured interviews to deeply understand how faculty think and believe about STEM culture and its effect on traditionally/historically excluded students. Human interactions, like the interaction between faculty and students, are understandable more through a qualitative approach [18]. Through qualitative methodology, researchers can clarify, compare, and generalize findings to other situations [19].

A. Participants and Recruitment

Our research team performed a group-level analysis of individual interviews and focus groups with STEM faculty at one institution. The findings for this study are a subset of that data, parsed out due to the uniqueness of the institution type. Participants received communication about the study and the option to participate from their department chairs. Names used in this study are pseudonyms assigned by the research team to protect confidentiality. Participants signed up for 60-minute virtual interviews held over Zoom and scheduled via Calendly. Table 1 shows participants' pseudonym names and the fields they teach in the institution.

Table 1

Participants' demographic information

Participant Pseudonym	Subject Area
David	Mathematics
Hiro	Bio-Engineering
Justin	Mathematics
Brendon	Academic Administrator

B. Data Collection and Analysis

Participants were asked a series of questions that focused on student experience, obstacles observed, and individual experiences with supporting students. The data, a subset of data from our larger study in progress. Early findings were analyzed by the three of the four authors, referred to as researchers. In a priming process, the researchers each reviewed two transcripts to identify codes. Then, they met to discuss codes and similarities where they derived their codes and constructed a code book. Each participant's transcript was analyzed by two researchers using MaxQDA coding software. MaxQDA also provided an overview of code frequencies and extracted quotes. Within this summary, we identified similarities throughout the codes, to identify themes. Findings presented are a result of this process.

IV. Findings

The study addressed three research questions: (1) How do faculty perceive STEM culture? (2) How do faculty describe the relationship between STEM culture and students' experiences? (3) What characteristics of STEM culture affect traditionally/historically excluded students' sense of belonging? Our analysis yielded thirteen codes among four participants. Through these codes, we found two themes across participants' perceptions of STEM culture and climate: *awareness* and *curricular challenges*.

A. Awareness

Participants have experience working with traditionally/historically excluded students as their teachers in introductory courses. David shares his experiences with teaching mathematics and some engineering concepts: David, an associate professor of Mathematics, describes the exclusions students feel about STEM fields:

> They still do not feel a sense of belonging in this area and this can be awareness for colleges and universities to put more effort to change their minds and engage more students in this field.

Despite all efforts in STEM In addition to what Hiro, a professor who identifies as South Asian and has extensive knowledge of campus support, describes a need to increase belonging and engagement in these field areas for traditionally/historically excluded students. Hiro states:

> I am aware of a lot of student surveys that go out and the results are pretty clear that students of color don't feel as a part of the community or say like their white counterparts, I suppose.

Hiro recognizes that even though they put so much effort into engaging students in STEM, there is still a gap. This observation shows the systemic issues surrounding diversity and inclusion within educational institutions, especially in STEM-related disciplines, continue to be an obstacle.

Brendan, an academic administrator describes how these structural obstacles impact students in the classroom.

> Several black students in the classroom, they always end up sitting together. I think that the black students are much less likely to engage in group work, in or outside of the classroom. That is what I have seen, I mean, that has just been my observation. And I work very hard to try to move that along, so they do feel the same, but I think, on and off, I realize, now, you know, in a class, you have two. That is what I meant that we do not have that many, so we are not really – our population at University, I do not think it really represents the American society very well.

The lack of representations of historically/traditionally excluded students in the STEM academic fields makes these students uncomfortable inside and outside the classrooms. This issue underscores the broader issue of diversity within higher education institutions and suggests a recognition of the importance of creating inclusive environments that reflect the diversity of the broader society that the participant mentions in the interview.

B. Curricular Challenges

The provided data highlights challenges faced by historically/ traditionally excluded students in STEM fields regarding academic preparedness and perceived potential for success, based on faculty perspective. Justin, a mathematics instructor, reflects on the institutional support for traditionally/underrepresented students.

> They're [faculty and administrators] not interested in why these people are failing. They say, 'oh, they are from a poor background. They will never learn.' That's not true. They will learn.

There is a misconception among some faculty members that traditionally/historically students are incapable of succeeding in STEM fields and faculty member challenges this belief, asserting that such students are capable of learning and succeeding if given the necessary support and resources.

Despite believing that students are limited due to their history, one participant finds significance in students' prior academic success. Brendon asserts that:

> But the problem is their preparedness is weak. If their preparedness is weak, then they start falling behind. I mean, top 10 percent, 20 percent people like you, you don't have problem. I mean, I'm sure if you have struggled in undergrad, you wouldn't have done PhD, but every student is not there. That's what I'm talking about.

Brendon emphasizes that not all students have the same level of preparation or access to resources, and while students with strong academic foundations may excel, others may struggle. This acknowledgment acknowledges the systemic barriers hindering traditionally excluded students in STEM fields and their academic success.

David knows the challenge of inadequate student preparedness and admits to having devised mechanisms that encourage more underrepresented students to continue in STEM programs.

> But I think that we need to extend it not only to the minority students; I think we need to extend it to students who do not test well in mathematics. And that, I think, has problems in and of itself, as well, so there's no right answer, but, yeah, I – I don't know how to describe it. I really want [laughs] – I wanna do my best, in everything we can, to improve students that are underrepresented in the field of science. And everything that we try may not be the best, but it's an attempt.

This quote emphasizes STEM educators' commitment to equity and inclusivity for all students. David recognizes some students who struggle with a lack of knowledge in mathematics need some support from colleges and instructors to transition to college level instruction. Additionally, David also recognizes the structural barriers, like testing, that create additional obstacles for students.

V. DISCUSSION & CONCLUSION

A. Discussion

The focus of the larger study was to explore the obstacles and challenges that students from historically/traditionally excluded group backgrounds face in their academic programs in STEM fields. Using research questions: (1) How do faculty perceive STEM culture? (2) How do faculty describe the relationship between STEM culture and students' experiences? (3) What characteristics of STEM culture do faculty believe affect traditionally/historically excluded students' sense of belonging? This subset of data was extracted from the larger study due to the unique identification of faculty responses.

From these early findings, faculty demonstrated a commitment to educating historically/traditionally excluded students. They shared their concerns regarding students' navigation of steep STEM terrain, especially in cases where they are outnumbered and attempt to get actively involved in the learning process [20]. In some regard, this was expressed in a deficit standpoint which disregarded the capital that students obtained prior to college. However, as participating faculty considered the culture of STEM and the climate of their institutions, they resonated with the need for improved support structures [21]. These proposed solutions included both human resources such as faculty mentorship, institutional structures (e.g., a specific program), and pre-college structures. Together, all four faculty participants identify the need to provide supportive academic environments like what is included within a bridge program bridge programs to prepare all students in STEM disciplines, and supportive interaction between faculty and students as effective solutions for supporting traditionally/historically excluded students.

B. Limitation

The study sample size is small in addition to early findings. Additionally, the participants recruited are from the same institution, experiencing the same campus climate and STEM culture. Furthermore, all the participants identified as men at the time of the study which creates a limited perspective of STEM culture and climate.

C. Implications

Moving forward, faculty within a program, department, and college should engage in routine and intentional dialogue to establish a congruent approach to supporting students from historically/traditionally underrepresented groups. As educators, it is important to increase the layers of support and participate in training to mitigate deficit-aligned thinking and increase awareness about how faculty can refrain from contributing to the "chilly" STEM climate and campus culture [22].

References

[1] E. O. McGee, "Interrogating Structural Racism in STEM Higher Education," *Educational Researcher*, vol. 49, no. 9, pp. 633–644, Dec. 2020, doi: 10.3102/0013189X20972718.

[2] R. M. Hall and B. R. Sandler, "The Classroom Climate: A Chilly One for Women?.," 1982.

[3] K. Eason, W. Gaskins, B. Guy, S. Martin, and S. Askarian Khanamani, "We Lose the Game Before We Start to Play: How Black Women Make Meaning of Their Experiences in Engineering Education," Jan. 2023.

[4] Connie Walton *et al.*, "Design and Implementation of a STEM Student Success Program at Grambling State University," pp. 103–121, Jan. 2019, doi: 10.1021/bk-2019-1328.ch007.

[5] C. M. Cunningham, G. J. Kelly, and N. Meyer, "Affordances of engineering with English learners," *Science Education*, vol. 105, no. 2, pp. 255–280, Mar. 2021, doi: 10.1002/sce.21606.

[6] E. S. O'Leary *et al.*, "Creating inclusive classrooms by engaging STEM faculty in culturally responsive teaching workshops," *International Journal of STEM Education*, vol. 7, no. 1, p. 32, Jul. 2020, doi: 10.1186/s40594-020-00230-7.

[7] A. L. Belanger, M. P. Joshi, M. A. Fuesting, E. S. Weisgram, H. M. Claypool, and A. B. Diekman, "Putting Belonging in Context: Communal Affordances Signal Belonging in STEM," *Pers Soc Psychol Bull*, vol. 46, no. 8, pp. 1186–1204, Aug. 2020, doi: 10.1177/0146167219897181.

[8] H. Haeger and C. Fresquez, "Mentoring for Inclusion: The Impact of Mentoring on Undergraduate Researchers in the Sciences," *LSE*, vol. 15, no. 3, p. ar36, Sep. 2016, doi: 10.1187/cbe.16-01-0016.

[9] A. E. Goering, C. E. Resnick, K. D. Bradford, and S. M. Othus-Gault, "Diversity by design: Broadening participation through inclusive teaching," *New Directions for Community Colleges*, vol. 2022, no. 199, pp. 77–91, 2022, doi: 10.1002/cc.20525.

[10] T. L. Fletcher, J. P. Jefferson, B. Boyd, S. E. Park, and L. Crumpton-Young, "Impact of COVID-19 on sense of belonging: Experiences of engineering students, faculty, and staff at Historically Black Colleges and Universities (HBCUs)," *Journal of Engineering Education*, vol. 112, no. 2, pp. 488–520, 2023, doi: 10.1002/jee.20512.

[11] E. A. Canning, K. Muenks, D. J. Green, and M. C. Murphy, "STEM faculty who believe ability is fixed have larger racial achievement gaps and inspire less student motivation in their classes," *Sci. Adv.*, vol. 5, no. 2, p. eaau4734, Feb. 2019, doi: 10.1126/sciadv.aau4734.

[12] C. A. Moss-Racusin, C. Sanzari, N. Caluori, and H. Rabasco, "Gender Bias Produces Gender Gaps in STEM Engagement," *Sex Roles*, vol. 79, no. 11, pp. 651–670, Dec. 2018, doi: 10.1007/s11199-018-0902-z.

[13] Rachel L. Roper and R. L. Roper, "Does Gender Bias Still Affect Women in Science," *Microbiology and Molecular Biology Reviews*, vol. 83, no. 3, Jul. 2019, doi: 10.1128/mmbr.00018-19.

[14] S. L. Rodriguez and J. M. Blaney, "'We're the unicorns in STEM': Understanding how academic and social experiences influence sense of belonging for Latina undergraduate students.," *Journal of Diversity in Higher Education*, vol. 14, no. 3, pp. 441–455, Sep. 2021, doi: 10.1037/dhe0000176.

[15] D. R. Brooms, "Exploring Black Male Initiative Programs: Potential and Possibilities for Supporting Black Male Success in College," *Journal of Negro Education*, vol. 87, no. 1, pp. 59–72, Jan. 2018, doi: 10.7709/jnegroeducation.87.1.0059.

[16] M. J. Hansen, M. J. Palakal, and L. White, "The Importance of STEM Sense of Belonging and Academic Hope in Enhancing Persistence for Low-Income, Underrepresented STEM Students," *Journal for STEM Educ Res*, May 2023, doi: 10.1007/s41979-023-00096-8.

[17] T. L. Strayhorn, *College students' sense of belonging: A key to educational success for all students*. Routledge, 2018.

[18] K. Kelly and B. Bowe, "Qualitative research in engineering education," 2011.

[19] M. C. Hoepfl, "Choosing qualitative research: A primer for technology education researchers," *Volume 9 Issue 1 (fall 1997)*, 1997.

[20] M. D. B. Massey, S. Arif, S. Embuldeniya, K. Nanglu, and J. Bielawski, "Ten simple rules for succeeding as an underrepresented STEM undergraduate," *PLOS Computational Biology*, vol. 18, no. 6, p. e1010101, Jun. 2022, doi: 10.1371/journal.pcbi.1010101.

[21] K. A. Griffin, "Addressing STEM culture and climate to increase diversity in STEM disciplines," *Higher Education Today*, 2018.

[22] J. M. Raines, "FirstSTEP: A preliminary review of the effects of a summer bridge program on pre-college STEM majors," *Journal of STEM Education*, vol. 13, no. 1, 2012.