Mapping structural equity with departmental profiles in physics graduate education

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Graduate physics education faces structural barriers limiting student access and participation. The Inclusive Graduate Programs (IGP) project supports physics departments in transforming their cultures to better serve diverse students. Our research developed departmental profile templates to gather information from program leaders, focusing on three core categories: admissions, post-entry support, and department-wide equity efforts. Admissions practices include deprioritizing GRE scores, holistic reviews, anti-bias training, fee waivers, and targeted recruitment. Post-entry support involves restructuring qualifying exams, fostering community, improving faculty-student communication, and mentoring. Equity efforts include events, inclusive gatherings, and partnerships with minority-serving institutions. Content analysis of nine programs showed only two demonstrate holistic efforts across all categories. Most invested unevenly, with post-entry support notably underdeveloped. While efforts aligned with identified needs, significant gaps remain. These findings emphasize the need for integrated, sustained equity initiatives in graduate physics education and offer a foundation for further research on institutional change in STEM fields.

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I. INTRODUCTION

Physics graduate education continues to attract research attention because of ongoing problems with racial and gender diversity [1–3], as well as low retention rates [2]. Although many STEM fields face similar challenges, these issues are especially severe in physics. A study by Miller and Coldren shows that physics contributes more than other disciplines to the lack of diversity in STEM [4]. While many efforts have been made within the field to improve these problems [5], widespread change has yet to be seen [6]. A major shortcoming of past efforts has been focusing solely on changes to policies and procedures, with too little attention given to the culture that shapes student experiences. For change to be both effective and lasting, it must address not only formal structures but also the underlying values and beliefs held within the organization.

Understanding the cultural elements of academic programs, such as their artifacts, values, and norms [7], is essential for identifying what needs to change and why [8]. A cultural approach to change is what motivated the development of the Inclusive Graduate Physics (IGP) project [6]. In this initiative, we partnered with twelve research-intensive physics graduate programs to support their efforts to initiate cultural change and build more equitable programs. One of our first steps was to assess the existing culture in each program, including both structures and values, so we could meet departments where they were and provide support tailored to their specific context. As part of this process, we first examined current practices ranging from recruitment and admissions to equity-focused initiatives and support systems for enrolled graduate students.

Although there has been a major drop in the use of Physics-Graduate Record Examination (P-GRE) post-COVID, traditional methods of admission for graduate physics applicants still rely heavily on the exam [9]. This metric has historically been in favor of the majority groups, with white and Asian men in particular having an advantage [10]. Moreover, the P-GRE has been found not significant in predicting completion of the Ph.D. program and is a small indicator of success in graduate courses [11, 12].

Research has shown that these traditional metrics are not directly representative of success in a graduate program, and that holistic approaches are more effective at eliminating biases and evaluating student applications fairly [13]. Through the use of rubrics and holistic admission practices, students from underrepresented backgrounds are able to achieve the same results as those from majority groups. These rubrics can test desirable traits, departmental fit, and research accomplishments to provide a fairer evaluation that lowers disparities with race, socioeconomic status, and gender [9]. However, even with change being spearheaded in admissions towards more diverse admissions, there is a prevalent issue in retaining these students.

Owens et al. [14] highlighted a disconnect between faculty and students when asked how to improve retention and reduce attrition in graduate programs. Faculty tended to focus on admissions processes, while students emphasized the need to improve departmental climate. Students identified key contributors to attrition, including toxic research group environments, inadequate advising and mentoring, and concerns about funding. The study suggests that sustainable progress towards greater diversity cannot be achieved through changes to admissions alone.

The social environment within graduate programs plays a crucial role in student success [15, 16]. Research recommends structures and practices that foster a sense of community, such as regular departmental lunches and larger advising committees that meet with students each semester [15]. These initiatives have been shown to benefit students by improving communication, strengthening community ties, and enhancing advising systems [17] – all of which are critical to student persistence and well-being [16, 18, 19].

II. BACKGROUND

This study was conducted as part of the Inclusive Graduate Programs (IGP) project [6], which was funded through a Catalyst award from the Alliances for Graduate Education and the Professoriate (AGEP) program of the National Science Foundation (NSF). The primary goal of the project was to lay the groundwork for a broader effort aimed at fostering cultural change to enhance diversity, equity, and inclusion in graduate education.

As part of this effort, the research team partnered with twelve research intensive physics graduate programs to support their efforts to create more inclusive departmental cultures. We began by identifying a group of physics departments that had previously participated in at least one disciplinary change initiative with an equity focus, such as the American Physical Society (APS) Bridge Program [5], APS Inclusion Diversity and Equity Alliance (IDEA) [20] and American Institute of Physics (AIP) Task Force to Elevate African American Representation in Undergraduate Physics and Astronomy (TEAM-UP) [21]. During this early phase, our objective was to document the range of change efforts these programs had engaged in and to understand what strategies had or had not been effective, based on their specific local contexts. The main data source we used to understand these efforts were the departmental profiles, which are the focus of this paper. In particular, in this paper, we address the following research question (RQ):

What structural changes have graduate programs made to advance equity, and what initiatives do physics faculty and students identify as priorities for improving equity going forward?

The departmental profile template that was provided to the IGP departmental teams included various categories. In this paper, we focus on the categories of *admissions* that include: deprioritization of GRE General Test (G-GRE) scores, deprioritization of GRE Physics Subject Test (P-GRE) scores, use of holistic admissions frameworks, integration of anti-bias training in admissions processes, expansion of application fee waiver access, and engagement in targeted recruitment through affinity-based conferences. Next, we analyze the categories on *post-entry structures and policies* that include: restructuring of qualifying exams to reduce bias and increase accessibility, community-building opportunities, strengthening communication channels between faculty and students, and development of supportive mentoring structures. Finally, we focus on *department-wide equity and inclusion efforts* that include the following categories: establishing DEI events, organizing inclusive events, partnerships with minority-serving institutions (MSIs).

III. METHODS

A. Participants

For this paper, we examined completed data sets from nine out of the twelve physics programs. These nine physics graduate programs are all research intensive graduate programs ranging from 50 to 300 students and geographically span the United States. The data sources used in this paper were completed by the IGP departmental teams, chairs, and administrative assistants.

B. Data Collection

The main data source for this paper is the set of departmental profiles collected during the Catalyst project. These profiles, along with interview and survey data from students and faculty, helped us identify the baseline culture of the participating physics programs. Building on this foundation, we collaborated with the departments to develop an institutional transformation proposal focused on implementing our change model. Sections of the proposal, written by the departments and centered on identified priorities, address the second part of our research question. We first use the profile data to examine structural changes aimed at advancing equity. Throughout this process, we supported departments in identifying initiatives that faculty and students viewed as most critical to improving equity. These priorities were incorporated into the final proposal.

The data from the proposal section captured the priority areas for advancing equity identified by the departmental teams. In June 2024, we organized a convening with four to six representatives from each physics programs (including faculty and students). Prior to the convening event, the research team solicited input from each team regarding the areas they intended to focus on. Based on these responses, several key themes emerged: fostering a supportive climate, strengthening advising and mentoring, improving communication between faculty and students, developing or improving bridge programs, refining graduate admissions processes, and revising qualifying procedures. These priorities were shaped by a combination of factors, including feedback from the research team following two-day campus visits, data collected by the research team, institutional data, and internal departmental reflections.

During the June convening, participants were invited to join working tables organized around these various change areas to facilitate cross-departmental discussion. Departmental teams then reconvened to reflect and refine their priorities. A key outcome of the convening was the collaborative development of focus areas and initial action steps by each departmental team.

Following the convening, the research team encouraged each department to engage internally with a broad range of stakeholders to finalize the specific areas they would prioritize in the proposal (getting input and buy-in). The proposal sections analyzed in this paper represent the culmination of these processes.

This study relies solely on self-reported departmental profile data, which introduces potential biases both from the self-reported nature of the information and from the lack of triangulation with other data sources or member checking. Without additional perspectives, the findings may reflect the views or interpretations of the individuals completing the profiles rather than a fully representative account of departmental practices. In a future journal publication, we plan to address this limitation by validating findings through member checking and by collecting input from multiple members of each IGP team to reduce self-report bias.

C. Analytical Approach

In this study, we used a quantitative content analysis approach [22]. Content analysis is a research method for making inferences from various sources such as texts, documents, images to the contexts of their use.

All subcategories were coded on a scale from 1 to 3, representing the degree of alignment with research-based practices that promote equity in graduate education, with 1 indicating low alignment and 3 indicating high alignment. For example, within the *post-entry structures and policies* category, the subcategory of community building opportunities, scores of **1 (low alignment)** were assigned to common, minimally supported activities such as seminars or efforts initiated solely by students. A score of **2 (medium alignment)** was used for occasional initiatives organized by departments, such as one-time social events or informal gatherings. A score of **3 (high alignment)** reflected sustained efforts supported by the department, including frequent social programming and financial or structural support for community building activities led by students. After coding each subcategory, we calculated index scores for each category by averaging the corresponding subcategory values. These index scores range from 1 to 3, where 1 indicates low alignment and 3 indicates high alignment with research-based practices.

Two researchers coded each category to ensure inter-rater reliability. When comparing results before editing based on rater discussion, the researchers first had a Cohen's kappa of 0.42, indicating fair agreement. After discussing, the researchers arrived at a Cohen's kappa of 0.77, indicating substantial agreement.

IV. RESULTS

We represented our analysis in heatmaps to give a visualization of our coding for *admission practices*, *post-entry support structures*, and *department-wide equity and inclusion efforts*. Figure 1 represents the three heatmaps of these categories across the nine programs.

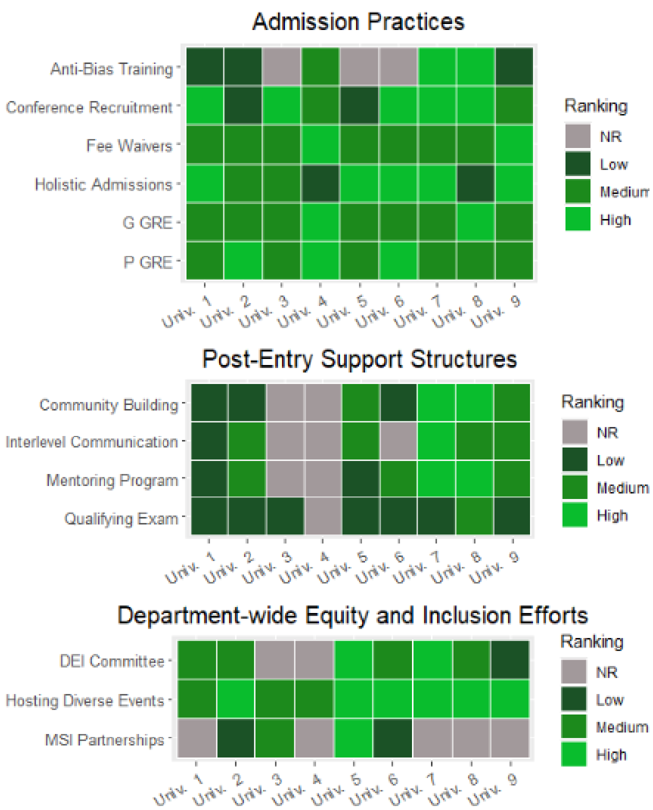

FIG. 1: Heatmaps of the physics programs' rankings in their *admission practices* (top), *post-entry support structures* (middle), and *department-wide equity and inclusion efforts* (bottom). Rankings are categorized as low, medium, or high, indicating the degree to which each program's practices align with research-based strategies for advancing equity. "NR" indicates that no response or data was reported for that category.

While most programs fall within a moderate range of alignment with research-based *admission practices*, Univ. 7 demonstrates relatively strong alignment, with the highest score in the sample. Univ. 6 and 8 also show above-average commitment towards research-based admissions practices. More specifically, most programs have shifted to making the G-GRE and P-GRE optional in the post-COVID-19 world. Univ. 2 is a unique case, requiring G-GRE scores only from international applicants while not considering P-GRE scores at all. Additionally, several programs have indicated they plan to eliminate G-GRE requirements entirely. Fee waivers are available at seven out of nine programs, typically offered to first-generation students or those facing financial hardship. Univ. 4 and 9 offer waivers on a first-come, first-served basis without demographic or other restrictions. Univ. 9 received a low score on Anti-Bias Training not due to internal policy but because state legislation prohibits such training. Univ. 2 and 3, both receiving medium scores for Holistic Admissions, were assessed at that level due to unique limitations. In particular, Univ. 2 enforces GPA cutoffs, while Univ. 3 does not consider applicants without prior research experience.

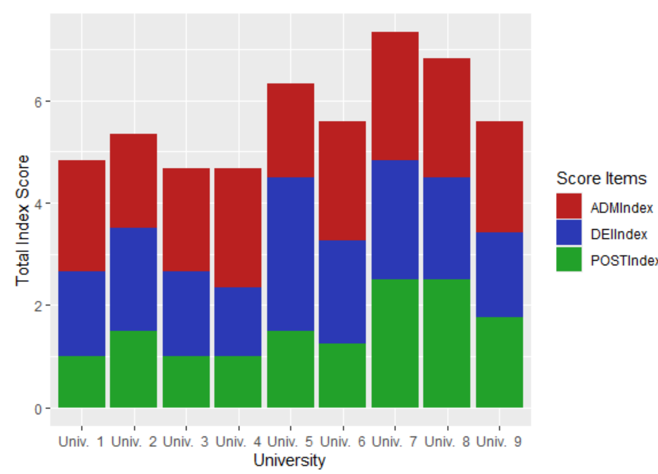

FIG. 2: A stacked bar chart of the index scores of the *admission practices* (ADMIndex), *department-wide equity and inclusion efforts* (DEIIndex), and *post-entry support structures* (POSTIndex) for each university.

Post-entry support structures are the least developed area across the nine programs. While two departments stand out for high alignment with research-based practices, and one shows medium progress, the majority exhibit minimal support, with three programs standing out for particularly low alignment. More specifically, aside from Univ. 8, all programs currently require students to complete a qualifying exam during the early stages of their doctoral studies. Univ. 8 has implemented a more flexible model in which students may either take the qualifying exam or complete a set of core courses defined by the department. This change was made in response to student concerns about stress and dissatisfaction with the traditional exam structure. Additionally, Univ. 2, 5, 6, and 9 have indicated plans to revise their qualifying exams, suggesting an intent to improve access and reduce unnecessary barriers.

Department-wide equity and inclusion efforts across the nine graduate physics programs are also generally underdeveloped, with only one program (Univ. 5) demonstrating strong structural alignment. Most departments fall into the low to medium range, reflecting either early-stage or inconsistent implementation of equity and inclusion efforts across the department.

Figure 2 shows a stacked bar chart of the three categories. The values represent the index scores, ranging from 1 to 3, where 1 indicates low alignment and 3 indicates high alignment with research-based practices. The stacked bar chart reveals that equity efforts in these graduate physics programs remain fragmented, with only a small number of programs demonstrating holistic alignment across *admission practices*, *department-wide equity and inclusion efforts*, and *post-entry support structures*. Most departments are engaging with equity in isolated or early-stage ways, and *post-entry support structures* continues to be the most neglected area.

Figure 3 highlights the areas of *post-entry support structures* that programs have committed to improving in the future as part of their participation in the IGP project. These planned changes, indicated with circles, are mapped onto the existing heatmap of *post-entry support structures* to examine whether the targeted reforms correspond to the areas most in need of attention, based on our assessment. While there is some alignment between areas of need and planned efforts, we also observe notable gaps. For example, Univ. 5 received a low score in the area of qualifying exams, however, this area was not identified as a focus for future change. This suggests that some departments may either lack the tools or internal feedback processes necessary to identify and prioritize the areas most in need of reform, or they may face cultural resistance to changing long-standing practices that are perceived as central to disciplinary identity.

In terms of specific proposed changes, when focusing on the qualifying exam, one of the universities plans to determine an alternative to the traditional written exam that still assesses student preparedness while reducing anxiety, supports diverse students and needs, and foregrounds research experience. In parallel to these changes, department teams noted that they further have specific plans for overcoming faculty hesitancies, which is focused on shifting a culture of deficit mindset. Another university proposes to reduce student stress related to the qualifying experience by enabling students to pass parts separately rather than all at once, allowing students to select relevant subject areas, and replacing written problems with presentations on research topics.

V. DISCUSSION & CONCLUSIONS

This paper reveals that equity-focused reform efforts in these nine physics graduate programs remain uneven and fragmented. While a few programs demonstrate strong alignment across *admission practices*, *post-entry support structures*, and *department-wide equity and inclusion efforts* for students, most show partial or limited progress in one or more areas. *Post-entry support structures*, in particular, stands out as the most underdeveloped area, signaling a need for departments to move beyond front-end interventions and invest in the full trajectory of student experiences in these programs (from admissions to graduation).

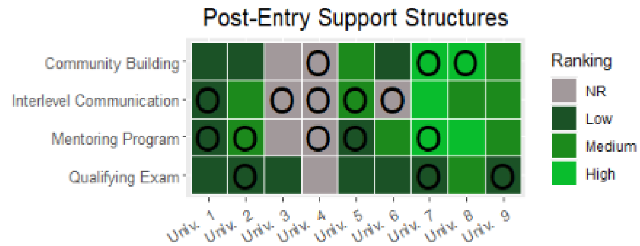

FIG. 3: Areas of future focus indicated by the IGP departmental teams (indicated with a circle) mapped onto the heatmap of the *post-entry support structures*.

The few misalignments between areas of need and areas targeted for future change further suggests that departments may lack clear diagnostic processes or face internal cultural barriers to addressing deeply embedded structures. These findings underscore the importance of intentional, data-informed strategies for structural change, and continued support.

As the cultural change frameworks introduced earlier highlight, departmental change requires more than isolated programmatic changes by involving shared values and norms that guide everyday decision-making [7]. However, these internal cultural barriers do not operate in isolation. In the current national climate, departments also face powerful external pressures that can reshape their reform agendas. Understanding departmental culture in context thus means recognizing how internal readiness for change is mediated by external political and resource environments.

Finally, we acknowledge two important limitations of this study. First, the departmental profiles included several non-reported or missing items across the nine departments. In addition, our analysis relied on a single data source to map departmental structures, which may not capture the full complexity of each department. Future research should expand on this dataset by incorporating interviews with department leaders to address gaps in the existing profiles, as well as student surveys to better understand their perspectives on post-entry departmental support.

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[1] *Science and Engineering Indicators 2018*, Tech. Rep. NSB-2018-1 (National Science Board, Alexandria, VA: National Science Foundation, 2018).

[2] R. Sowell, J. Allum, and H. Okahan, *Doctoral Initiative on Minority Attrition and Completion*, Tech. Rep. (Council of Graduate Schools, Washington, DC, 2015).

[3] D. Sachmpazidi, Research on equity in physics graduate education, The International Handbook of Physics Education Research: Special Topics , 4 (2023).

[4] N. S. Foundation, Nsf includes alliance: Inclusive graduate education network, Online (2018), accessed: 2025-05-30.

[5] American Physical Society, Aps bridge program (2024), accessed: 2025-05-29.

[6] B. Goldberg, G. Cochran, C. Henderson, M. Wittmann, D. Sachmpazidi, S. Woods, D. Codding, and E. Su, Inclusive graduate programs: An agep pilot in physics and astronomy, in *APS March Meeting Abstracts*, Vol. 2024 (2024) pp. S61–009.

[7] E. Schein, *Organizational Culture and Leadership* (Jossey-Bass, San Francisco, 2004, 2004).

[8] D. Sachmpazidi, C. Turpen, J. Petrella, R. P. Dalka, and F. N. Abdurrahman, Recognizing dominant cultures around assessment and educational change in physics programs, Physical Review Physics Education Research **20**, 010132 (2024).

[9] N. T. Young, *The Past, Present, and Future of Graduate Admissions in Physics* (Michigan State University, 2021).

[10] C. W. Miller and K. G. Stassun, A test that fails, Nature **510**, 303 (2014).

[11] M. Verostek, C. W. Miller, and B. Zwickl, Analyzing admissions metrics as predictors of graduate gpa and whether graduate gpa mediates ph. d. completion, Physical Review Physics Education Research **17**, 020115 (2021).

[12] C. W. Miller, B. M. Zwickl, J. R. Posselt, R. T. Silvestrini, and T. Hodapp, Typical physics ph. d. admissions criteria limit access to underrepresented groups but fail to predict doctoral completion, Science Advances **5**, eaat7550 (2019).

[13] N. T. Young, K. Tollefson, R. G. Zegers, and M. D. Caballero, Rubric-based holistic review: A promising route to equitable graduate admissions in physics, Physical Review Physics Education Research **18**, 020140 (2022).

[14] L. Owens, B. M. Zwickl, S. V. Franklin, and C. W. Miller, Misaligned visions for improving graduate diversity: Student characteristics vs. systemic/cultural factors, in *Physics Education Research Conference 2018* (2018).

[15] R. Barthelemy, M. Lenz, A. Knaub, J. Gerton, and P. Sandick, Graduate program reform in one department of physics and astronomy: From tragedy to more progressive policies and an evolving culture, Physical Review Physics Education Research **19**, 010102 (2023).

[16] D. Sachmpazidi, *Investigating the Relationship Between Departmental Support Structures, Self-Efficacy and Intention to Persist: An Examination of Students' Experience in 19 Physics Graduate Programs Across the United States*, Ph.d. dissertation, Western Michigan University (2021), dissertations.

[17] M. Verostek, C. W. Miller, and B. M. Zwickl, Modeling when and how physics phd students search for a research group: The role of interests and prior research experiences in timely group integration, Physical Review Physics Education Research **20**, 020119 (2024).

[18] C. M. Golde, The role of the department and discipline in doctoral student attrition: Lessons from four departments, J. High. Educ. **76**, 669 (2005), [J. High. Educ. **76**, 669–700 (2005)].

[19] T. Campell and D. Campell, Faculty/student mentor program: Effects on academic performance and retention, Research in Higher Education **38**, 727 (1997).

[20] American Physical Society, Aps inclusion, diversity, and equity alliance (idea) (2025), accessed: 2025-05-23.

[21] American Institute of Physics, Team-up together (2025), accessed: 2025-05-23.

[22] K. Krippendorff, *Content Analysis: An Introduction to Its Methodology*, 2nd ed. (Sage Publications, Thousand Oaks, CA, 2004).