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RESEARCH ARTICLE

Physics & Astronomy Community Excellence: Structured Near-Peer Mentorship in Doctoral Degree Programs

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Abstract

We have developed a near-peer mentorship program in the Department of Physics and Astronomy at the University of California, Irvine. The Physics and Astronomy Community Excellence (PACE) program is a graduate student led initiative designed to acclimate students and foster community through structured near-peer mentorship. Established in 2018, PACE provides guidance on academic resources, mental health, and various aspects of the graduate experience. Survey data indicates that PACE has had strong positive impacts on participants. Mentors, including those from historically underrepresented groups, report benefits including increased leadership skills, sense of belonging, and motivations for continuing in the field.

Keywords: near-peer mentorship; inclusive academic environments; academic persistence; graduate student retention

1 Introduction

1.1 Rationale

Among college students and working professionals in physics-related disciplines, there is a diverse range of experiences, aspirations, and challenges that influence their engagement with the field. Physics, as a foundational science, attracts those who are curious about the universe, keen to solve complex problems, or are driven to advance technology. Unfortunately, physics education pathways show substantial attrition at multiple stages. About 45% of students who declare a physics major do not complete their bachelor's degree Mulvey and Nicholson (2014), and of those who do, only 30–40% of U.S. physics bachelor's recipients enroll in graduate programs within a year of graduating

of Physics (AIP). Moreover, the demographics of those who persist in physics fields do not represent the broader population. There is a persistent underrepresentation of women and students from racially minoritized backgrounds — defined here as individuals from Latinx, Black, and Indigenous backgrounds — in physics fields, a well-documented issue that indicates systemic inequities. In 2020, racially minoritized students earned 26% of bachelor's degrees, 24% of master's degrees, and 16% of doctoral degrees in physics, despite comprising 37% of the U.S. population in 2021 National Science Foundation (2023). Additionally, men were employed in the large majority of science and engineering occupations compared to women (72% vs. 28%; National Science Foundation (2023)), while women earned just 24% of physics bachelor's degrees of Physics (AIP) — a notable contrast to fields like chemistry, where women earned 53% of bachelor's degrees National Science Foundation (2023).

Institutions may be able to reduce attrition in physics pathways and increase the representation of women and racially minoritized students in physics fields by creating more welcoming environments through mentoring. Physics students who participate in mentoring programs report a greater sense of belonging and science identity Thiry et al. (2011); Hazari et al. (2017), and mentoring availability has been positively related to academic success and reduced dropout rates Grant et al. (1992), as well as students' self-efficacy, persistence, and successful career trajectories Borg et al. (2005); Eby et al. (2013). Peer mentoring in particular may be especially beneficial for racially minoritized physics students Zaniewski and Reinholz (2016); Estrada et al. (2018) and mentees who are women Dennehy and Dasgupta (2017), despite unequal access to this resource Thiry et al. (2011). Minoritized STEM students who serve as peer mentors and who participate in peer-mentoring training have reported increased leadership skills and STEM knowledge Trujillo et al. (2015), and have demonstrated increased retention and academic success Trujillo et al. (2015); Good et al. (2000).

Although our study is descriptive, rather than causal, PACE operates within a minority-serving institution and maintains a mentor pool with a comparatively high proportion of women, creating an environment consistent with prior research showing that access to female near-peer mentors supports women's experiences in STEM (Dennehy & Dasgupta, 2017). More broadly, mentoring research suggests that such structural conditions may also support racially minoritized students' sense of belonging and persistence in STEM (e.g., Thiry et al., 2011; Estrada et al., 2018).

2 Overview of the PACE Program

2.1 Background

The Physics and Astronomy Community Excellence (PACE) program focuses on near-peer mentoring and is led by graduate students in the Department of Physics and Astronomy at the University of California, Irvine (UCI). The PACE program was established in 2018 by two graduate students, Dr. Arianna Long and Dr. Katy Rodriguez Wimberly, with the support of Prof. Franklin Dollar. The program goals are to improve student success and strengthen community through near peer-mentorship of first-year graduate students. The PACE program's holistic approach focuses on students' mental health and awareness of resources and the "hidden curriculum" of academia Redish (2010). A lack of knowledge surrounding the often unspoken culture of physics can create major barriers for graduate student success, and disproportionately affects those from minoritized racial/ethnic backgrounds, first-generation students, or students from low socioeconomic backgrounds Saunders and Serna (2004); Stephens et al. (2014). In 2021, the PACE program was awarded four years of support from the American Astronomical Society (AAS) funded National Osterbrock Leadership Program (NOLP), which was matched by the UCI Physics Department. This funding was used to support fellowships for graduate student mentors, PACE program leaders, and student travel to AAS meetings to spread awareness of the program.

In this work, we provide an overview of the PACE program from the perspective of the PACE mentors, as prior work on STEM mentorship programs often focuses on the mentee perspective (e.g., Stassun et al. (2010); Thiry et al. (2011); Estrada et al. (2018); Trujillo et al. (2015); Rath et al. (2018)). We describe the mentors' demographics, their reasons for serving in this role, and their perspectives after participating. We end with recommendations for future implementation of the PACE program and for future research to better understand how the PACE program benefits the mentors and mentees who participate.

This study extends prior work on mentoring in physics by focusing on the mentor perspective, a dimension that is rarely examined systematically. Whereas most prior studies document how peer mentoring supports mentee belonging, persistence, or identity development (Thiry et al., 2011; Estrada et al., 2018; Zaniewski & Reinholz, 2016), our work provides a complementary view of how mentors themselves experience and enact these processes within a graduate-level, student-led program at a minority-serving institution. In this way, the present study offers descriptive evidence on program design, mentor demographics, and self-reported experiences rather than causal evidence of retention or participation outcomes. Our goal is to inform future research on how graduate-led mentoring structures may contribute to more inclusive departmental cultures. A distinctive contribution of this work is that the PACE mentor pool includes a substantially higher proportion of women (35–50%) than is typical among physics graduate populations nationally, a field in which women earn only about one-quarter of physics bachelor's degrees (AIP, 2023) and an even smaller proportion of doctoral degrees. This demographic composition is noteworthy given evidence that access to female peer mentors enhances women's sense of belonging, confidence, and persistence in STEM (Dennehy & Dasgupta, 2017). The strong representation and persistence of women mentors observed in PACE is theoretically significant, as prior research shows that women's access to female mentors can enhance their persistence and sense of belonging in STEM. These findings suggest that graduate-student-led programs such as PACE, situated within a minority-serving institution, may exemplify academic program structures that foster conditions supportive of inclusion for women and other historically underrepresented groups in physics.

2.2 Theory: Description of specific components

A core component of PACE is its intentional graduate student-driven structure with minimal faculty support and oversight. Department assistance is provided primarily in the form of logistical support to reserve meeting spaces or order refreshments. The program has been managed from its inception through continuous graduate leadership, led by a small cohort of PACE Leaders (ranging from six to eight in a given year). The PACE Leaders serve a multifaceted role that involves selecting and training the PACE mentors and organizing and facilitating the program meetings. The PACE Leader cohort generally consists of students across a range of years in their graduate career, serving as a mentorship pipeline that ensures the PACE program's continuity and long-term success.

In addition to program management, PACE Leaders serve as advocates for holistic student success, fostering an academic culture that prioritizes student well-being, professional development, and academic excellence. They engage with broader

communities, such as the American Astronomical Society (AAS) and the American Physical Society (APS), to share beneficial practices, highlight the benefits of peer mentoring, and contribute to discussions on graduate student support. Through this structured mentorship framework, PACE Leaders play a crucial role in strengthening the graduate student community by training and empowering the next generation of mentors and leaders.

The two founding components of PACE are Fire Up Fridays (FUF) and Exceleration, both of which are described below. Multi-component mentorship structures in other instances have demonstrated increased benefits for students, particularly for those from historically underrepresented groups Stassun et al. (2010); Rodriguez Wimberly et al. (2023). Both FUF and Exceleration leverage teams of PACE mentors, who we describe in Section III below. In its first year, PACE solicited mentors through a department-wide advertising and recruitment campaign. In later years, mentors were recruited from the cohort who had just completed their first year in the program as PACE mentees. This ensured that mentors were graduate students with PACE experience to guide each new incoming class. Mentors complete an application listing relevant mentorship experiences and describing their reasons for serving as a mentor.

Exceleration Exceleration is a structured one-on-one near-peer mentoring initiative designed to support first-year graduate students. This program strategically pairs incoming students with more senior graduate mentors (Exceleration mentors), providing them with a framework for guidance and support. The primary objective of the program is to facilitate a smooth academic and professional adjustment while fostering a sense of belonging within the department. To achieve this objective, Exceleration incorporates mentorship training, structured meeting recommendations, and evidence-based mentoring practices aligned with the UCI Mentoring Excellence Program. Participants receive guidance on setting appropriate boundaries, maintaining productive conversations, and leveraging department-specific resources. Through regular mentor-mentee interactions, participants gain insights into the departmental culture, expectations, and available resources, ensuring they develop the skills necessary to thrive in their graduate careers.

In later years, mentors were intentionally recruited from the just-completed first-year PACE mentee cohort, establishing a built-in mentee-to-mentor pipeline that refreshes the mentor pool annually. This pipeline, coupled with the program's high proportion of women mentors, expands opportunities for first-year students, especially women, to encounter and later become female mentors.

Fire Up Fridays (FUF) FUF consists of monthly interactive academic and professional development workshops for first-year graduate students. These workshops provide a dedicated space for students to develop essential skills such as time management, goal setting, work-life balance, advisor selection, and funding strategies through a combination of structured activities and informal discussions. The topics in the curriculum were identified based on programming from the National Center for Faculty Development and Diversity as well as annual surveys of department graduate students that capture interest and expertise. Each session incorporates FUF mentors to share their experiences and insights, offering guidance on navigating the challenges of transitioning to graduate school. Additionally, these workshops serve as a platform for first-year students to socialize and build a sense of community with their peers and more senior graduate students in the department. By fostering an inclusive and supportive environment, FUF aims to develop a collaborative academic culture among graduate students.

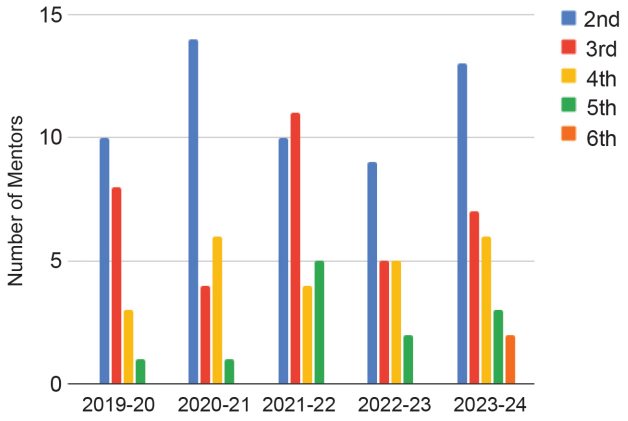

Figure 1. PhD Year for Mentors per Academic Year

2.3 Methods and Data Description

We used a mixed-methods approach to capture mentor demographics, participation, and perspectives. We define mentors as graduate students serving in Exceleration or FUF or mentoring roles. We obtained quantitative demographic data from university institutional data reports. Graduate student PACE Leaders compiled annual survey reports prior to, and at the end of, each year of the program (2019–2023). These reports track mentor and mentee involvement in FUF workshops, Exceleration pairings, and mentor preferences and perspectives related to their involvement in PACE. For this assessment, the primary data collection instruments are the mentor application form administered during the summer, prior to the start of the academic year and the PACE Program and the mentor exit survey which was administered at the end of the academic year.

The mentor application form included demographic applicant questions (name, contact information, year in the PhD program and physics subfield), their prior experience in the PACE program either as a mentor or mentee, and whether they had completed the campus' Mentoring Excellence Program. There were a series of Likert-type items (1 = Does not apply to me, 5 = Very like me) assessing applicants' mentoring and communication skills, familiarity with campus resources, and ability to support student well-being. It also included open-ended items asking "Why do you want to be a mentor?", "What qualities make for a good mentor?", and "What are your biggest concerns in mentorship?". The exit survey included four Likert-type items (1 = Does not apply to me, 5 = Very like me), "Being a PACE mentor had a positive impact on my grad student experience", "I learned something about myself in my time as a mentor", "As a mentor, I feel like I am positively contributing to my department community ", and "I would recommend becoming a PACE mentor to the current PACE mentees". It also included the open ended item, "If a rising second year asked you to explain your experience as a PACE fellow, what would you say? How did this program help you?". Mentors were informed that their responses would not negatively impact their ability to participate in the PACE program, although there is a concern of social desirability bias, with the mentors potentially responding in ways they felt that the program leaders would be most satisfied. The self-reported skills in the application also were not verified independently which brings into question their accuracy.

We conducted an inductive thematic analysis of mentors' open-ended responses describing their motivations for serving in the PACE program in the application form. Two researchers independently reviewed all responses to identify recurring ideas and collaboratively developed a preliminary codebook that captured major thematic categories (e.g., positive contribution, prior

Table 1. Demographics for Mentors and Mentees. First-generation college student status, racial/ethnic minority status, and gender distribution are represented as proportions. Standard deviations are shown in parentheses.

	Mentors				Mentees			
Year	N	1st Gen	Minority	Female	N	1st Gen	Minority	Female
2019-20	25	0	0.36 (0.16)	0.40 (0.10)	34	0.03 (0.03)	0.12 (0.06)	0.44 (0.09)
2020-21	32	0	0.19 (0.07)	0.50 (0.09)	31	0.06 (0.04)	0.19 (0.07)	0.26 (0.08)
2021-22	29	0.03 (0.03)	0.17 (0.07)	0.41 (0.09)	34	0.29 (0.08)	0.21 (0.07)	0.29 (0.08)
2022-23	26	0.23 (0.08)	0.19 (0.08)	0.35 (0.10)	26	0.25 (0.08)	0.11 (0.06)	0.27 (0.09)
2023-24	25	0.22 (0.08)	0.22 (0.08)	0.48 (0.10)	21	0.32 (0.10)	0.05 (0.05)	0.19 (0.09)
2024-25	29	0.23 (0.43)	0.17 (0.25)	0.31 (0.47)	21	0.00 (0.00)	0.14 (0.36)	0.24 (0.44)

mentee experience, knowledge sharing, diversity/equity goals). The coders then jointly refined category definitions through iterative discussion to ensure conceptual clarity and agreement. Each coder subsequently applied the finalized codebook to all responses, and interrater reliability was calculated as percent agreement, yielding 93%. Discrepancies were resolved through consensus.

3 Analyses: Who are PACE mentors?

PACE mentor demographics are noted in Table 1. First-generation college student status ranges from 0–23%, the percentage of students from a racially minoritized background ranges from 17–36%, and females make up 35–50% of the mentor population. In regards to race/ethnicity as well as gender, the mentor pool is similar to or more diverse than the corresponding mentee population (the first year graduate student cohorts in the Physics and Astronomy department) that they are serving.

In terms of their year in the graduate program, we see that mentors are primarily 2nd year and 3rd year graduate students with the numbers dropping as they advance in their graduate education (Figure 1).

Across cohorts, women comprise 35–50 percent of mentors, and mentors show sustained participation (44 percent repeat; mean persistence = 0.56), indicating a stable mentor pool that prominently includes women. Although outcomes such as PACE program retention were not measured, these patterns suggest a departmental environment in which women remain actively engaged in mentoring across years.

At the end of each academic year, PACE mentors completed a brief survey about their experiences in the program. The survey included ten 5-point Likert-type items (1 = Strongly disagree, 5 = Strongly agree) assessing mentors' experiences in the PACE program. Figure 2 presents responses to all ten items. Mean ratings across the ten Likert-type items ranged from 4.06 to 4.88 (SDs = 0.33–0.81), indicating generally high agreement with statements about belonging, peer and faculty support, and comfort within the department. This suggests that these mentors are well positioned to welcome and acclimate incoming students.

During the application process, mentors reported their prior mentoring experience. 18.18% reported participating in some form of formal mentorship training, with 27.29% completing the UCI Mentoring Excellence Program, a five-week certificate program aimed at providing participants with strategies and techniques for effective mentoring, helping them to develop a personalized mentoring philosophy and plan, and teaching them conflict resolution techniques, among other skills. Additionally, 44.00% of PACE mentors were repeat mentors.

The mentor application survey included four 5-point Likert-type self-rating items (1 = Does not apply to me, 5 = Very like me) assessing applicants' mentoring and communication skills, familiarity with campus resources, and ability to support student well-being. Applicants reported their mentoring skills on a 5-point scale (1 = Does not apply to me, 5 = Very like me) during the application process. On average, they rated their mentoring skills at 4.03 (SD = 0.86) and communication/listening skills at 4.41 (SD = 0.77). They assessed their knowledge of campus resources at 3.67 (SD = 0.86) and their ability to mentor diverse student populations at 3.55 (SD = 1.15). These lower ratings for resource knowledge and diverse mentoring skills highlight potential areas for enhancing future PACE mentor training.

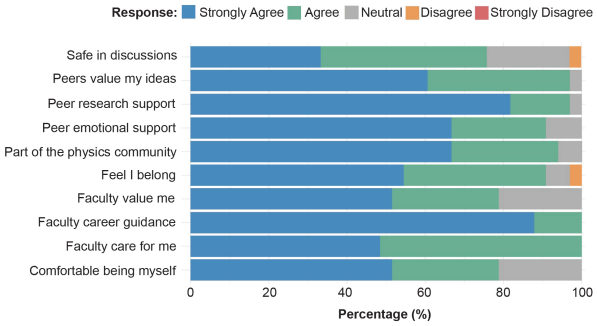

Figure 2. Belonging and Support in Graduate School

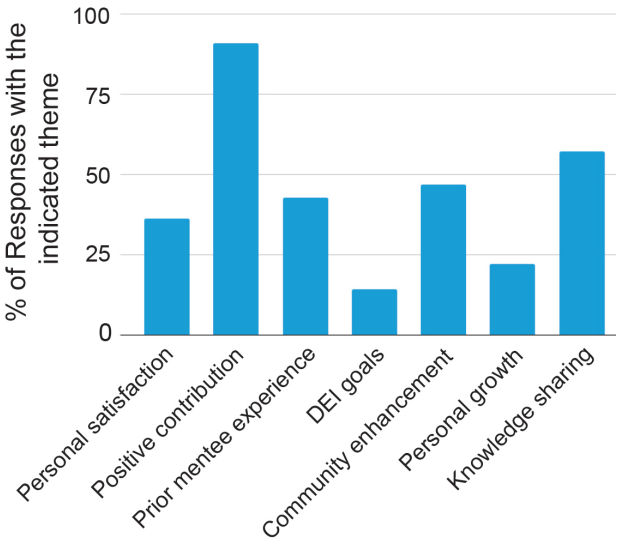

Figure 3. Motivations for Serving as a PACE Mentor

Mentors were also asked to report through an open-ended response item their reasons for wanting to serve as a PACE mentor (Figure 3). While there were a range of responses, the most common were to make a positive contribution to the department and the development of incoming graduate students. Respondents also noted a desire to spread their knowledge, referenced their own positive mentoring experiences, and expressed interest in

Table 2. Number of Years as a PACE Mentor

Years	N	% of Total
1	52	55.9
2	19	20.4
3	11	11.8
4	8	8.6
5	3	3.2

supporting personal and professional networks.

One mentor notes:

> *When I first came to UCI, I was unsure whether I would be able to succeed here. Transitioning to living in Irvine, taking classes again, and finding a research group were challenging, and sometimes I felt lost in the process. Thankfully, my PACE mentor was able to provide helpful guidance and reaffirming support that made my transition much better…After my positive mentee experience, I wanted to pay it forward by becoming a PACE mentor.*
> *(Motivation themes: positive contribution, prior mentee experience, knowledge sharing)*

Positive prior mentee experiences during their first year of graduate school were a common motivation reported by applicants for seeking to become PACE mentors. The next two quotes exemplify the motivation theme related to the desire to increase equity in the program through knowledge sharing—a particularly relevant theme at UC Irvine, a minority-serving institution with a significant population of first-generation and low-income students. As described by one mentor:

> *As a first-generation college student and immigrant, I often lacked access to 'hidden knowledge' and faced additional hurdles throughout my academic journey. Reflecting on these experiences, I'm committed to creating spaces where folks have access to the information they need and feel welcome to ask questions and express themselves freely.*
> *(Motivation themes: positive contribution, DEI goals, knowledge sharing)*

This applicant explains that their lack of prior knowledge concerning the culture of academia negatively impacted their success and expresses a desire to ensure that others who may be disadvantaged in their program do not face the same challenges. Another applicant shared:

> *I really think mentoring in return is one of the best things you can do to aid equity in physics—so much of this field and this degree is more manageable if you know the ropes and have access to people who can tell you about their experiences…I've struggled a lot in this program and have been actively keeping track of the things that I wish I had known.*
> *(Motivation themes: DEI goals, positive contribution, knowledge sharing)*

This applicant indicates a strong desire to share their knowledge to help students succeed in the program, specifically to increase equity.

At the end of the academic year, PACE mentors are surveyed on their experience in the program. Mentors were asked to respond to the statements: "Being a PACE mentor had a positive impact on my graduate experience", "As a mentor, I feel like I am positively contributing to my departmental community", "I learned something about myself in my time as a mentor", and "I would recommend serving as a PACE mentor to the current PACE mentees". Responses to these items were highly positive, averaging (out of 5): 4.17 (SD = 0.87), 4.08 (SD = 0.93), 3.91 (SD = 0.93), and 4.21 (SD = 0.88), respectively.

Related to the interest in serving as a PACE mentor, many of the mentors participated in the program for more than one year (Table 2), with the mean number of years served as a PACE mentor being 1.96 years.

This figure underrepresents the interest in serving as a mentor in multiple years, as many of the recent PACE mentors are still early in their graduate career and have the potential to continue serving as mentors for years to come. To account for this, we calculated the mean persistence rate, which captures whether a mentor served in this role every year that they could. A persistence rate of 1 means that a PACE mentor served in this role every year they had the opportunity to, while a value of 0 signifies that they mentored in one year, but not in additional years. The persistence rate for the program was 0.56. In other words, on average, mentors participated in this role in 56% of the years they were eligible to be mentors.

4 Discussion of Outcomes and Reflections from PACE Leaders

We found that the mentor pool is equally or more diverse than the first-year cohort and includes a comparatively high proportion of women. While we did not focus on mentee outcomes, the program's mentee-to-mentor pipeline and women's representation among mentors constitute structural conditions that prior research (CITE) links to improved experiences for women mentees.

The strong representation and continued participation of women mentors in PACE reflects an academic program structure consistent with prior research showing that access to female near-peer mentors enhances women's belonging and persistence in STEM Dennehy and Dasgupta (2017). Although we did not assess mentee outcomes directly, this sustained representation suggests that graduate-student-led programs such as PACE, situated within minority-serving institutions, may help create environments that support inclusion for women and other historically underrepresented groups in Physics.

To provide a preliminary perspective on the impact of serving as a PACE Leader, we share informal reports from PACE Leaders, all of whom were former PACE mentors and are co-authors of this manuscript. These reflections offer valuable insights into the potential benefits of leadership roles within the PACE program and align with the program's goals of fostering professional development and community-building.

The PACE Leadership role provides a unique opportunity for graduate students to shape their departmental culture and develop skills applicable to academic and professional settings. PACE Leaders report that their involvement enhanced their leadership and management skills. For instance, they noted that leading the program has prepared themselves for future roles in academia by offering hands-on experience in mentoring, program management, and advocacy for student well-being. Two of the five former PACE Leaders, both women, have obtained competitive postdoctoral fellowships or faculty positions. It is important to note that while these examples illustrate potential long-term benefits, our data are descriptive and do not directly assess professional outcomes. The other three PACE Leaders who more recently graduated have obtained prestigious postdoctoral fellowships at leading research institutions. While these outcomes are not directly attributable to PACE Leadership alone, the leaders report that their experiences in the program contributed to their ability to compete for such opportunities.

These reflections align with the objectives of the National Osterbrock Leadership Program (NOLP) and illustrate how graduate students perceive leadership benefits from their PACE experiences. While such experiences may contribute to later professional opportunities, our data are descriptive and do not directly assess career outcomes. Future research should systematically evaluate the impact of PACE Leadership to validate and expand

on these preliminary insights.

5 Potential Implications and Future Directions

The PACE program has become a key component of the graduate experience within the UCI Physics department. While prior studies have documented the benefits of near-peer mentor programs for college student mentees, both broadly and in STEM fields Pon-Barry et al. (2019); Zaniewski and Reinholz (2016), we explored the PACE program from the mentor perspective. The PACE program provides mentors a unique opportunity to autonomously lead the program with minimal faculty and administrative oversight. We found that the PACE mentor pool was equally or more diverse than the first year graduate cohort, which could contribute to a more positive and welcoming experience for minoritized and female students Kricorian et al. (2020). A large majority of mentors reported a variety of prior mentorship experiences and high quality motivations (in the context of Self-Determination Theory, SDT; Deci and Ryan (2000)) for participating in PACE. For example, mentors reported a desire to create a positive experience for incoming graduate students, to contribute to the diversity of the department, and for their own personal growth. Overall, the PACE mentor role appears to be a positive experience, as demonstrated by mentors participating in 56% of the years that they had the opportunity to do so.

The PACE mentor pool had notably greater (1.5 to 2 times) female representation than the mentee cohort. The gender imbalance in physics and other mathematics-intensive fields has been well-established Ceci et al. (2009) and may reflect, at least in part, low-autonomy teaching practices and mathematics reasoning approaches traditionally expected of students Fennema et al. (1998); Gallagher and De Lisi (1994). Future implementations of the program will consider how to best support and leverage the high interest in mentoring and leadership that the PACE female students demonstrate. We also found that PACE mentors tend to be in their second and third years in graduate school, with more senior students less likely to participate. As a student who is close to completing their PhD would likely have an increasing amount of expertise to share, it is worthwhile to consider how the program can better encourage their participation. For example, the program could provide opportunities for senior students to serve as a PACE mentor instead of a Teaching Assistant. The program could also highlight the value of the PACE mentoring role in preparing for and securing postdoc or faculty jobs.

5.1 Next steps with PACE program

The PACE program has established itself as a successful support structure for incoming physics and astronomy graduate students. The PACE leaders and organizers have recently begun to expand the program to provide structured resources and mentorship beyond the first year. This includes Attitude Thrusters, a series of workshops that address topics relevant to research, fellowship and proposal writing, conference preparation, and other critical aspects of graduate education. Attitude Thrusters sessions are open to graduate students of all levels as well as postdoctoral researchers, fostering an environment of shared learning and professional development. The Attitude Thrusters workshops are intended to enhance students' research skills, promote knowledge exchange, and cultivate a collaborative academic community within the department—all of which align with the PACE applicants' reported motivations for participating in the program (Figure 3). The department has also started a new program, *Nurturing Opportunities to eleVate undergrAduates (NOVA)*, to create graduate-undergraduate mentorship opportunities. NOVA includes workshops on graduate school applications, one-on-one mentorship between graduate students and undergraduates, and guidance on applying to summer research programs and internships.

The PACE program aims to foster an environment of peer mentorship, professional development, and community-building that may create the conditions shown in prior research to support women's and racially minoritized students' success and retention in physics (e.g.Dennehy and Dasgupta (2017). Although outcomes such as retention were not directly measured here, the program's context is within a minority-serving institution and with a high proportion of women mentors, which reflects structures that theory and prior evidence identify as beneficial for equity in STEM.

5.2 Next steps with near-peer mentor research

We recommend that future work leverage self-determination theory (SDT; Deci and Ryan (2000)) to explore the potential impact of the PACE program on mentor and mentee outcomes and to clarify the mechanisms that may contribute to these outcomes. The PACE program, intentionally led by graduate student mentors with minimal oversight, aligns strongly with SDT's framework for facilitating autonomy satisfaction: a basic psychological need that is defined as having a sense of volition, self-endorsement, and acting in alignment with one's values Deci and Ryan (2000). Extensive high-quality (often experimental) SDT research conducted across a wide range of diverse populations demonstrates that autonomy satisfaction increases intrinsic motivation, a type of high-quality motivation that positively relates to persistence, creativity, well-being, and performance Ryan and Deci (2017). We hypothesize that autonomy-satisfied mentors will experience a greater sense of confidence, belonging, and motivational quality, and will be more likely to implement autonomy-supportive mentoring practices to facilitate mentees' autonomy satisfaction. We built this hypothesis on the previously reported mentor results, which indicate that PACE mentors have a high sense of belonging (80% "strongly agree" and "agree" responses to departmental support items) and positive impacts on their graduate experience (M = 4.17, SD = 0.87). While this trend has not been documented specifically for the mentor-mentee relationship, it has been documented for instructors and students Pelletier and Sharp (2008), administrators and faculty McMurran et al. (2024), and employers and employees Foss et al. (2015). Additionally, mentoring may increase mentees' autonomy satisfaction as evidenced by increased performance and confidence Eby et al. (2013), motivation and retention Chun et al. (2012), and sense of belonging, particularly for underrepresented groups Ortiz-Walters and Gilson (2005). We propose for our future work to more directly examine the PACE components, such as the graduate-led Exceleration and Fire up Fridays (FUF), in relation to mentors' autonomy satisfaction, and then to examine whether mentor autonomy satisfaction is positively related to mentee autonomy satisfaction.

A key extension of this work involves applying SDT to address the persistent underrepresentation of women and racially minoritized students in physics. The PACE mentor population, which includes 35–50% women and 17–36% racially minoritized students, is notably more diverse than the institution's first-year graduate cohort (Table 1) as well as the broader physics field in the U.S. National Science Foundation (2023); of Physics (AIP). This diversity, combined with mentors' reported motivations to support incoming students and enhance departmental community (Figure 3), positions PACE as a potential mechanism for facilitating autonomy-supportive and welcoming academic environments. Future work will track mentee-to-mentor transitions

by gender to test whether women mentees disproportionately persist into mentor roles and whether such transitions mediate mentee-reported belonging and motivational quality. The SDT framework can also be used to better understand how PACE can support mentees' autonomy, such as allowing mentees to set personal goals during Exceleration sessions or tailoring FUF workshops to their needs, leading to higher motivational quality and persistence Ryan and Deci (2017), both of which are critical outcomes for minoritized students who face systemic barriers in physics Thiry et al. (2011); Estrada et al. (2018).

6 Declarations

6.1 List of abbreviations

- DEI (Diversity, Equity, and Inclusion)
- FUF (Fire-Up Friday)
- NOVA (Nurturing Opportunities to eleVate undergrAduates)
- PACE (Physics and Astronomy Community Excellence)
- SDT (Self-Determination Theory)

6.2 Ethical Approval (optional)

Not applicable.

6.3 Consent for publication

The study was considered to be an exempt study by the University of California Irvine Institutional Review Board (protocol 7332) and was conducted following all relevant guidelines.

6.4 Competing Interests

The authors declare that they have no competing interests.

6.5 Funding

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6.6 Author's Contributions

M.B.M, S.J., and B.K.S performed the data analysis and methodology. R.R.S., S.U.S., T.S., V.V., H.G., J.R., A.L., M.K.R.W., and F.D. collected data and participated in the design of PACE. All authors contributed to writing the manuscript.

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