

Critical analysis of a physics mentor program

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Peer mentorship offers a promising strategy for promoting diversity, equity, inclusion, and belonging in physics. However, implementing a peer mentorship program in a predominantly white, male environment without critical insights can reinforce harmful narratives about who belongs in this field. Critical Race Theory provides a framework to prevent such harm by centering the experiences of students underrepresented in physics. This paper describes a large peer mentorship program providing academic and psychosocial support to undergraduates enrolled in physics classes at the Massachusetts Institute of Technology (MIT). Mentors were surveyed anonymously to understand their experiences as a function of ethnicity, race, gender, gender identity, and sexual orientation. The survey was designed to test the hypothesis that the mentor program creates a counterspace for marginalized group members where they feel a strong sense of belonging. We find that the mentor program fosters a greater sense of belonging than the mentors' home department. It creates a counterspace for marginalized group members in part by reducing the prevalence of harmful comments, actions, and behaviors within its community of practice. Three results stand out from the quantitative and qualitative analysis of the survey. Black mentors responding to our survey have the strongest sense of belonging in their major, possibly because they access other counterspaces supporting their academic success. Meanwhile, gender minority status, especially being non-binary or transgender, is the strongest predictor of a lack of belonging in our sample, and microaggressions are a key factor. Finally, faculty play a particularly strong role in fostering a sense of belonging or exclusion.

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1. Introduction

Peer tutoring and mentorship are promising means to increase diversity, equity, inclusion, and belonging in physics and other STEM fields.^{1,2,3,4} More advanced students can serve as role models and provide academic and other support including advice about classes, the hidden curriculum, how to find and prepare for research opportunities, and more. Mentors also advance their own teaching and mentoring skills and can gain a greater sense of belonging, self-efficacy, STEM identity, and motivation to persist.^{5,6,7,8}

Peer mentorship can improve the retention and success of STEM students of color and other marginalized groups.^{9,10,11} Achievement and outcome gaps in higher education are due not merely to individual circumstances;¹² structural barriers exist whose resolution requires systemic change focusing on belonging, STEM identity development, academic support, and personal support.¹³

Much recent research has investigated the effects of Learning Assistant (LA) programs¹⁴ on both LAs and their students. The LA model shares some similarities with peer mentorship, though it also differs in important ways. LAs and peer mentors in our program both provide course-specific academic support to their peers and receive similar pedagogical training. However, while LAs are incorporated into the teaching teams of the courses they support and participate in in-class learning activities, mentors are not formally part of a teaching team and interact with their mentees solely outside of class. Though course content is the predominant topic of discussion for many of our mentor-mentee dyads, general academic and career advice or psycho-social support are also important elements of many mentor relationships, and the one-on-one nature of these relationships means that there is notable variation (and personalization) in the topics considered. Students in LA supported classes report that LAs provide forms of support identified in the literature as elements of mentorship, but they often do not consider LAs to be mentors.¹⁵ Nevertheless, Learning Assistant programs provide similar benefits to peer mentorship, such as enhancing LA's disciplinary identity,^{16,17} improving equity of outcomes for students in LA supported classes,¹⁸ and supporting LA's development of metacognitive awareness and motivation.¹⁹

Critical race theory (CRT) provides a framework for analyzing the causes and identifying solutions to the marginalization of people of color and others. CRT posits that racism is endemic, built into existing power

structures, and should not be viewed as a collection of individual actions.²⁰ This implies that addressing inequity in physics requires building new structures which nurture rather than oppress. Another key idea of CRT, the importance of counternarratives centering racially marginalized people, can be realized in the counterspaces created by peer mentorship.²¹ CRT has influenced the design of mentorship programs^{22,23} and has been applied to study the experiences and practices of graduate student mentors of undergraduates²⁴ and the effect of mentorship on racially minoritized faculty members' sense of belonging.²⁵

CRT scholars posit that analysis methods must be critically examined. "QuantCrit" (Quantitative Critical Race Theory) is a framework for applying the insights of CRT to quantitative methods.²⁶ In addition to the principles of CRT, QuantCrit recognizes that categories and numbers are not neutral.²⁷ For example, choices of racial and gender categories are socially constructed to serve institutional goals rather than student needs. Numbers may be used to advance deficit thinking by presuming that conditions not measured, such as previous discrimination, do not matter. In the social sciences and in physics education research, numbers do not speak for themselves and can be given meaning through qualitative methods based on the experiences of people.

This article extends the existing literature by empirically investigating the effects of a peer mentorship program on the sense of belonging of the (primarily undergraduate) mentors in a university-based peer mentorship program through the lens of CRT. We present initial results from a survey-based formative assessment seeking to answer the following research questions:

- What is the impact of the mentor program on mentors of different identities?
- In what ways does the mentor program create a counterspace for marginalized group members?

1.1 Counterspaces

The concept of a counterspace is central to the intent of the MIT Physics Mentor Program and to the following discussion of our survey results. CRT posits that racism is ubiquitous in U.S. society, and hence that spaces (physical or metaphorical) which counter mainstream narratives and provide respite from and solidarity against microaggressions and structural

inequalities are crucial parts of oppressed people's adaptive responses to injustice. A counterspace is not defined merely by the absence of attacks on one's identity but also positively as a place promoting self-enhancement and psychological wellbeing. Case and Hunter²⁸ describe counterspaces as spaces which "promote positive self-concepts among marginalized individuals... through the challenging of deficit-oriented dominant cultural narratives and representations." This challenge, for instance, may take the form of constructing and sharing narratives which center the experiences and aspirations of marginalized people and critique the systems and conditions which oppress them or it may serve as a repository of knowledge to help individuals withstand and confront their oppression. Counterspaces may form organically or be created with explicit intent and may exist within or outside of the formal structure of an institution.^{29,30}

2. MIT Physics Mentor Program

At MIT all undergraduates are required to take two semesters of physics. The MIT physics department has offered an academic peer mentorship program every semester since March 2020. The Physics Mentor Program is offered to help these students, as well as physics majors taking sophomore and junior level subjects, by pairing them as mentees with mentors who are advanced undergraduates or beyond (including graduate students and a few postdoctoral researchers and other staff) proficient with the physics content and who participate in ongoing training in mentorship skills. Mentees meet with their mentor for 40-60 minutes weekly outside of class. Most mentors meet separately with three mentees per week. Mentors and mentees are matched based on their interests and preferences. Mentors commit up to four hours per week (including preparation and reflection time) and are paid a stipend.

Mentees receive academic assistance for a particular course as well as general support and advising and they build relationships with their mentors as whole people with intersecting identities, similar to the critical race mentoring approach of Jain and Solórzano.³¹ In addition to helping mentees learn physics, mentors are prepared to offer help adjusting to MIT; to provide advice on majors, undergraduate research, internships or graduate school; and to refer mentees to additional help as needed. Mentors reflect on their mentoring and teaching experiences in a weekly community of practice meeting with faculty and staff, all of whom are committed to improving their mentoring skills and to learning from one another.

Additionally, first time mentors participate in a semester-long pedagogy class covering cognitive, metacognitive, and affective aspects of learning.

Any student taking the physics classes covered by the program can become a mentee at no cost; and between 15% and 20% of students in the supported classes choose to do so. During its first seven semesters the program served 1,567 mentees of whom 14% are physics majors. The program utilized 265 mentors of whom 22% are physics graduate students, 25% are physics majors, 46% are other undergraduate majors, and the rest are postdocs, staff, or faculty. Most mentors serve more than one semester.

The pedagogy class and community of practice meetings provide a space for mentors to share their insights and experiences with each other. Topics of discussion include: imposter phenomenon, stereotype threat, mental health, identity, belonging, critiques of MIT institutional culture, and Critical Race Theory. The program intentionally serves as a place where students can share experiences counter to the dominant narratives of meritocracy that prevail in academia. As such, the Mentor Program shares characteristics of counterspaces as defined above. However, while the community of mentors is heterogeneous across race, gender, and most other dimensions, the program was conceived and is led by a group of white physics staff and faculty, and our intention for it to be a counterspace does not make it so. The extent to which it succeeds in providing a setting in which minoritized community members feel that they belong is the core question addressed in the remainder of this paper.

3. Mentor Survey Results

A brief anonymous survey was offered to former mentors concerning their experiences of belonging in academic spaces as well as the sources of persistence in their major, degree program, or other academic role. After an Informed Consent section and Demographic questions, the survey included 11 Likert scale items (each with a five-point scale ranging from strongly agree to strongly disagree) and two open-ended questions. The closed-ended questions explore where and by whom mentors feel marginalized and supported, and the open-ended questions give space for respondents to voice their experiences and to tell us what they think is important. The design of the survey was influenced by CRT's assertions that racism (and other forms of oppression) are endemic and that the stories and experiences of oppressed people are essential not only for understanding but also for transforming systems of oppression.

The survey was sent to 260 mentors who had completed at least one prior semester of service; of these, 73% were undergraduates when they served as mentors (of whom about one third were physics majors), 22% were physics graduate students, and 5% were physics postdocs, staff, or faculty. We received 96 responses with 74%, 19%, and 7% in these three groups, respectively.

The demographic questions included ethnicity and race using IPEDS categories with multiple selections; we did not collect or use nationality or citizenship. Gender identity and sexual orientation were also requested as well as first generation to college status. Respondents could also self-declare identities.

For purposes of analysis we grouped together marginalized ethnic and racial categories using the PEER designation (“Person Excluded because of their Ethnicity or Race”) of Asai.³² This includes people identifying as Black or African American, Latinx or Hispanic, and peoples indigenous to the spaces comprising the United States and its territories. By avoiding the commonly used term “underrepresented minority” we strive to avoid the otherwise white-centered framing. We further disaggregate racial and ethnic categories and center the experiences of groups severely underrepresented in STEM in cases where we have enough responses to preserve anonymity.

We use the designation SGM (Sexual and Gender Minorities) for respondents who choose a gender identity other than Man or Woman or a sexual orientation other than Straight. The American Psychological Association notes,³³ “The term ‘minority’ may be considered pejorative in the context of race and ethnicity; however, it is seen as acceptable in the context of sex and gender.” Additionally, we separately analyzed the responses of mentors who identified as transgender or non-binary (NB/T). This is a strict subset of the SGM category, but we have chosen to include it separately in light of recent legal attacks on trans people’s right to exist.

3.1 Quantitative analysis

One Likert-scale item (“CoP/Class”) invited respondents to agree or disagree on a five-point scale with the statement “I felt like I belonged in the Community of Practice meetings and/or Pedagogy Class (if applicable).” Four Likert-scale items asked about respondents’ sense of belonging in two different contexts: the mentor program (Mentors and Instructors) and the mentor’s major, research group, or department (Peers and Senior). The items were reverse-coded to ask about occasions when the

respondent felt a lack of belonging (Table 1) due either to other mentors, the mentor program instructors, or to peers or more senior people in the respondents' major, research group or department. ("Peers" refers to other students in general, not to the category PEER defined above.) For example, the first item in this group was "Sometimes I felt like I did not belong in the mentor program because of the comments, actions, or behaviors of other mentors."

Table 1. Likert Scale Items Related to Inhibitors to Belonging

Mentors	Instructors	Peers	Senior
Sometimes I felt like I did not belong in ...			
the mentor program	the mentor program	my major, research group, or department	my major, research group, or department
because of the comments, actions, or behaviors of ...			
other mentors	the instructors	peers	People more senior than me

For each survey item, responses were compared across different groups of respondents characterized by their demographic information. To simplify the comparison, Likert scale responses were converted to numerical scores with the greatest and least sense of belonging set at 5 and 1, respectively. Figure 1 shows the distributions of survey responses as stacked bar charts for all five survey questions for four groups of respondents (one group per panel). The bars are ordered top to bottom from the greatest (5, blue) to least (1, red) sense of belonging.

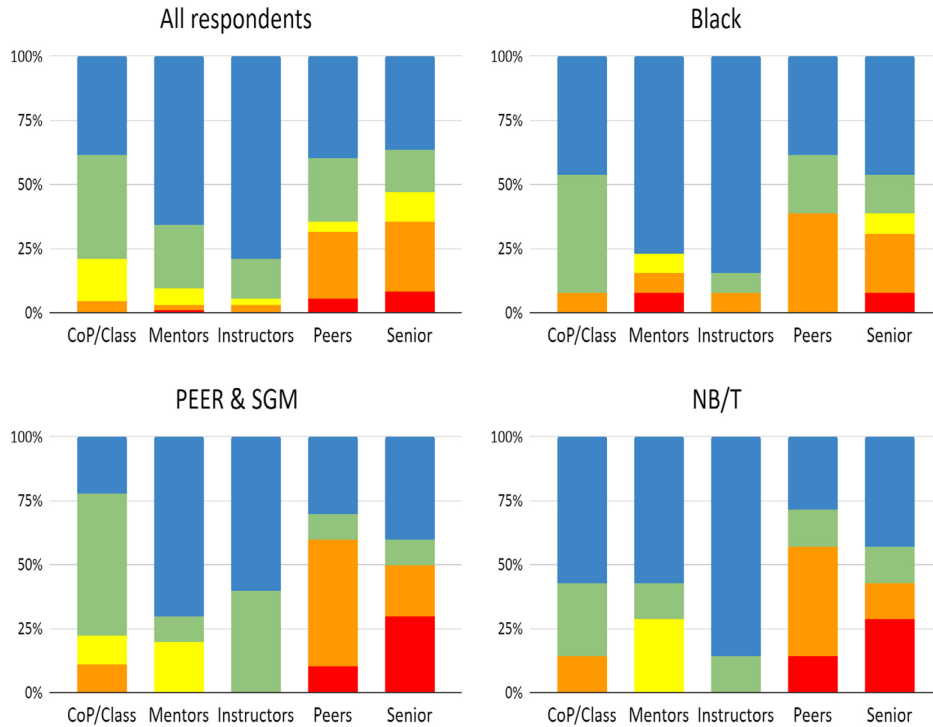


Figure 1: Belonging Survey Responses

Originally we began analysis with the means and medians for each group and survey item following common practice. However, we found that these numbers did not tell the full story in the data. Motivated by QuantCrit, we present distributions to ensure that all respondents' sense of belonging is represented visually in Figure 1. The results are revealing.

First, all groups expressed a strong overall sense of belonging in the mentor program as shown by the large proportion of blue and green bars in the three left columns of each panel in Figure 1 (CoP/Class, Mentors, Instructors). However, a few mentors sometimes felt they did not belong because of the comments, actions, or behaviors of other mentors or the program instructors. CRT reminds us that racism is endemic.

Second, the right two columns in each panel (Peers, Senior) show that belonging is frequently assaulted in the respondents' home department, especially for sexual and gender minorities. In all cases the distribution of Likert responses is bimodal, with one peak corresponding to a strong sense of belonging (blue) and another to exclusion (orange or red). This is true even for the most privileged groups (e.g., straight men, not shown). What

varies most strongly across groups is the fraction of those who do not feel a sense of belonging in their home department.

The differences in reported belonging between the mentor program setting and the respondents' home department are both personally meaningful (e.g., the difference between “strongly” and “somewhat”, e.g. red and orange) and, in most cases, statistically significant. Table 2 shows the differences between Likert mean values and the statistical significance of these differences.

Table 2. Mentor Program as a Counterspace for Belonging

Group	Number	Instructors vs Senior	Mentors vs Peers
SGM	28	1.68 ***	1.29 ***
NB/T	7	1.57	1.29 *
PEER & SGM	10	1.50 *	1.50 **
Latinx	14	1.43 **	1.36 **
PEER	28	1.36 ***	1.14 **
Women	51	1.31 ***	0.98 ***
Men	41	1.02 ***	0.54 **
Black	13	1.00	0.69

Note. The differences in Likert means are given for the items indicated in each column and the demographic groups shown in each row. Asterisks give the statistical significance of nonzero differences with $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***) using the paired t-test.

Several things are striking about these results. First, Black mentors show the least difference of belonging of any marginalized group, although the differences with other groups are not statistically significant. (They are, however, meaningful in the sense defined above.) Black respondents have the strongest sense of belonging in their major of any marginalized group. We speculate that this may be because these mentors have strong support systems within their majors or department, or they have other counterspaces which enhance their sense of belonging and STEM identity such as the MIT

Office of Minority Education. Testing this hypothesis requires further research.

Second, sexual and gender minority status is a stronger indication of exclusion for our mentors than race or ethnicity. About half of the members of the SGM, SGM & PEER, and NB/T groups sometimes feel that they do not belong in their home departments, compared with about one-third for the most privileged groups.

Finally, instructors and senior people in the mentors' home departments play a strong role in fostering a sense of belonging or exclusion. The longest blue bars (strongest belonging) in Figure 1 are for instructors in the mentor program while the longest red bars (strongest exclusion) are for senior people in the major.

QuantCrit reminds us that numbers do not speak for themselves. Yet even by using only quantitative data, by disaggregating we have found significant differences in experience depending on gender and race. Because belonging is a major factor in student persistence and learning,³⁴ our results are significant in revealing barriers to success in STEM that would not be apparent from grades, for example.

3.2 Qualitative analysis

Open-ended responses from the survey ("Please comment on the preceding questions" about belonging, for example) shed light on the quantitative results and help answer our research questions. While overt racism, sexism, homophobia, and transphobia are rare, several mentors reported exclusionary behavior in their major or home department, especially SGM members:

Mentor 13 (SGM): *During my experience at MIT, I took classes where professors told students stuff such as that they "obviously hadn't tried" in pre-reqs and they should go back and take those before "wasting their time" as well as calling students out on their speech patterns.*

Mentor 62 (PEER & SGM): *I experienced countless microaggressions at MIT from peers and instructors, especially faculty, but overall in large group settings I was supported.*

While rare, this also happened in the mentor program setting:

Mentor 38 (NB/T): *While sometimes people would say kind of weirdly microaggressive and out of pocket things in community of practice meetings, it was very uncommon. A lot of it had to do with disbelief about experiences with racism and transphobia... It is important to add that the CoP meetings were still one of the more welcoming spaces on campus as compared to the sheer hostility I would face in my own major. A major where faculty are pretty well-known for constant misgendering and weird constant micro-aggressive comments.*

Although sexual or gender minority status is not often targeted explicitly, exclusionary behaviors such as those described by these mentors are relatively common in physics spaces.³⁵ Moreover, sexual and gender minorities are at high risk for mental health problems exacerbated by gender-based stressors:³⁶

Mentor 14 (SGM): *Elitism among peers really hurt my self-esteem and sense of belonging, especially when I struggled incredibly badly in both mental and academic terms my freshman year.*

One Black mentor described the camaraderie emerging from collaborating with peers, which could account for the stronger sense of belonging compared with other minoritized groups:

Mentor 28 (Black): *Outside of the mentor program and within, there is a type of camaraderie that emerges from everyone tackling the MIT firehose together that makes things feel more bearable. It doesn't feel like anyone is taking shortcuts or has it easier than anyone else, which in turn makes looking at fellow mentors/students pushing through their workload quite inspiring.*

Additional research is needed to determine how widespread this feeling is and what factors or features of the MIT environment support thriving.

The open-ended questions also shed light on how the mentor program creates a counterspace for marginalized group members. The program structure and practices foster a helpful and welcoming environment:

Mentor 58 (Black): *I do feel like I had more a sense of belonging in the mentor program than in my own major as in my own major there sometimes are people more unwilling to help others.*

Mentor 72 (Latina): *The mentor program was one of the few places at MIT that I truly felt I belonged, and this was because of the instructors and the culture of the program.*

4. Conclusions and future work

The peer mentor program studied in this paper creates a space of greater psychological safety and belonging for students of all identities compared with their home departments. The effects are largest for the most marginalized groups. Interestingly, the Black mentors in our program reported a stronger sense of belonging in the major than other minoritized racial groups. Gender minority status, especially being non-binary or transgender, is the strongest predictor of a lack of belonging in our sample. Several mentors refer to microaggressions from peers and faculty. Whether these results are unique to MIT should be explored.

QuantCrit suggests several important directions for further research. We have provided one quantification of belonging and its variation with demographic variables but have not shown that it is in any way optimal. A clear improvement would be to gather more qualitative data, ideally from focus group interviews. Our survey was too brief to reveal much about how the mentor program enhances belonging and the effect this has on persistence. Another direction would be to study belonging in other academic programs as possible counterspaces for minoritized students in STEM. Our results suggest that faculty play an especially important role in fostering a sense of belonging. Further research will support the transformation of traditional learning environments into anti-oppressive ones supporting the success of all students.

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