THE POWER OF PEER MENTORING IN ENABLING A DIVERSE AND INCLUSIVE ENVIRONMENT

in a Chemical Engineering Graduate Program

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In diverse cohorts, students tend to preferentially cluster with others of similar backgrounds.[1] For students from underrepresented backgrounds, this social segregation can lead to isolation and reduced graduation achievement.[2] To counteract this undesirable side effect of increasingly diverse populations in engineering graduate programs, active efforts to increase inclusivity and diverse social connections are needed. We propose peer mentorship as a method of actively encouraging inclusivity in diverse graduate programs.

Peer mentorship is a well-established method of addressing varied relationship and academic challenges in universities.[3] In undergraduate engineering programs, these mentorship programs seek to socially integrate students and improve sense of belonging,[4-6] improve the retention of underrepresented students,[7-0] increase quality of learning,[8,11] and create "living-learning" communities.[12] In graduate STEM programs broadly, peer mentorship is primarily used to develop 1:1 professional relationships among underrepresented individuals.[13-15] Studies have shown that for underrepresented groups in academia, forming interpersonal relationships is a more difficult barrier to overcome than structural barriers such as funding or administrative policies.[16] Further, studies have shown that improving a student's sense of social belonging can improve her or his academic achievement.[2] Thus, as departments look to improve student body diversity, they must also create a space that enables strong interpersonal connections to achieve high retention and success rates of their diverse students. Put another way, departments must create inclusive communities, not just diverse ones.

Here, we present the implementation and results of the first two years of a peer mentor program for first-year doctoral (Ph.D.) students in the chemical engineering graduate program at the University of Michigan (U of M). This program differs from typical peer mentor programs in two ways. First, the program is compulsory for all first-year Ph.D. students, not just those from underrepresented backgrounds or students who self-select into the program. Second, first-year students are assigned to small groups with one peer mentor, who facilitates academic and social activities intended to encourage connection between the mentees. We find that the first cohorts of students to participate in the program show higher degrees of social cohesion and academic achievement than non-participating cohorts who began their Ph.D.s before the department's implementation of the peer mentor program.

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METHODS

Peer Mentor program implementation

Composition of Peer Mentor groups. Each peer mentor group consists of approximately six first-year Ph.D. students ("mentees") to one senior Ph.D. student Peer Mentor. Mentees are assigned by graduate program faculty such that diversity in each group is maximized with respect to gender, race, citizenship, and topical research focus. Based on the composition of the Ph.D. program overall, an average group contains one or two women, one or two non-U.S. citizens or permanent residents, and one or two underrepresented minorities (URMs). These identities are not mutually exclusive—*e.g.*, a female URM student would count both in "women" and "URM." The remainder of individuals in each six-person group are from well-represented groups in U.S.-based engineering graduate programs, *i.e.*, men, U.S. citizens and permanent residents, and non-URMs.

TABLE 1
Key milestones for peer mentor program implementation

June Week 1	Call for mentors & mentor application
June Week 3	Selection of mentors
June Week 3	Assignment of mentees to mentor
June Week 4	Mentor training
September Week 1	Fall semester starts
September Week 1	Introduction of peer mentor program to mentees
December Week 1	Interim evaluation of mentees and mentors
December Week 3	Fall semester ends
January Week 1	Spring semester starts
May Week 3	Mentees take Doctoral Candidacy Exam (DCE)
May Week 3	Comprehensive evaluation of mentees and mentors

TABLE 2
Department demographics and survey respondent populations. Note that survey respondents self-identified demographic information. Respondent populations for a given demographic in some cases exceed those of the official department population.

		Department population	Fall 2016 respondents	Spring 2017 respondents
All Mentored Students (MS)		53	37 (70%)	47 (89%)
Year of participation	*Year 2*	28	19 (68%)	26 (93%)
	Year 1	25	18 (72%)	21 (84%)
Gender	*Male*	33	22 (67%)	29 (88%)
	Female	20	15 (75%)	18 (90%)
U.S. citizens & permanent residents		42	28 (67%)	35 (83%)
Ethnicity	*White*	23	17	21
	Asian	7	7	6
	Black (URM)	4	1	2
	Hispanic (URM)	5	3	3
	Native American (URM)	0	0	0
	Other (URM)	2	0	3
	Not specified	1	0	0
International students		11	9 (82%)	12 (~100%)
Ethnicity	*White*	0	2	2
	Asian	0	6	7
	Black (URM)	0	1	1
	Hispanic (URM)	0	0	1
	Native American (URM)	0	0	0
	Other (URM)	0	0	1
	Not specified	11	0	0

		Department population	Fall 2016 respondents
All Not Mentored Students (NMS)		81	22 (27%)
Year of participation	*Did not participate*	81	22 (27%)
Gender	*Male*	53	14 (26%)
	Female	28	8 (29%)
U.S. citizens & permanent residents		52	17 (33%)
Ethnicity	*White*	31	12
	Asian	7	1
	Black (URM)	5	2
	Hispanic (URM)	4	0
	Native American (URM)	1	0
	Other (URM)	1	2
	Not specified	3	0
International students		29	5 (17%)
Ethnicity	*White*	0	2
	Asian	5	3
	Black (URM)	0	0
	Hispanic (URM)	0	0
	Native American (URM)	0	0
	Other (URM)	0	0
	Not specified	24	0

Selecting and training mentors. Peer mentors are senior Ph.D. students in the chemical engineering program. They are selected based on academic and research performance and prior involvement in the department. The group of six mentors each year is also chosen to represent a diverse cross-section of the department with regards to gender, race, citizenship, and topical research focus. Mentors are compensated with a $3,000 stipend for the academic year. Half is paid directly as a stipend, while the other half is available for academic travel expenses.

Mentors meet as a group biweekly with the faculty advisor for guided discussion (*e.g.*, review of select mentorship literature) and as-needed training. While mentors are not required to participate in additional trainings, they are encouraged to attend bias awareness, mentorship, and professional development workshops offered outside the department. In the third year of the program, we additionally added a lead peer mentor chosen from previous peer mentors to serve as a peer advisor for the next class of mentors.

Mentor group activities. Each mentor group meets approximately once per week for social and/or academic activities. In the Fall semester, these activities focus on developing social bonds between students, providing a diverse study group, and orienting students to graduate coursework. In the Spring semester, activities focus on preparing the students for the Doctoral Candidacy Exam (DCE) all first-year Ph.D. students take in May, which evaluates progress on coursework and a preliminary research product. To ensure that all students can participate in social and academic activities regardless of financial situation, all mentor groups are provided with $600 over the academic year to fund activities. Participation is enforced as part of the grade for a pass/fail seminar course required of all first-year graduate students. In the third year of the program, a peer mentor course was added to the first-year curriculum to formalize participation.

A list of key milestones for program implementation is shown in Table 1.

Assessment

Analysis populations. All demographic data was anonymously self-reported by students. We define"URM" as Hispanic, black/African American, or other, and "Non-URM" as white or Asian. International students are those that indicated citizenship other than the United States, regardless of university attendance. U.S. citizens and permanent residents were analyzed as one group. We refer to our control group of students that did not participate in the program as mentees as "not mentored students" (NMS), while students that have participated in the program are "mentored students" (MS). NMS are students who joined the graduate program before the peer mentor program was implemented, and thus did not have the option to participate in such a mentor program. Of note, mentor program participation was compulsory for all Ph.D. students in cohorts that matriculated in the department after peer mentor program implementation (*i.e.*, participation was compulsory for all MS). MS are further subdivided into "Year 1" and "Year 2." Year 1 students were mentees in academic year (AY) 2015-2016 (N=25). Year 2 students were mentees in AY 2016-2017 (N=28). All demographic populations are detailed in Table 2.

Survey administration. Two surveys were used to evaluate the impact of the peer mentor program. All responses were anonymous and voluntary, and the survey was distributed via email solicitation. To encourage participation in the survey, respondents could opt into a drawing of a $25 gift card. While it is possible that some students may have submitted multiple survey responses, we deem this a negligible risk and did not observe any duplicate gift card drawing entries.

In December 2016 (end of Fall semester), all Chemical Engineering Ph.D. students at U of M (both MS and NMS) were solicited via email to take a department "Social and Academic Activities" survey on behalf of the graduate program. Of 59 completed surveys, 37 MS responded (70% response rate), and 22 NMS responded (27% response rate). In May 2017 (end of Spring semester), the Year 1 (N=26, 93% response rate) and Year 2 (N=21, 84% response rate) cohorts were surveyed again with the intent of establishing an annual program evaluation. Year 2 students were only re-surveyed on social atmosphere questions to avoid duplicative effort. We hypothesize that the lower response rate to the December 2016 survey was due to the timing of survey administration over the winter holidays. Unless otherwise noted, May 2017 data is used for MS and December 2016 data for NMS.

Due to small population sizes for URMs (see Table 2), we will only use the broader "URM" grouping to preserve anonymity when discussing survey responses.

Qualitative data collection. MS and NMS had opportunities to leave qualitative feedback on all surveys administered. Mentors (N=13) provided qualitative feedback via 1:1 exit interviews.

RESULTS

Increased department inclusivity and community

As shown in Figure 1 (next page), we observed an increase in disagreement with the statement "I feel the department community is not inclusive" across MS surveyed populations relative to their NMS counterparts. Specifically, 73% and 50% of URM MS and international MS students, respectively, disagreed with the department not being inclusive compared to 25% and 20% of their NMS counterparts. When looking at the number of students who agreed that the department community was not inclusive, only 17% of international MS agreed compared to 80% of international NMS. We view this increase in perception of department inclusivity as a first and critical step in enabling improved student academic and research performance.

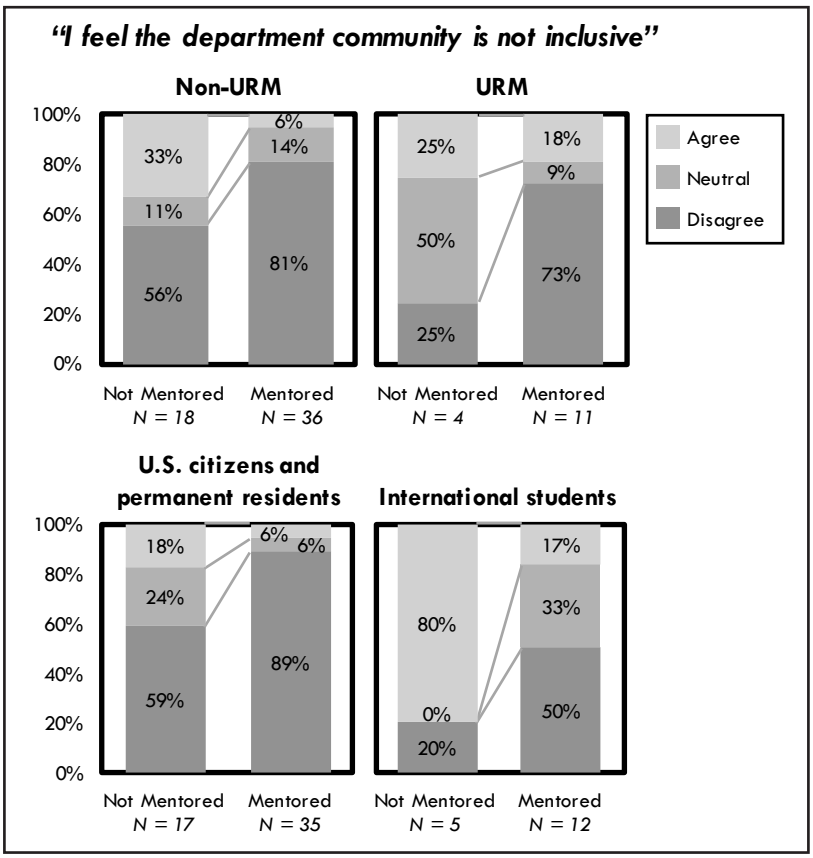

Figure 1. *Assessment of department's inclusivity as perceived by Ph.D. students.*

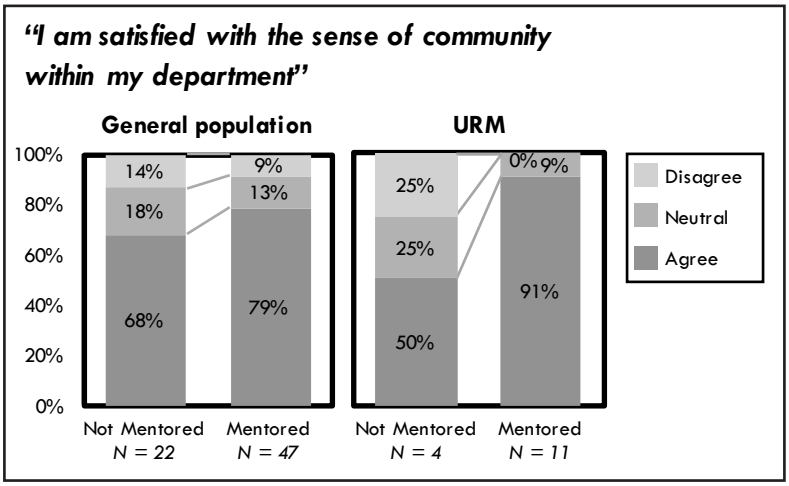

Figure 2. *Assessment of department's sense of community as perceived by Ph.D. students.*

Inclusivity is also a key component of creating community in a diverse population,[1] which we hypothesize will be a key driver to increase retention among minority populations.[2] With peer mentorship, students increase their agreement that they are satisfied with the sense of community in the department from 68% to 79%; for URM students, a jump from 50% to 91% in agreement is observed, as shown in Figure 2.

The peer mentor program provides a framework for diverse students to interact with one another casually, outside of a formal academic setting. We posit that the engineered social interactions inherent to the peer mentor program provide the "activation energy" for students to overcome cultural barriers and engage with students of different backgrounds. Indeed, we see a reduction in perceived cultural barriers fairly equally across populations, as shown in Figure 3.

Strengthened peer social bonds

This increase in community and reduction in cultural barriers can enable stronger social bonds among classmates — a key driver in the sense of belonging, inclusivity, and retention.

As shown in Figure 4, the majority of MS in both Year 1 and Year 2 cohorts indicated that they knew at least two people in their cohort better due to the peer mentor program. We can extrapolate that the peer mentor program has strengthened a median of three relationships per student. Here, students serve as their own "control", as they are asked to compare their current social connections to a hypothetical in which they did not participate in the peer mentor program. Interestingly, while men on average feel they know 2.5 people better due to the peer mentor program, women reported on average knowing 3.7 people better. This is in line with Colvin, et al.,[17] who observed that women experienced greater relationship benefits relative to men with peer mentoring.

While U.S. students saw little change in the number of colleagues they knew well before and after the peer mentor program, we see in Figure 5 (page 84) that a majority (67%) of international MS knew at least three people well, versus only 20% of international NMS. These bonds have consequences for students' relationships outside the lab. As shown in Figure 5, 70% of MS spend leisure time with their classmates at least once a week, while only 41% of NMS do so at that frequency. This cannot be explained by arguing that mentored students still see each other in classes, and therefore are more likely to transition to regular social activities. Year 1 students no longer take core chemical engineering classes together in the second year of the Ph.D. curriculum, and yet 67% of these MS reported spending leisure time with their classmates at least once a week while 73% of Year 2 MS (who just finished

their first year and a full load of ChE core classes at the time of the survey) do so.

These personal social bonds are also correlated with an increased frequency of collaboration. In Figure 6 (page 84), we see an increase in the frequency of course collaboration for MS, driven in part by 36% of MS agreeing that collaboration "is/was… essential to [their] completion of assigned coursework" at least once a week, versus 14% of NMS. As mentor groups generally meet once a week, a possible explanation is the study group rhythm established by peer mentors. We also see this phenomenon when asking "how often do/did [students] study or do homework in a group"; while 59% of NMS did so once a week or more, 80% of MS did so at the same frequency. Women in particular increased their frequency of group work with the peer mentor program, as seen on the left-hand side of Figure 6.

Finally, we see in Figure 7 (page 84) that the frequency at which MS interact with colleagues in research settings versus socially are on par with one another. We will observe whether this changes over time.

While some of these outcomes might be attributed to attrition of social bonds with graduate tenure, they do not seem to be due to any inherent differences in the class composition. Of NMS, 82% agreed with the statement "I was/am easily able to make friends with my classmates," while 77% of MS agreed.

In both groups, 68% agreed with the statement "I often attend the department social events." No other significant networking or collaboration programs were underway in the Chemical Engineering Department at the time of this program. Thus, we feel confident asserting that these outcomes can largely be attributed to the peer mentor program. This further supports our hypothesis that the mentoring program provides an activation energy for overcoming barriers to develop social bonds with diverse peers.

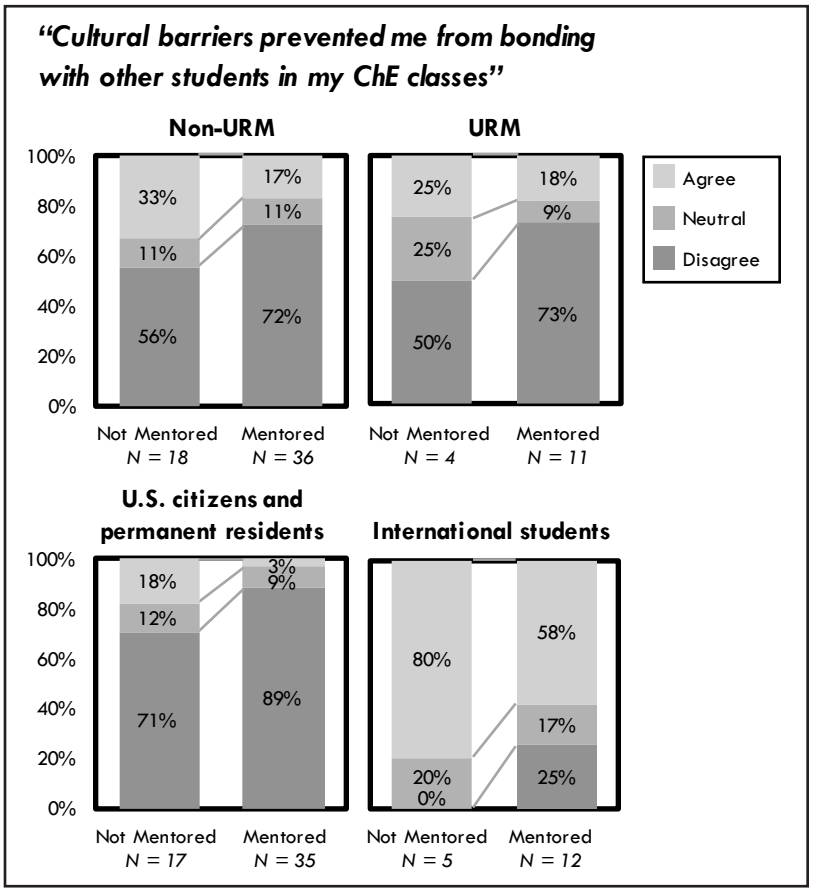

Figure 3. *Students' perception of cultural barriers and their impact on social bonds.*

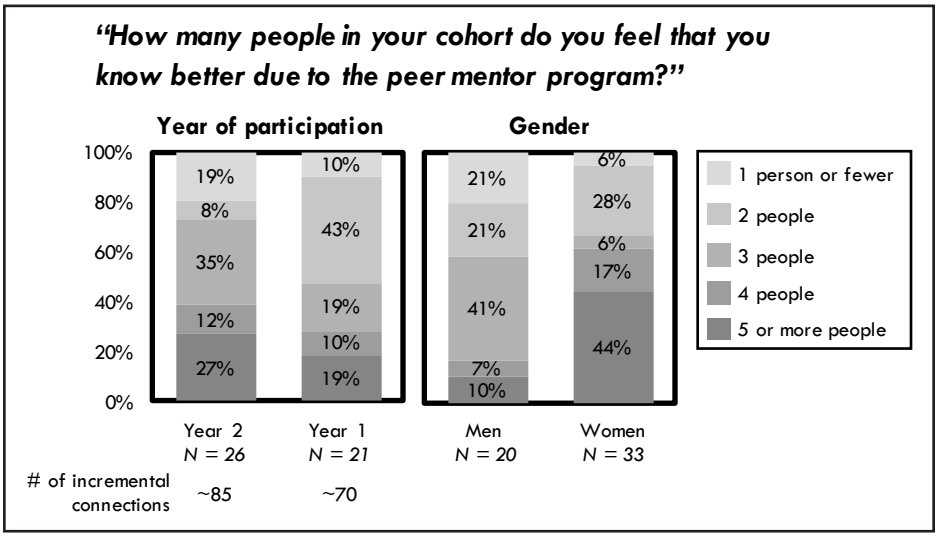

Figure 4. *Mentees' assessment of the expansion of their personal networks due to the peer mentor program.*

Improved coursework and research outcomes

We hypothesized that increasing collaboration in coursework and research would correlate with improved academic outcomes. We measured students' academic outcomes by their scores on the Doctoral Candidacy Exam (DCE) and their grade point average (GPA) in core chemical engineering courses.

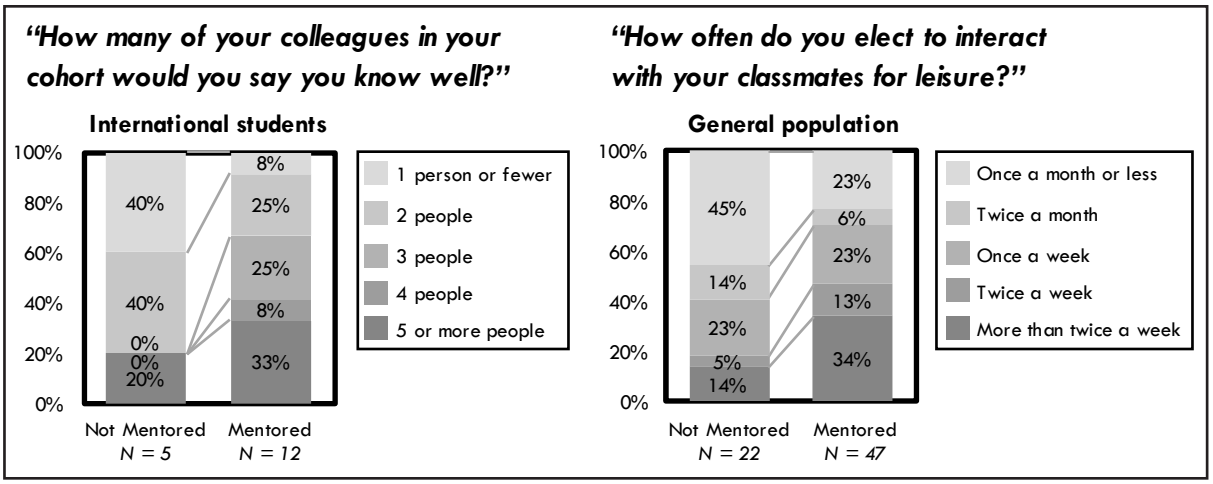

Figure 5. Assessment of the number and strength of social bonds among students.

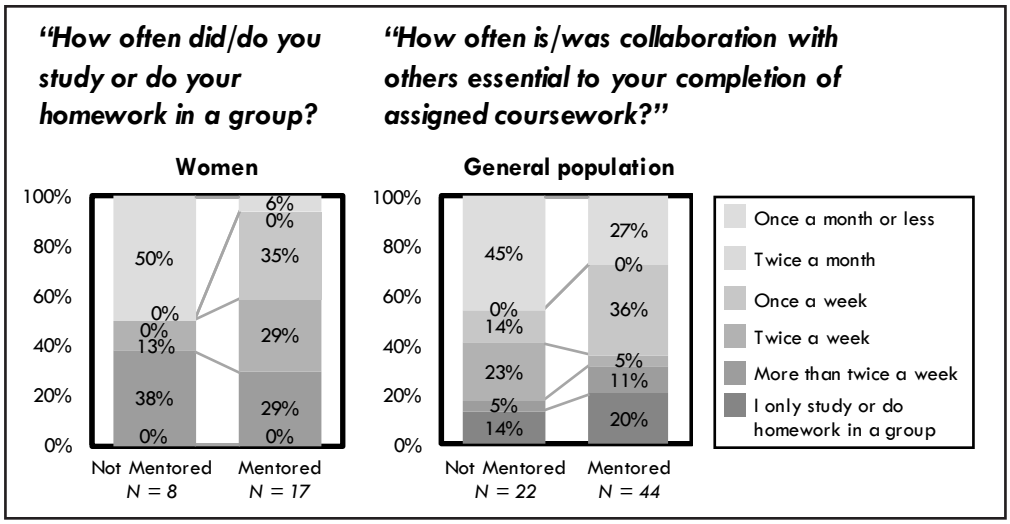

Figure 6. *Assessment of academic collaboration among students.*

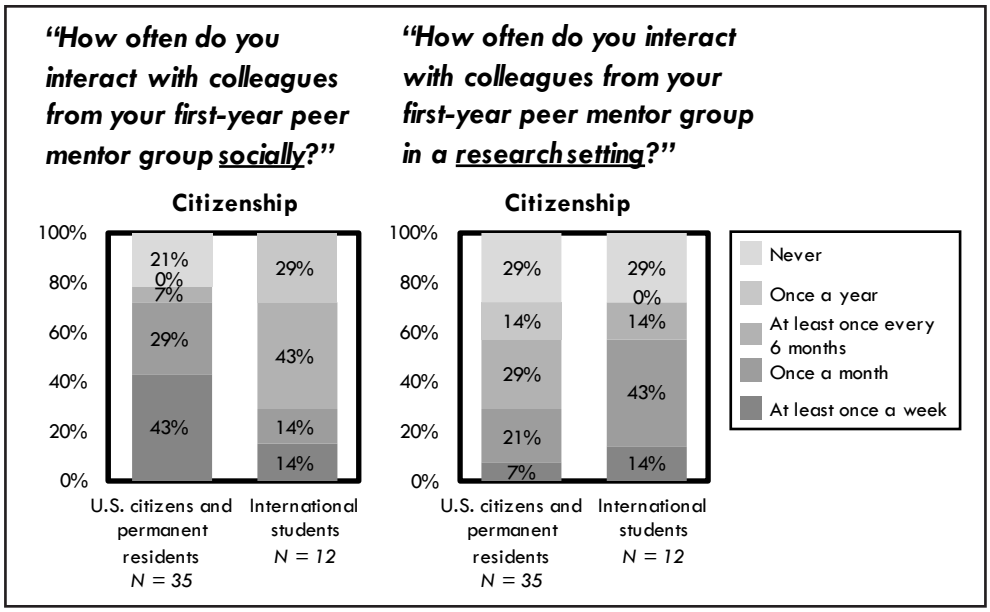

Figure 7. *Mentees' sustained social and research interactions with peer mentor group colleagues.*

The cumulative distributions of students' GPA and DCE are shown in Figures 8A and 8B (8B is on page 86). For U.S. citizens and permanent residents, the distributions are presented based on race (Figure 8A). For international students, distributions are based on gender (Figure 8B). Note that population sample sizes differ from department demographics in Table 2 due to some score-record unavailability.

For U.S. citizens and permanent residents, we show in Figure 8A that 0% of Hispanic NMS had a GPA above 3.4, while 80% of Hispanic MS had a GPA above 3.4. Additionally, the average GPA of Hispanic students increased from 3.15 to 3.64 with the implementation of the peer mentor program.

For international students, we observe in Figure 8B that the percentage of male international students with a GPA greater than 3.7 increased from 44% to 89% as the peer mentor program was implemented; no significant change was seen for women.

Male students' core GPA increased from 3.65 to 3.72 after peer mentor program implementation, while female students' GPA remained constant. This increase cannot be attributed to

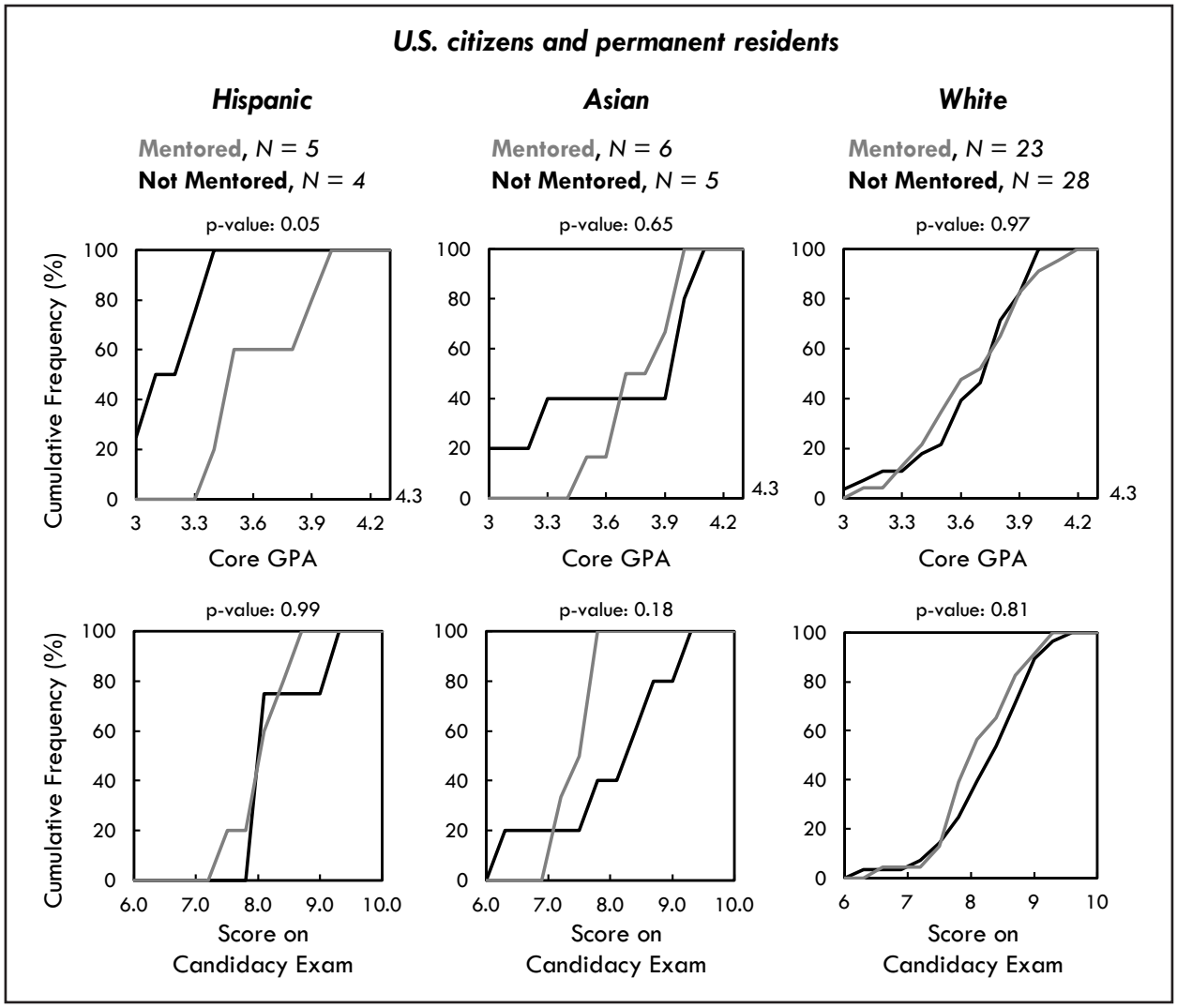

Figure 8A. *Cumulative distribution of grade point average (GPA) and score on the Doctoral Candidacy Exam (DCE) for U.S. citizens and permanent residents based on their race. In these plots of cumulative distribution, as the MS line diverges from the NMS line, the likelihood of the peer mentoring program having had an impact on the students increases. The likelihood is measured in terms of p-value using Komolgorov-Smirnov statistical test.*

any changes in the academic quality of the incoming cohort, as average undergrad GPA of incoming students remained unchanged. However, the observed improved academic performance of MS may in part be explained by increased collaboration; while only 20% of international NMS "[studied] or do… homework in a group" at least once a week, 63% of international MS did so.

Additionally, the peer mentor program had a strong positive impact on student preparation for the DCE. When surveyed, 78% of Year 1 and 96% of Year 2 students agreed that peer mentor group meetings helped them prepare for their DCE. Additionally, the percentage of students who achieved the requirements for candidacy increased from 85% to 93% after the peer mentor program was implemented in the department.

Development of experienced mentors

Peer mentors also benefit from their role in the program, both professionally and personally. Multiple mentors reported that their experience helped them decide on the type of career they will pursue after their graduate studies, *e.g.*:

- *"Being a mentor showed me the educational impact I can have [in] an individual's and group's educational experiences; these experiences have reassured my desire to pursue a career in academia."*

Mentors also reported that their experience was unique among leadership career preparation opportunities available to graduate students, particularly with regards to the diversity of the groups.

- *"The role of Peer Mentor was my first leadership role*

where people truly depended on me for guidance, which made me conscious of the accountability I have for my words, advice, and behavior."

- *"Learning how to understand what motivates graduate students from diverse backgrounds gave me a tool I will use throughout my future career in academia."*
- *"Being a mentor provided me with learning opportunities that I would likely not have had in any other program within the University."*

Multiple mentors noted that their experience fostering inclusivity in diverse groups had inspired them to establish similar programs at their future institutions as academics, *e.g.*:

- *"I will definitely push to have a similar program in any department where I end up. It takes the luck out of finding an older graduate student to help you get on your feet in your first year, and I've seen how much of an impact that can have."*

The primary issue mentors struggled with was a desire for formal training on mentorship, accompanied by the realization that mentorship meant more than just leading a group:

- *"I am more of a quiet leader, which works well for individual relationships but made it difficult for me to connect with my group early on. While this improved over the course of the year, I wondered if I could have been better prepared for this role from the start."*

The aforementioned lead peer mentor role was established in response to this feedback.

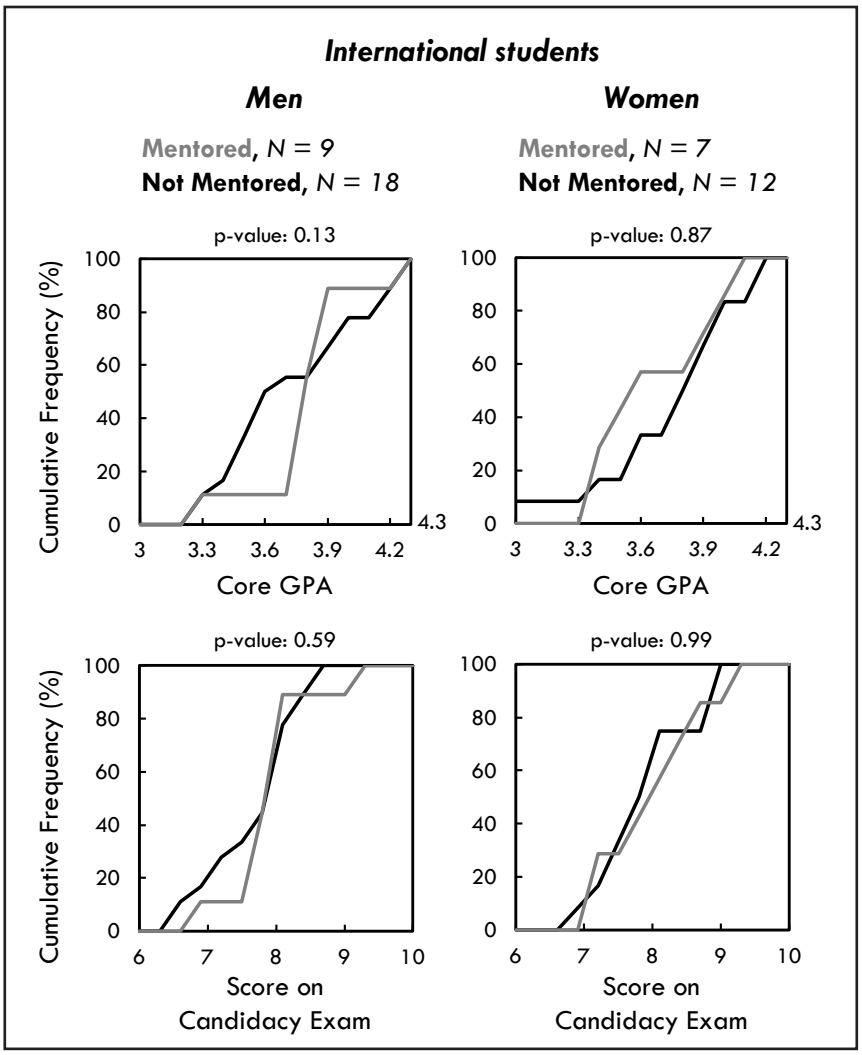

Figure 8B. *Cumulative distribution of grade point average (GPA) and score on the Doctoral Candidacy Exam (DCE) for international students based on their gender. In these plots of cumulative distribution, as the MS line diverges from the NMS line, the likelihood of the peer mentoring program having had an impact on the students increases. The likelihood is measured in terms of p-value using Komolgorov-Smirnov statistical test.*

Sustaining outcomes and measuring future success

The program's sustained impact will be measured annually on the metrics above. Ultimately, we hope that improved social bonds will translate into research and professional bonds between students. We can currently measure these through forward-looking questions, as shown in Figure 9. We observe that a majority of students (74%) who have participated in the peer mentor program agree that they are likely to "seek out… a colleague from [their] peer mentor group to give [them] feedback on a future research activity." Importantly, both international students and URMs agree at a higher rate (92% and 82%, respectively) than the general population.

As we begin the third year of the peer mentor program, we continue to improve the program in response to participant feedback. The lead peer mentor position mentioned previously was implemented to facilitate development of a formal curriculum for the program and for mentor instruction. A shared curriculum (*e.g.*, good research habits, professional development planning) across all mentors has standardized the experience across all mentor groups. This effort is further aided by a new peer mentorship course, which both provides a dedicated time per week for group meetings and a formal means of enforcing participation. Finally, we have increased attention on mentor instruction based on feedback from prior mentors and we are actively planning for mentors to participate in unconscious-bias training before assuming their roles.

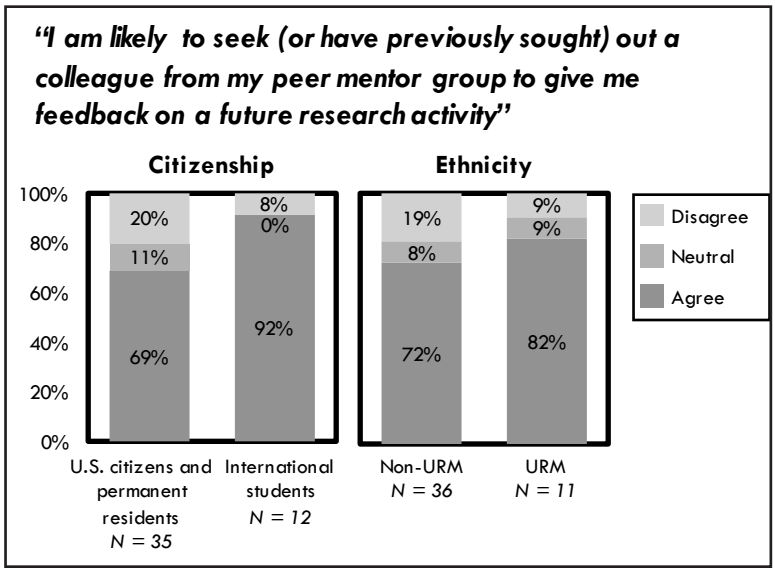

Figure 9. *Mentees' perception of professional collaboration networks created with the peer mentor program.*

Study limitations

At the time of writing, the second academic year of the program had just concluded, and thus it is premature for us to make assessments as to whether the program has achieved its goal of increasing retention. Additionally, small minority populations in engineering graduate programs limit the level of detailed analysis that can be done on populations without compromising student confidentiality. As an example, one hypothesis may be that international students would preferentially cluster by nationality,[1] and that peer mentoring may help students interact socially and academically with students from different countries. However, we could not study this without seriously compromising student confidentiality. Longer timelines, and thus a larger sample of students that have participated in the peer mentoring program, will help establish statistical significance—or not—of the effects we see here on minority population groups. We are encouraged by the results we have seen in the first two years, and will continue to closely monitor student feedback moving forward.

CONCLUSIONS

More than 87% of mentored students would recommend that other departments, both at University of Michigan and elsewhere, implement similar peer mentor programs. We also see evidence of this in practice; there have been at least three separate instances where a U of M engineering graduate student or faculty outside of chemical engineering has mentioned hearing about the peer mentor program to the program director.

As engineering graduate programs continue the process of increasing student diversity, efforts to enable inclusivity must go hand-in-hand to enable an environment in which students of all backgrounds have the tools and connections to be successful. Borrowing from the experience of using peer mentoring in engineering undergraduate programs to enable social inclusivity or academic success,[4,8] here we show that in a graduate chemical engineering program peer mentoring can enable social inclusivity and academic success in parallel. While we hypothesized that the quality and number of social bonds translated into academic performance through increased collaboration among mentees, peer mentors also observed that the inverse was true. In the words of one mentor,

"I had one international student who would work independently and come up with clever solutions. Other students would see that and go to him for help, which led to him being comfortable asking questions in return and actually opened the door for social conversation that had nothing to do with fluid flow."

We observed increases in perceived inclusivity, community, strength of social bonds, and performance on the candidacy exam in the general mentee population. This response brings us to a second critical aspect of our program: all students participate, not just those in minority populations. Consequently, participant enthusiasm across all demographics is critical to the success of the program, and a clearly demonstrated added-value for all students assists with this. Importantly, URMs, international students, and women are not left behind the general population on these metrics, and in many cases see an out-size benefit from the program relative to their majority population counterparts.

How does this one hour a week lead to lasting cultural change, though? In short, we propose that it forces students out of their familiar social circles in a way that allows each student to contribute to the group. As one student commented, "we met weekly for 90 minutes to do [homework] and it was great to work with people I wouldn't normally work with." Another student, commenting on the social benefits of the program, noted that "I don't do very well in large social gatherings, but am a lot more comfortable talking to people in a smaller, continued group of people, and then branching out from there." A key aspect of our peer mentor program is that it does not rely solely on social interactions or academic study groups; both are necessary for students to have an opportunity that plays to their strengths. Students gain hands-on experiences that celebrate diversity as a core part of the academic and social experience—which in turn leads to a more inclusive community and stronger department.

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