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Improving Engineering Students' Outcomes via Multiple Forms of Mentorship

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Abstract

A group of interdisciplinary faculty at Hostos Community College, an institution that serves a largely first-generation student population that is over 90% minority, 69% women, who often live below the poverty line and lack academic role models, has created the NSF-funded Hostos Engineering Academic Talent (HEAT) Scholarship Program designed to increase the number of low-income academically talented students who persevere and graduate with associate and baccalaureate degrees in engineering. HEAT provides its scholars with financial support, a combined mentoring model where scholars work with STEM faculty and more advanced engineering students throughout the year, and the opportunity to participate in mentored research experiences. Student successes include improved GPAs, rates of retention, graduation from 2- and 4-year institutions, and acceptance to STEM graduate programs or entering the workforce as compared to students not participating in HEAT. Surveys of Scholars indicate that combined mentorship is the most important component of HEAT. Thus, HEAT is a model of intervention that serves to expand the STEM pipeline to create a more inclusive and diverse engineering workforce.

Introduction

In response to the nationwide effort to increase the number, caliber, and diversity of the STEM workforce, a group of interdisciplinary faculty at Hostos Community College (HCC) has created the NSF-funded Hostos Engineering Academic Talent (HEAT) Scholarship Program in partnership with The City College of New York's Grove School of Engineering (CCNY's GSoE). HCC, located in the South Bronx neighborhood of New York City, serves a population that is more than 90% minority and 69% women. HEAT was conceived with this national movement in mind and designed to increase the number of low-income, academically talented students who persevere and graduate with associate and baccalaureate degrees in engineering. The primary components of HEAT are the financial support it provides its Scholars, and participation in a combined mentoring experience where students work with faculty and peers during the year. HEAT also exposes students to mentored research, professional development, and career exploration opportunities.

There is a wealth of literature on improving the likelihood of college student success that indicates financial support alone is not enough to help students succeed (Patel & Rudd, 2012), while mentorship in science education contributes positively to the likelihood of student retention and graduation (Loue, 2010). A closer look at the literature on mentoring in and out of academia however, indicates that there continues to be challenges with this type of research (Crisp & Cruz, 2009; Allen et al., 2008; Jacobi, 1991). Among them is a failure to distinguish between different forms of mentoring and to study a combined mentoring model. While most of the research has focused on mentoring of college undergraduates by faculty advisors, the role of mentor can be provided by staff, senior students, peers, friends, and family. To date, no other research has looked at the combined impact of faculty and peer mentoring. Since HEAT once again makes use of both faculty- and student-led mentoring models, this is a unique opportunity to expand our understanding of the impact of two forms of mentoring as a combined approach. HEAT then, with its target population and use of a combined mentoring approach, provided an opportunity to continue to study the impact of this high-impact practice in unique ways.

This is a follow-up to a preliminary study by Rodríguez et al. (2020), that showed the academic performance of the initial cohort of HEAT Scholars was significantly higher than a match-paired group of students with similar majors, class standing, course enrollment, and course history. The current study seeks to expand on Rodríguez et al. (2020) by exploring the impact of combined faculty and student-led mentoring on the academic success of the first three cohorts of 30 HEAT Scholars. It is expected that the combined intervention of faculty and peer mentoring will also show improvements in the GPA, rate of retention, and rate of graduation at a community college as compared to students not participating in the mentorship activities. Towards this end, quantitative and qualitative approaches, consistent with research on mentorship, were employed.

The Study

HEAT Program and Scholars

Table 1 illustrates the number of HEAT Scholars per cohort and their progress over the five-year life of the project. There were three cohorts of 10 Scholars, and each cohort spent, on average two years at HCC and two years at GSoE. HEAT Scholars were low-income academically talented students with demonstrated financial need. They were required to maintain a minimum overall GPA of 3.0, and a minimum College Math and Science GPA of 3.0 with no STEM courses grades below "B-" to remain enrolled in the HEAT Program. The 30 scholars in this study were majoring in Chemical (5), Civil (9), Electrical (8), Environmental (2) and Mechanical (6) Engineering (see bottom of Table 2) as part of the Hostos Joint Dual Engineering Degree Program with The City College of New York's Grove School of Engineering. Out of the 30 HEAT Scholars, 37% were women, 67% were Black or African American, 23% Hispanic, 7% White, and 3% Asian (see top of Table 2).

Table 1.
HEAT Program Design | Progress of HEAT Scholars from HCC to CCNY's GSoE

HEAT Co-hort	Number of Scholars	Yr1	Yr2	Yr3	Yr4	Yr5
1	10	HCC.f	HCC.s	GSoE.j	GSoE.sr	
2	10		HCC.f	HCC.s	GSoE.j	GSoE.sr
3	10			HCC.s	GSoE.j	GSoE.sr
New HEAT Scholars Per Year		10	10	10	0	0
Supported HEAT Scholars Per Year		10	20	30	30	20
		TOTAL 30 HEAT Scholars				

Class standing is indicated by letters f, s, j, and sr, which represent freshman, sophomore, junior and senior, respectively. Each row indicates expected progress and duration of each HEAT cohort.

Table 2.
HEAT Scholars Profile

Characteristics	Number
HEAT Scholars	30
Race / Ethnicity&	
Black or African-American	20
Hispanic	7
White	2
Asian	1
Gender	
Female	11 (37%)
Male	19 (63%)
Expected Major	
A.S./B.E. Chemical Engineering	5
A.S./B.E. Civil Engineering	9
A.S./B.E. Electrical Engineering	8
A.S./B.E. Environmental Engineering	2
A.S./B.E. Mechanical Engineering	6

*Source: Data retrieved from CUNYfirst and Scholars self-reported their demographic information on a technical program survey.

Combined Mentoring

Presented below is an outline of the combined faculty- and peer-mentoring model in the HEAT Program and the evaluation methodology used to assess the combined intervention on HEAT Scholars' academic performance and development (see also Rodríguez et al., 2020).

Faculty Mentoring

Three STEM faculty served as mentors (all Hispanic), which were assigned nine, ten and eleven scholars respectively. Mentorship assignments were determined by a consideration of student and faculty feedback that was collected before the start of the academic year about whom they wish to work with, and ease of scheduling. Scholars who had no preference were randomly assigned to a faculty mentor accordingly. While faculty were not trained on mentorship directly, they were provided guidance on the characteristics of successful mentoring as outlined by Crisp and Cruz (2009), and the empirically validated functions of faculty mentorship identified by Paglis et al. (2006), which include elements of psychosocial, career, academic, and research development. The goal then was for each mentoring session to center upon any of these three main pillars: Academic Issues such as classes, course schedule, school projects/papers/exercises, and study habits; Professional Development considerations that may include job, conference, and grant opportunities, and interview techniques; and Personal Matters such as life experiences shared by student and life experiences shared by the mentor.

The faculty-led mentorship meetings were scheduled biweekly throughout the academic year with sessions that lasted up to 60 minutes. The informally structured meetings initially took place in the faculty's office where they could discuss program, academic, professional, and personal matters. In the early spring during which this study began, the university was forced to close due to the COVID-19 pandemic, at which point the mentoring sessions continued by shifting to telephone and online conference software as meeting spaces.

Peer Mentoring

Fourteen students, selected from the HCC Black Male Initiative (BMI) Together wE Achieve More (TEAM) Program, served as HEAT peer mentors. Each peer mentor was assigned one or two scholars. Mentorship assignments were based on feedback collected from students and peers prior to the academic year, shared research interests and majors, and scheduling. Among the goals of the BMI TEAM program is to train and provide peer mentorship to science and engineering students. All peer mentors completed a peer-mentor training course during the academic year. These mentorship meetings were designed to be held biweekly throughout the academic year but sometimes were changed to monthly meetings depending on the needs and availability of the students. As with the faculty mentorship, peer mentorship was designed to take place in person, but shifted to an online format due to the COVID-19 pandemic.

Evaluation

Consistent with Campbell and Campbell (1997) who explored the effects of faculty mentoring on the academic success of minority students, success was assessed by examining changes in Grade Point Average (GPA), rate of retention, and graduate/transfer outcomes. Additionally, HEAT Scholars' perception of the mentoring experience was also examined. End-of-semester satisfaction surveys were used to assess the degree to which the mentoring influenced students' academic, professional, and personal growth.

Results

HEAT Program Outcomes

A quantitative analysis illustrates the positive effect of combined mentorship on rates of retention, graduation, transfer from two- to four-year institutions and GPA. HEAT started with its first cohort of 10 Scholars in Fall 2019, and as of Fall 2022, ~90% of HEAT Scholars (out of 30) had either remained enrolled, graduated with an associate degree, transferred to 4-year institutions, and/or are working in engineering. Nineteen Scholars had earned their A.S. in Engineering. Nineteen out of 30 HEAT Scholars had earned their A.S. in Engineering degree to date; 15 Scholars matriculated to engineering programs at GSoE; six Scholars matriculated to engineering programs outside of the partnership to institutions that include Cornell University (4), New Mexico Tech (1), and Princeton University (1); and two Scholars have earned their B.E. degree from GSoE and one from Cornell University. Participation in mentored research has been an important component of the program. HEAT scholars have authored two peer reviewed publications as well as received awards for their presentations at the Annual Biomedical Research Conference for Minority Students (ABRCMS) and Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) National Diversity

in STEM Conference. Nearly 80% of HEAT Scholars have participated in undergraduate research experience and/or presented their research in local, regional and/or national conferences, and/or have been selected for summer internships, including those with NASA, BNL, and research-intensive universities including Columbia University, Cornell University. Four of them have been recognized nationally for their outstanding research work at disciplinary meetings such as ABRCMS 2020, 2021 and 2022.

Our most recent survey indicates that 78% of HEAT Scholars found the faculty mentoring (52%), or peer mentoring (26%) were the most valuable aspects of HEAT. Published data collected prior to the onset of the pandemic indicated HEAT Scholars' GPAs were on average significantly higher compared to the match-paired group of students with similar majors, class standing, course enrollment and course history and suggests that combined mentorship has a significant impact on raw outcomes in courses for community college students (Rodríguez et al., 2020).

Feedback from mentors and mentees indicate that the transition of mentoring to an online modality had no impact on the outcomes of the programs. Anecdotally, some responses indicate that the online modality mentorship enhanced communication between mentors and mentees.

Some HEAT Scholar's Reflections via End-of-Semester Surveys regarding faculty mentoring, peer mentoring and HEAT programs are listed below (Rodríguez et al., 2022):

HEAT | Faculty Mentor

- ✓ "Faculty mentorship is the most valuable aspect to me because I was able to meet with my mentor every two weeks. My mentor was not only interested in my grades but also focuses on internships, mental health, and other professional concerns. Faculty mentorship helped me in expanding my horizons. The financial support that the HEAT program offers is also important because it helps us focus more on our classes than working to pay off minor bills. The coursework was also important during the semester. Peer mentorship was also important because the peers have been exposed to most of the struggles we face with our classes, so their advice was of great benefit."
- ✓ "Faculty mentorship is one of the aspects I mostly value about Heat Scholarship. Knowing that you have someone supporting and orienting in the academic level in your side makes me very confident about my success."
- ✓ "The best advice usually comes from the faculty mentor. First of all he knows your field very well, he has an idea about every single you are taking. Faculty mentor is a light that illuminates your pathway to graduation."

HEAT | Peer Mentoring

- ✓ "Peer mentoring is extremely important because I get to guide my fellow scholars out of tough situations I was in"
- ✓ "In order to succeed, peer mentor is important. But, a lot of advice you can get from your peer mentor, you already got it from your faculty mentor. I can say that my peer mentor has been mentored by my faculty mentor, which explains his success. Therefore, because of the faculty mentor assistance, my peer mentor becomes the least valuable."
- ✓ "It would be a game changer to have faculty and peer mentoring sessions on a mandatory schedule that would have detailed information on what should be covered every time. This way the newly recruited students would fully benefit from their time with HEAT and there would be a near uniform formation across the program year after year. This could even be added to the program description and count as training/workshop on students' resume."

HEAT Program

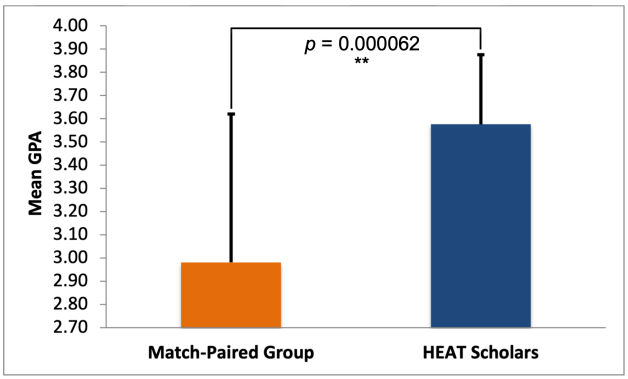
- ✓ "It has been the conner stone to my academic success so far, both financially and otherwise."
- ✓ "Best program ever , we are so grateful to those faculties and professors that fought for us to benefit it and we hope that the program doesn't only limit to hostos community College and City college, we hope the program can keep supporting the same students that graduated and decided to pursue their dreams in case City college doesn't host their STEM major."

Each Cohort of HEAT Scholars have similar cumulative GPAs after at least one academic year of combined mentorship while at HCC. Specifically, Cohort 1, Cohort 2 and Cohort 3 have GPAs of 3.58 ± 0.20, 3.62 ± 0.33,

3.53 ± 0.38, respectively, which are not statistically significant at $p < 0.05$ (one-way ANOVA $F(2,26) = 0.189$, $p = 0.829$). It is worth highlighting that these Scholars' mean GPAs include their core engineering major courses. Thus, maintaining their mean GPAs as a cohort represents success due to the challenging courses they were taking during this period and the obstacles they faced during the transition from in-person to distance learning mode due to COVID-19 pandemic.

Figure 1.

A comparison between HEAT Scholars' and the Match-Paired Group's GPAs as of Fall 2022 semester or for the last semester of Scholars at Hostos after having at least one academic year of combined mentorship. p-value < 0.05 (**) was determined with one-tailed t-test. Error bars represent the standard deviations. Source: HCC Office of Institutional Research.



In comparison to a match-paired group of students with similar majors, class standing, course enrollment and course history (GPA = 2.98 ± 0.64), as seen in Figure 1, the HEAT Scholars' mean GPA after at least one academic year of combined mentorship while at Hostos (GPA = 3.58 ± 0.30) is significantly higher, $F(1,48) = 19.291$, $p = 0.000062$. This outcome extends the findings of Rodríguez et al. (2020) and is further demonstration that combined mentorship might have a significant impact on raw outcomes in courses.

Conclusions

Hostos Community College is among the large group of community colleges nationwide engaged in the effort to increase the number, caliber, and diversity of the STEM workforce to meet the demand for a skilled STEM workforce in the United States. HEAT, with its primary components of financial support to its Scholars and a combined mentoring experience where students work with faculty and peers during the year, has contributed to this effort. The findings reported here extends the work of Rodríguez et al. (2020), which indicate that HEAT's combined mentoring model is the most valuable aspect of the program, as stated by the HEAT Scholars in their own words, and that the combined mentorship model appears to have a direct and positive impact on academic performance and outcomes.

HEAT Scholars' survey responses and the impact on academic performances and outcomes reveal the importance of a systemic mentorship program in higher education where students have an opportunity to explore and reflect upon their academic, professional, and personal journeys (Johnson, 2007). A successful combined faculty- and peer-mentoring model together with a strong extracurricular network support could contribute to enhance students' socio-economic mobility and meet the high demand for a skilled STEM workforce in U.S. HEAT then is a model of intervention that could serve to expand the STEM pipeline to create a more inclusive and diverse engineering workforce, and we expect the HEAT model to be generalizable to other STEM programs at a variety of institutions whose students could benefit from its implementation.

Future Considerations

Given the multifaceted nature of the HEAT Program, including the financial support, the combined mentorship, mentored research, professional development and career exploration opportunities, it remains difficult to isolate the factors that are directly responsible for the outcomes noted in this report. Among the challenges in drawing conclusions are separating the impact of the faculty mentorship from the peer mentorship. While the current design does not allow for speaking for these components in isolation, we believe, based on the feedback from our Scholars, that the two mentorships modality work in a complementary fashion with the faculty mentoring providing career orientation, academic and professional support and the peer mentoring providing the nuances of the coursework from a student's perspective. While it is expected that neither

mentorship modality in isolation would be able to provide the wholistic levels of support seen in the current combined model, further research is required to make this determination.

Similarly, while we believe that the engagement of our HEAT Scholars in undergraduate research has had a positive impact on their academic performance and professional development (Haeger & Fresquez, 2016), there remains a need for further research in this area. Additionally, challenges faced during the program period, such as the dramatic shift in pedagogical practices due to the pandemic, are opportunities for future inquiry.

Finally, it must be acknowledged that the faculty component of the combined mentorship model may need to be reconsidered to become a more institutionally sustainable and transformational practice. As designed, HEAT faculty were compensated for spending approximately 12% of their workload on the mentorship component of the program. While the program data indicated the effectiveness of the approach, as designed it is not likely to be a feasible long-term institutional model. Mentoring models must adopt a more institutionally sustainable approach to the faculty component of the combined mentorship model to be viable in the long-term. One such approach may consider the use of group mentorship, as defined by Kroll (2016) that is a collection of three or more individuals, connected by their social relationship, distinctly gathered for the specific and shared purpose of intentionally challenging and supporting the others to enhance personal growth and professional skills/development of the others. The faculty component of the combined mentorship model then may conduct mentorship meetings with multiple scholars concurrently to use their time more efficiently while maintaining the defining characteristics of mentorship outlined above.

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