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Work In Progress: Multiple Mentor Model for Cross-Institutional Collaboration and Undergraduate Research

Dr. Karen Watkins-Lewis, Morgan State University

Dr. Watkins-Lewis is an Assistant Professor in the Department of Psychology at Morgan State University. She earned her undergraduate degree in Mechanical Engineering and her Doctorate in Developmental Psychology from Howard University. She completed post-doctoral fellowships at the University of Maryland and the University of Virginia. Dr. Lewis's research centers on increasing awareness on the various psychosocial factors that influence academic achievement, retention and leadership in science and engineering among students of color. She is currently in partnership with a number of institutions, including the University of Washington Tacoma. Dr. Lewis is affiliated with the Meyerhoff Scholars Program, where she has lectured incoming cohorts on race, science, and social Justice.

Dr. Heather Dillon, University of Washington

Dr. Heather Dillon is Professor and Chair of Mechanical Engineering at the University of Washington Tacoma. Her research team is working on energy efficiency, renewable energy, fundamental heat transfer, and engineering education. Before joining academia, she worked for the Pacific Northwest National Laboratory (PNNL) as a senior research engineer working on both energy efficiency and renewable energy systems, where she received the US Department of Energy Office of Science Outstanding Mentor Award.

Dr. Rebecca N. Sliger, Tacoma Community College
Bonnie J. Becker
Erica Cline
Cheryl Greengrove
Dr. Petronella A. James, Morgan State University

Dr. Petronella James is a faculty member at Morgan State University in both the Electrical Engineering and Transportation departments. Dr. James has experience in accreditation, program assessment and evaluation process and was recently (2016-2019), the accreditation coordinator for the school of Engineering. Her interest in engineering education emphasizes developing new classroom innovations and assessment techniques and supporting student engagement. Her research interests include broadening participation in STEM, equity and diversity, engineering ethics, online engineering pedagogy, program assessment solutions, transportation planning, transportation impact on quality of life issues, and bicycle access. She is a proud Morgan Alum (2011), having earned a Doctorate in Civil Engineering, with a focus on transportation. Dr. Petronella James earned her Doctor of Engineering (Transportation) and Masters of City & Regional Planning. She completed a B.S. Management Studies, at the University of the West Indies (Mona), Jamaica.

Angela Edes Kitali
Adrienne Scarcella

Work-In-Progress: Multiple Mentor Model for Cross-Institutional Collaboration and Undergraduate Research

Abstract

In this paper we describe our work in progress (WIP) partnership between three academic institutions to enhance multiple-mentor models for undergraduate research students. Our collaboration includes a unique planning effort to thoughtfully increase the number of women/BIPOC students in our programs, and support them in pathways to graduate education. We have designed a scaffolded undergraduate research experience for students that includes traditional summer research experiences, course based research experiences, and a multi-mentor model for graduate pathways. Our preliminary results indicate that the scaffolded research experience can translate to many types of academic institutions, including creating research opportunities with community college students. Our team has developed materials for mentor training, recruiting students, and long-term funding strategies using templates for faculty grants. In our first course offerings students have demonstrated a strong increase in research identity as observed in student journal prompts and survey results.

Introduction

This research project is focused on developing and supporting equitable pathways to STEM graduate education for Women and Black, Latinx, and Indigenous students. Nationally, only 20% of undergraduate engineers and computer scientist degrees are awarded to women, and only 6% are women of color [1]. Black/African American, Hispanic, and Native American students earned 16.1% of bachelor's degrees in 2018. In the faculty ranks for engineering, only 6.4% of these groups are represented, and 15.7% are women [2].

Specific problem: Research experiences for undergraduates are well established as an important tool to support students in moving to graduate programs, in particular for underrepresented students [3]–[5]. Underrepresented students -- including women and Black, Indigenous, and Latinx students -- have reported that mindset and mentoring are important factors in succeeding in STEM fields, but they often lack mentors of the same gender and race [6], [7].

Black, Indigenous, and People of Color (BIPOC) and women faculty in engineering and computer science also shoulder a double burden of service work in mentoring and supporting underrepresented students [8]. This mentoring work is critical to addressing representation in engineering, and needs to be tackled concurrently with student focused interventions.

The focus of this project is addressing these two connected problems using a scaffolded undergraduate research experience that facilitates multiple mentors for students. This type of mentorship program allows the smaller number of women and BIPOC faculty/staff in these institutions to co-mentor a larger number of students and increase pathways to graduate programs. This paper explores our preliminary efforts

including pilot courses structured as traditional course based research experiences (CUREs) and the mentoring course (M-CURE).

A CURE is a research experience that is included in an undergraduate class with the goal of providing an authentic research journey to students [9]. An M-CURE is a type of CURE focused explicitly on mentoring with the goal of helping students progress to graduate programs and publication of results [10].

Research Questions:

- How does scaffolded undergraduate research (CURE and M-CURE) support students in pathways to graduate education in STEM fields?
- How does scaffolded undergraduate research (CURE and M-CURE) facilitate institutional change and reduce burdens on women/BIPOC faculty?

Background

Mentored undergraduate research in science and engineering is well recognized as a high impact practice in higher education [11]. Female and underrepresented students who are mentored in undergraduate research demonstrate higher levels of engagement, academic confidence, and performance [12]. Funded, course-based undergraduate research optimizes inclusion by (1) creating equal access to information on successful career pathways, (2) providing guidelines and expectations for effective interactions between students and mentors, (3) reducing financial constraints for students, and (4) creating mentee selection criteria that minimizes faculty selection bias [13] . Female and undergraduate students of color in STEM are more likely to pursue graduate degrees when they are mentored by faculty in research [14]–[17].

Inclusive, mentored experiences in faculty-based laboratory settings provide opportunities for a broader community of students to increase graduate school readiness, solidify an identity in science, and cultivate new ideas to explore throughout their careers [18]. Laboratory experience can bolster expertise in direct and professional skills, both of which are associated with graduate school success. Direct skills include critical reading, technical writing, and employing the scientific method, including data collection, analysis, and dissemination of findings. Professional skills include a variety of workplace characteristics, such as attention to detail, teamwork, and a tolerance for changing goals and tasks [19]–[21]. A scaffolded approach with research experiences embedded in the curriculum over multiple years (Figure 1) can be particularly powerful, as more experienced undergraduate researchers develop distinct skills and a deeper understanding of the process of research [21].

Within well-constructed laboratories exists a community of teamwork, support, and social connectedness, all of which undergird a positive sense of science identity [22]. Laboratory settings also provide students with the opportunity to assist with the development and investigation of new queries, at any point, from beginning to end. Female and underrepresented students often face biased treatment from faculty and exclusion from other students, both of which can result in reduced access to academic support and lower performance [23]. Mentors can counter, reduce, or intercept such social barriers by developing a broader, more inclusive network of students and faculty. Networks that foster community promote feelings of belongingness among at risk students who otherwise may not feel welcomed or valued. A sense of belongingness in the science community is associated with persistence in STEM [24]–[26].

While mentoring plays a vital role in promoting undergraduate student interests in research and graduate school, it is not without cost to faculty. Time for mentoring is often in competition with time needed to accomplish goals in research, publishing, teaching, and other duties directly tied to the tenure and promotion process [27]. Women and BIPOC scholars dedicated to broadening opportunities for students from underserved communities face a unique challenge. That is, they must find time for mentoring in the face of demands for research productivity, inequitable service loads and expectations to excel in research and teaching with lower levels of peer and institutional support [8]. Research findings on women and BIPOC faculty experience suggest that overwhelming demands place underrepresented faculty at a disadvantage, specifically for lower research productivity and service when compared to White male faculty. Thus, the emotional load can shorten what social scientists refer to as "mental bandwidth [28]", which can tax the attention and focus required for effective undergraduate mentoring. Literature on structured programs suggests that faculty mentoring is better managed when it occurs within the context of an organized initiative supported by each administrative level at the college or university. Successful programs for undergraduate research mentoring and support must be endorsed by departmental and university leadership. Successful programs also create reliable guidelines for faculty mentoring, and offer time and/or compensation as incentives (e.g., course releases, stipends, included in criteria for merit raises [29])

Program Structures

To address these systemic issues in higher education, the research project is designed to create a scaffolded research experience for students as shown in Figure 1. We are working at three partner institutions (two minority serving institutions and one community college) to operationalize undergraduate research experiences, while dismantling systemic racism and institutional barriers. The institutions include University of Washington Tacoma (UWT), Tacoma Community College (TCC) and Morgan State University (MSU).

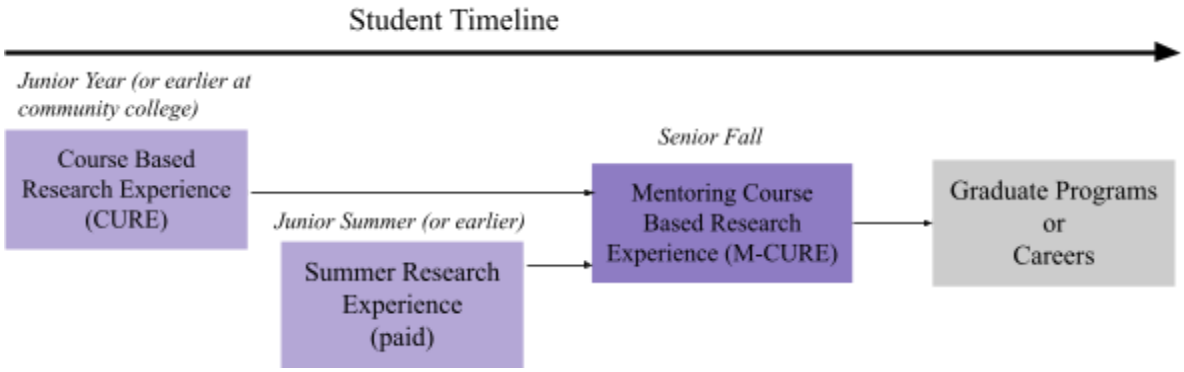

Figure 1. Overview of the scaffolded research experience we designed for our undergraduate students.

At the core of this research project is a mentoring course based undergraduate research experience (M-CURE) designed to allow women/BIPOC faculty to mentor more students efficiently while supporting student progression to graduate programs. By structuring this as a course, the "invisible service" burden for mentoring that BIPOC and women faculty experience becomes part of the

institutional framework, normalized for compensation and teaching load. The M-CURE courses are open to all research students at the partner institution campus, but funding and programmatic support are directed to BIPOC and women students.

Building Community

A few years ago some members of our team met at a conference focused on supporting underrepresented students. We had a few conversations that identified possible ways to collaborate and our team started to form. In January 2022 we were funded with a pilot grant to explore a multiple-mentor model for broadening participation using undergraduate research. Our team met bi-weekly to make progress on our goals, and to build community between our project team members.

In a project focused on collaboration, we believe how our team tackled this project may be as important as our final results. One of our most important goals was to build a sense of community with the hope that our team's partnership would last for many years and support the career development of all our project partners. With this in mind, our methods included several core values based on prior collaborative work [30]:

- *Passion and kindness*. We are all strongly committed to supporting women/BIPOC students in STEM pathways. We are also committed to helping one another flourish in our careers.
- *Authenticity, respect and inclusion*. We try to all bring our authentic selves to our meetings, and we respect the input of others. This means taking time to make space for a lot of conversation and iteration of our ideas. We also take time at the beginning of the meeting for anyone to share what may be happening in their personal lives - an important way to connect with each other across time and space. We also try to be flexible about meeting attendance, understanding that our schedules and lives are complex, and allowing ourselves grace to review the meeting notes asynchronously if needed.
- *Listening and Leveraging*. We try to listen carefully to one another about our tasks. We also try to make sure everyone is contributing in ways that best leverage their unique strengths. An important part of our time this year was getting to know one another and building our trust as a team.

After a year of meeting together these values have been normalized by our team. We are proud of taking this time to work together and build this structure, which we hope will benefit us over a long-term collaboration.

Support Structures

To make requesting external funding easier for undergraduate students, the research team developed a Research Experience for Undergraduates (REU) statement that could be copied and pasted into NSF grants by our colleagues. The idea is that this would allow many of our current and potential collaborators to easily include our work in NSF proposals. We have also advertised this to faculty at the University of Washington in Seattle (the closest research focused R-1 institution) as a preferred mechanism for funding our students. This has the advantage of providing our students with funding, while also supporting the

career of women/BIPOC faculty at minority serving institutions (MSIs). In 2022, we ran a test of this method by including our project as part of the workforce development piece for a United States Department of Transportation grant.

The research team met with our external advisory board several times during the year. We consulted with them about our funding strategies, brainstormed student barriers, discussed our collaboration on M-CURE tasks, and our recruitment efforts. As we hoped, one of our industry advisory board members is interested in building a more formal collaboration with our team. One board member is meeting with us again later this year to discuss how students from other institutions can become involved in our summer research experiences.

The research team developed a 2 hour training with a slide deck for our future research mentors. This work was led by a team member from our Center for Equity and Inclusion at UWT. The training includes topics such as land acknowledgements, tools for connecting mentors with knowledge of local tribes and the history of systemic racism in the United States, micro affirmations, and mentoring best practices. The mentor training will be tested on faculty mentors if additional funding is available in 2023 for our work to continue.

Methods

Our methods include both student surveys and qualitative review of student work and research journals. Due to small sample sizes in our first year of the project, we have limited the results shared to the student surveys to protect the identity of the student participants. We plan to continue data collection in future years and report on the qualitative data in the future.

To assess in part how students experienced our new CURE and M-CURE courses we asked them to complete pre and post surveys. The survey content included basic demographic information, student mindset, and research identity based on the work of Corwin et al. [31]. We shared the surveys with all the students participating in the pilot course offerings. Since we had only 5 students in our pilot CURE course and 2 students in our pilot M-CURE course we do not have statistically significant results, but we have helpful comments from students and a baseline for how we plan to continue data collection over time.

Results

CURE Course Design and Survey

Early in our discussions our team confirmed that one of the largest barriers to research experiences for many of our students is time and funding. Since we did not have grant funding for undergraduate students this year, we decided to implement a small CURE in the summer for credit. This aligns well with our broader thinking about how students experience research during a pathway to graduate programs. This represents the first box on the left in Figure 1.

We designed the summer course to have many of the important ideas of a research project. The pilot course was taken in the summer of 2022 by 5 undergraduate students from one four year institution and the community college. The number of students was small because the mechanical engineering program is relatively new and many students had internships. There were two women and several first generation students in the pilot class. All the students were engineering students, mostly rising juniors and seniors.

We selected wave energy for our research focus since the project did not require any prior knowledge that would create prerequisite barriers. We worked hard to find institutional funding to supplement student fees, particularly for community college students. Key topics in the course included:

- Design process and iteration
- Construction of multiple prototypes
- Literature review
- Reflective research journals (weekly)
- Professional communication and skills (resumes, Linkedin, etc.)
- Poster presentations and storytelling (videos)
- K-12 outreach

Figure 2. Undergraduate students participating in the wave energy summer CURE. Students are testing simple prototype ideas in a fish tank.

At the end of the class, students had created several functional prototypes for small-scale wave energy generation with the goal of reducing erosion and increasing oxygen levels in the water. At the end of the course we asked students to complete a survey based in part on the validated instrument by Corwin et al. [31]. Student survey responses were particularly positive for student research identity experiences. A summary of key findings from the survey is below.

- 100% of the students in the course responded ‘strongly agree’ to the statement, “In this course, I was expected to formulate my own research question or hypothesis to guide an investigation.”
- 100% of the students responded ‘strongly agree’ or ‘agree’ to the statement, "In this course, I had time to revise or repeat work to account for errors or fix problems.”
- 100% of the students responded ‘strongly agree’ or ‘agree’ to the statement, "In this course, I had time to share and compare data with other students.”
- 100% of the students responded ‘strongly agree’ or ‘agree’ to the statement, "In this course, I had time to collect and analyze additional data to address new questions or further test hypotheses that arose during the investigation.”
- 100% of the students responded ‘strongly agree’ or ‘agree’ to the statement, "In this course, I had time to revise drafts of papers or presentations about my investigation based on feedback..”

The student reactions to the course were overwhelmingly positive. A few example comments from the student survey:

- “This has been a very valuable experience. I got to work with the engineering design process hands on and see what it is like to brainstorm designs from just a vague idea/goal. I also got to have enough exposure to literature that I am much more comfortable with reading it, interpreting it, and pulling out the key points. I also got experience with working as a team to accomplish the same goal and saw how everyone's input and research was considered and implemented. It was a very positive team environment that I feel very good about at the end of the course.” - CURE student
- “This research was invaluable for me. I learned so much and found new value in things that I never have before. Such as writing papers based on literature, saw the importance of numerical modeling first hand, and learned how to interact with the broader scientific community on platforms like LinkedIn.” - CURE student

M-CURE Course Design Survey

One important goal for our pilot project was to develop the M-CURE class in a way that was easy for other instructors to replicate. The class was offered at one of the four year institutions in the Fall of 2022 as a pilot for a few students that were interested in graduate programs. This element of the program structure is the third box in Figure 1.

The M-CURE class is designed for any student with prior research experience to learn about graduate programs and publishing. In Fall 2022 both students had worked on prior projects with other researcher mentors in engineering or mathematics. Key topics in the course included:

- Research paper writing (abstracts, literature review, background, methods, results, etc.)
- Graduate school essays and entrance exams
- Finding a graduate school that fits your interests, finances, etc.
- Finding a supportive faculty advisor at graduate school
- Research journals (weekly)
- Professional communication and skills (resumes, Linkedin, etc.)
- Poster presentations and storytelling (videos)
- K-12 outreach

Students were asked to complete a pre and post survey about research identity. This class is still in progress, but student journal comments indicate significant positive shifts in research identity. All the students in the class are planning to apply to graduate school.

One important aspect of the M-CURE pilot course was developing materials for other instructors to replicate this class. We worked as a team to develop a syllabus that could be adopted by other instructors. The syllabus includes recorded video lectures of some of the graduate mentoring topics. This would allow other faculty members to easily adapt them for their classes. In addition, we developed reflective prompts for students to think about weekly and in-class activities to supplement the course development.

Another important aspect of this course is the use of labor based grading. This method was developed by Dr. Asao Inoue [32] as a way to make grading less colonial. We have now tested this method in the

CURE and M-CURE course and found it to be well aligned with the goals of the course, since it provides a structured method for organizing resubmission of student work.

Collaboration Results

One of the great benefits of this planning grant is the strong relationship that has developed between the community college engineering program and the four year institution. Tacoma is the third largest city in the state of Washington, yet until 2020 there was no public university mechanical engineering program in the city. TCC faculty are focused on teaching, rather than research, and do not have the resources to develop significant undergraduate research opportunities. Collaborating with a four year institution has allowed students to participate in research between their sophomore and junior years, and we are exploring ways to bring research into the first and second years. Approximately 46% of TCC's students are first generation college students, so this program may be their first exposure to the idea of research and graduate school.

Discussion and Future Work

Research Question 1: How do CURE and M-CURE structures support students in pathways to graduate education in STEM fields?

The research team offered two pilot courses that we hope will become fixtures of our institutional partnerships. As part of the pilot courses, we were mindful about how to share our materials with other instructors, carefully preparing video lectures, class activities, and rubrics that could be used by other faculty. The team developed assessment surveys and organized our own ideas about how students might be encouraged to participate without additional cost (or needing to sacrifice an internship).

The research team plans to expand the CURE offerings dramatically during the next two academic years at our institutions. The CUREs will be taught primarily as technical electives in engineering or embedded directly in traditional core engineering classes like dynamics and heat transfer. As this occurs, we will continue data collection and plan to share a larger data set in the future. The preliminary survey results are very promising but since the data set is very small we consider this a work in progress.

The research team plans to continue to offer the M-CURE course every fall at one institution with the hope to expand it to other universities as resources permit. This course allows one BIPOC/woman faculty member to mentor up to ~25 students in graduate pathways. The "co-mentorship" model supports the career of women/BIPOC faculty careers and provides needed identity experiences to undergraduate research students.

Research Question 2: How do CURE and M-CURE structures facilitate institutional change and reduce burdens on women/BIPOC faculty?

This research question is still being studied as part of the work in progress nature of this report. We did confirm that layering scaffolded CUREs aligns well with other external grants. Working with several other project teams to build in funds for CUREs and undergraduate research experiences was successful with at least three new collaborations moving forward. Most of these funding efforts were led by faculty colleagues that were not a part of our core research team, so this indicates early success toward institutional change.

Perhaps most importantly, our team developed a shared set of values that allows us to structure our work together. We enjoy working together and plan to build on our first year to continue to dismantle systemic bias in higher education using undergraduate research to support student identity formation and graduate pathways.

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Appendix

[after peer review we plan to include the syllabus developed for the M-CURE course, but it is full of author identity information so has been removed for now]