Undergraduate Research and Mentoring in Separations

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Abstract

A Research Experiences and Mentoring (REM) program was developed to provide summer research and mentoring opportunities to underrepresented minority community college students. It was the goal of the program to introduce underrepresented minority community college students to STEM research opportunities they are not traditionally exposed to and aid in their transfer to the University of Arkansas. Over the course of the 10-week program, several strategies to expose the students to these opportunities and maximize the quality of their experience were implemented. This report details these strategies and the degree to which they both increased the awareness of STEM opportunities and influenced the students to pursue them. A common issue among this demographic of students is low self-confidence in STEM areas, often due to lack of successful peers or role models. REM students were paired with students from a parallel Research Experience for Undergraduates (REU) program to address this issue. Both programs contained strong representation of underrepresented minority groups. All seven REM students were from underrepresented minority groups, including five women. Four out of seven REU students were from underrepresented minority groups. This diverse community fostered the self-confidence of both the REU and REM students. Overall, the program was a strong success based on the outcome of student projects and reports, the feedback from the students, and the continued interest from the NWACC students to transfer to the University of Arkansas. The final component of the REM program is ongoing mentoring for the seven local REM students over the course of the upcoming academic year.

Keywords

Undergraduate research experience, Undergraduate mentoring, Community College, Underrepresented minority students, membrane separations

Introduction

The Ralph E Martin Department of Chemical Engineering at the University of Arkansas has hosted a National Science Foundation Research Experience for Undergraduates (REU) Site for over 4 years. The REU Site is titled ‘From Bench to Market: Engineering Systems for High Efficiency Separations’. The REU Site has been particularly successful in recruiting students from underrepresented minority groups in science and engineering. Specifically, from 2017-2021 (four total summers with no program in 2020 due to the pandemic) the participants were 44% female and 53% from underrepresented racial and/or ethnic groups.

In 2022, not only did the REU Site host 7 undergraduate students from around the country, a parallel National Science Foundation Research Experiences and Mentoring (REM) program hosted 7 students. This REM program focused on transforming our efforts to help undergraduate students from Northwest Arkansas Community College (NWACC) succeed in careers in science and engineering. From our previous REU programs and conversations with NWACC students and faculty, we were able to identify a need to increase the awareness of STEM research opportunities available to community college students, as well as their confidence to pursue them. Further, it was also common among the community college students interested in STEM to have the goal of transferring to the University of Arkansas but lack opportunities to purse meaningful experiences that strengthen their application. To address these needs, the REM program was designed to provide a year-long tailored research and mentoring program for undergraduate community college students from underrepresented groups. It was the goal of the program to demonstrate to these students that STEM research at the University of Arkansas is an opportunity within their capabilities and strengthen their transfer application to the University of Arkansas. To accomplish this, the program was structured to maximize exposure to mentors, colleagues and post-undergraduate STEM environments. It was hypothesized that frequent interactions with faculty, graduate students, and colleagues from the parallel REU program will foster a community within the program that will lead to increased confidence in STEM research among the REU students. It was also hypothesized that experiences in laboratory and professional environments would strengthen the desire of the REM students to transfer to the University of Arkansas and pursue STEM careers. Finally, the program will also increase the visibility of the Membrane Science Engineering and Technology (MAST) Center (a National Science Foundation Industry and University Cooperative Research Center) and careers in science and engineering among undergraduate students at NWACC and the Northwest Arkansas region.

Methods

The program was structured such that the program managers consisted of two faculty members and two graduate students. Faculty members worked to develop the structure of the program, application process, final report, final presentation, and social functions. Graduate students acted as the point of contact between the faculty and students by leading meetings, providing weekly feedback, following up with advisors when necessary, and introducing students to the area. The program had an undergraduate student to graduate student coordinator ratio of 7:1.

Student in the REU and REM programs applied through the REU and REM websites using an internally developed application system. Along with basic personal information, they submit a resume, transcript, personal statement, and two reference letters. The applicants were ranked by the PI and Co-PIs to select participants from underrepresented groups, as defined by the NSF. Factors that were considered in selection included reference letters, career goals, grade point average, academic rank, and degree program. Every effort was made to select cohorts with a diverse range of underrepresented students in STEM fields. Applicants with no prior research experience were be given priority. For the REU program students were selected for around the country while for the REM program students were selected from NWACC. REM students were paired with REU students based on research interests and ongoing projects of faculty members selected to be advisors. Specific projects were decided on between the students and their advisor. It was suggested that the students work on different projects but not required.

Program orientation began with an initial session run by the program managers to introduce the students to each other and their lab partners, outline expectations, and answer questions. The students then attended safety training and a library training session. At the end of the first day the students were introduced to their advisors and given a laboratory tour. Laboratory access was also confirmed at this point. The students were then tasked to work with their advisors and graduate student mentors to begin training and developing their projects throughout the rest of the first week.

Weekly research meetings were held by the graduate student managers and faculty as available to check in with the students. This time was designed to assess the students' weekly progress, provide a forum to practice presenting technical ideas, give feedback, answer questions, and communicate any upcoming events or deadlines. A major component of these meetings was a session for students to develop and present a 'quad' slide summarizing their current progress. Figure 1 provides sample quad slides created by the students. Commonly used in industry and government to provide short updates on ongoing projects, the four quadrants of the quad slide included introduction, methods, results, and conclusions/future work [1]. The introduction quadrant contained information needed by the audience to understand the motivation for the project. This included relevant background information to identify a salient problem and the innovation of the student's project. The methods section outlined the plan to accomplish the previously discussed innovation, including details about necessary data to be collected and equipment to be used. Results presented key data, and conclusions/future work summarized key points and future directions.

At the first meeting, graduate students presented the structure of the quad slide and provided a template for the students. The students also spoke briefly about their advisor, their advisor's field of study, and any basic details about their project they were able to provide. This continued to introduce the students to the others while allowing the program managers to assess the progress of the students. Early assessment of the students' integration into the laboratory was key to maximize the relatively short 10-week period. The students then used the provided template and instructions to create their own quad slide. Subsequent research meetings offered students a forum to present their quad slide and receive feedback from their colleagues and the program managers. Half of the students presented each week, and as such the students were required to provide biweekly updates to their slides. The students practiced their final presentations during this time beginning in week seven.

Funding was provided for the students and program managers to travel to chemical production companies in Longview, TX. Program managers rented vehicles and drove the students to the sites. University of Arkansas alumni were heavily involved in selecting the companies to be visited. Plant tours of Eastman Chemical Company [2] and Invista plastics [3] were organized. The students were given presentations from company leaders discussing the products produced and the processes to produce them. Plant and laboratory tours were then provided by pertinent personnel. The companies were selected to provide views of two very different company styles, one much larger and more commodity based (Eastman) and one much more focused on research and product development (Invista). A reception was held following the tours to give the students additional networking opportunities with the alumni professionals.

The program finished with the students writing their reports and giving their final presentations. Reports varied in length between approximately 5 to 20 pages depending on the types of data

Figure 1. Example of Quad slides

collected. All reports followed a specific template designed to aid the program managers in collecting important information necessary for post reporting requirements. Rough drafts were due one week in advance to both the program managers and the student's advisor. This allowed for sufficient time to give and implement feedback, as well as the program managers to confirm the advisor's involvement in the development of the students' final report. Final presentations were practiced and improved over the final three weeks of the program. 10 minutes per person was allotted to each presentation, including time to answer questions. Students who worked alone aimed for 7-8 minutes where those who worked in pairs targeted 14-16 minutes. A presentation session open to the department and relatives was held on the final day of the program. The final task for the students was to fill out a survey and give feedback on the program to the program managers and the overall REU experience at the University of Arkansas. The survey assessed the students' knowledge of and previous experience with research before and after the program to demonstrate the effect of the program.

At this point the REU program concluded, but a key component of the REM program was to maintain contact with the students and provide ongoing mentorship for at least the next academic year. At the beginning of the program's final week, a meeting was held with the REM students and the program managers to discuss the feedback from the REM students and plan future mentoring activities. Monthly presentations were planned to include speakers from the University of Arkansas, local chemical engineering companies, and remote speakers from larger companies located across the United States. The MAST center network was heavily utilized to coordinate these events.

Results

The two main goals of the REM program were to increase the confidence of underrepresented minority students to pursue STEM opportunities, and to aid NWACC students attempting to transfer to the University of Arkansas. Both the REU and REM programs both contained a majority of students from underrepresented minorities. Four of the seven REU students were underrepresented minorities (all women, one Hispanic). All REM students were underrepresented minorities, including 5 women, 2 Hispanic, and one African American. Faculty advisors were also from underrepresented minorities. Of the eight faculty advisors, three were women and two were Hispanic. One of the graduate student program managers was female as well. Additionally, he partnership with NWACC provided a meaningful opportunity for community college students to progress toward transferring to a STEM major at the University of Arkansas. Of the REM students, two had successfully transferred for the Fall semester following the program, and the rest expressed continued interest.

The balance between faculty and graduate student program managers proved to be effective. The faculty program managers created a well-defined program structure that the graduate student program managers were able to easily communicate to the students.. The balance between the program managers allowed for confidence in what needed to be communicated to the students and for the information to be communicated effectively. This was particularly important for this program given the various traveling obligations that are often common to faculty members around this time of year. Having a contact similar in age also aided the transition to the both the new university and the new location, especially with limited means of transportation. The balance between students and program managers also allowed for the appropriate individual attention as necessary while still managing the needs of the group. The quantity and quality of interactions between the students and the program managers clearly established a sense of community among both the REU and REM students. This was critical to the confidence of the REM students and the speed they were able to integrate themselves into the lab.

The degree to which the students' projects had been defined by the advisors prior to the program varied. It was observed that this and how the students were trained heavily influenced whether the students decided to work with their REU partners or on their own project. The majority of the groups worked with the students to develop projects after their arrival and trained the students together. This resulted in all the REM students working with their REU partners except for one group. One REM and one REU student did not have a partner based on the availability of different groups for a total of four individual projects and five group projects. Of the nine projects, four focused on technologies for water purification, three focused on techniques for protein separations, one investigated cell viability on specialized surface coatings, and one developed engineering education principles regarding the use of hydrogen. Student feedback from the final meeting with the REM students indicated that the partnership helped their confidence and progress in lab as hoped. The students in pairs spoke to the benefits of having a partner, namely that having the person to discuss the project with helped their understanding tremendously. This allowed the project to seem much more manageable and address a common concern the students had at the beginning of the program, regarding the complexity of the project. The students working individually still felt that having a familiar colleague in lab was helpful to acclimating to the environment.

The heavily structured orientation helped aid the chaotic start of the program. A number of administrative issues out of the control of the program managers surfaced pertaining to inputting the students into the university system. This affected many components of orientation including ID cards, parking, and laboratory access. Structuring the orientation and providing time to check in with the students about these tasks allowed for quick discovery of problems and for most of them to be resolved before the end of the first week. Discussing the importance of an efficient start instilled a sense of urgency in the students from the beginning. This was a common observation by the program managers at the first research meeting, as the students seemed to have a good understanding of their projects and enthusiasm to begin as soon as possible. Safety training was completed per the appropriate guidelines, and library training attempted to provide a foundation for the students to learn how to use the resources provided by the library to do so search the literature efficiently. Communicating these topics and discussing how to take information from scientific literature early was very important since most of the students had not had any experience digesting complex scientific literature.

Weekly research meetings were very well received by the students. The first meetings were crucial for the program managers to identify the progress the students had made integrating into the laboratories. Notably, there were two groups of students who had only had one meeting with their advisor over the first week and had not spent any time in laboratories. Knowing this helped the program managers assist the student and their advisor to coordinate training and an efficient as possible start to the project. The first meeting was key to establish the format and content of the quad slide. The program managers spent approximately 30 minutes describing the types of information relevant to each section of the slide, why it was relevant, how it should be collected, and how it should be presented. Feedback from the students specifically mentioned this session as helpful to creating their quad slides and understanding the framing of their projects. The alternating presentation schedule between the REU and REM students was received well by both groups. It was clear that the chance to observe many other presentations in the two-week period between when each student gave their presentation gave the students substantial guidance to improve their presentations. Dramatic improvements were observed both week to week for the students overall as well as with each iteration of the presentation each student gave. This same improvement was observed for the final presentation as well. The final week of presentations clearly incorporated feedback that was given to the presentations of the previous week. Substantially positive feedback was given by the students regarding having the chance to practice before the final presentation. It was evident that the practice session helped refine timing and introduced the students to problems with their presentation they had not yet encountered. This resoundingly positive feedback provided evidence that the frequent interactions and presentation improvement process from these meetings greatly increased the confidence of the REM students.

Student feedback regarding the trip to Longview was also quite positive. Even though the trip was toward the beginning of the program it was still refreshing for the students to have the chance to leave the laboratory. The Eastman plant tour mainly focused on the scale of the plant. The tour consisted of driving around the plant being introduced to different petrochemical unit operations and processes. The time at Invista was spent discussing the business of technology development, many of the well-known consumer products Invista contributed to, and observing laboratory equipment much more closely than was possible at Eastman. The balance between the two catered well to the group. Some students found the scale and environment of Eastman more appealing while others preferred the laboratory environment of Invista. The students did comment that more companies related to their specific backgrounds, such as pharmaceuticals and other applications falling closer to bio or mechanical engineering, would also have been appreciated. Regardless, final meeting feedback showed the exposure to the professional industry environment was a positive influence on the desire of the REM students to enter STEM fields.

Both the students and the program managers were pleased with the outcome of the final presentations and reports. Figure 2 contains a collection of results obtained by the REU and REM students. As previously discussed, the efforts taken to provide the students time to practice and refine both products were initially stressful for the students but ultimately were extremely helpful for developing the final product. Final presentations all fell within the allotted time, though some fell a few minutes short. Slide quality was generally good, and the main ideas and results were generally effectively communicated. As expected, some students had more results than others, though as a whole there were no cases of alarmingly little results. The reports followed this same trend. Some demonstrated better results and understanding of the results than others, but overall, the reports were clear and contained quality results. From the student feedback, writing and formatting these reports was possibly the biggest learning curve for the students. The resulting reports clearly show an initiative to learn and a much better understanding of these principles, which the students will be able to apply to a wide variety of future writing tasks. In fact, this initiative, particularly among the REM students, was one of the most resounding outcomes of the program.

Summary

An REM program was designed to address the need to increase the access of underrepresented minority community college students to meaningful STEM research opportunities. The structure of the program to pair the REM minority community college students with the REU students from other institutions like the University of Arkansas, created a community environment that provided

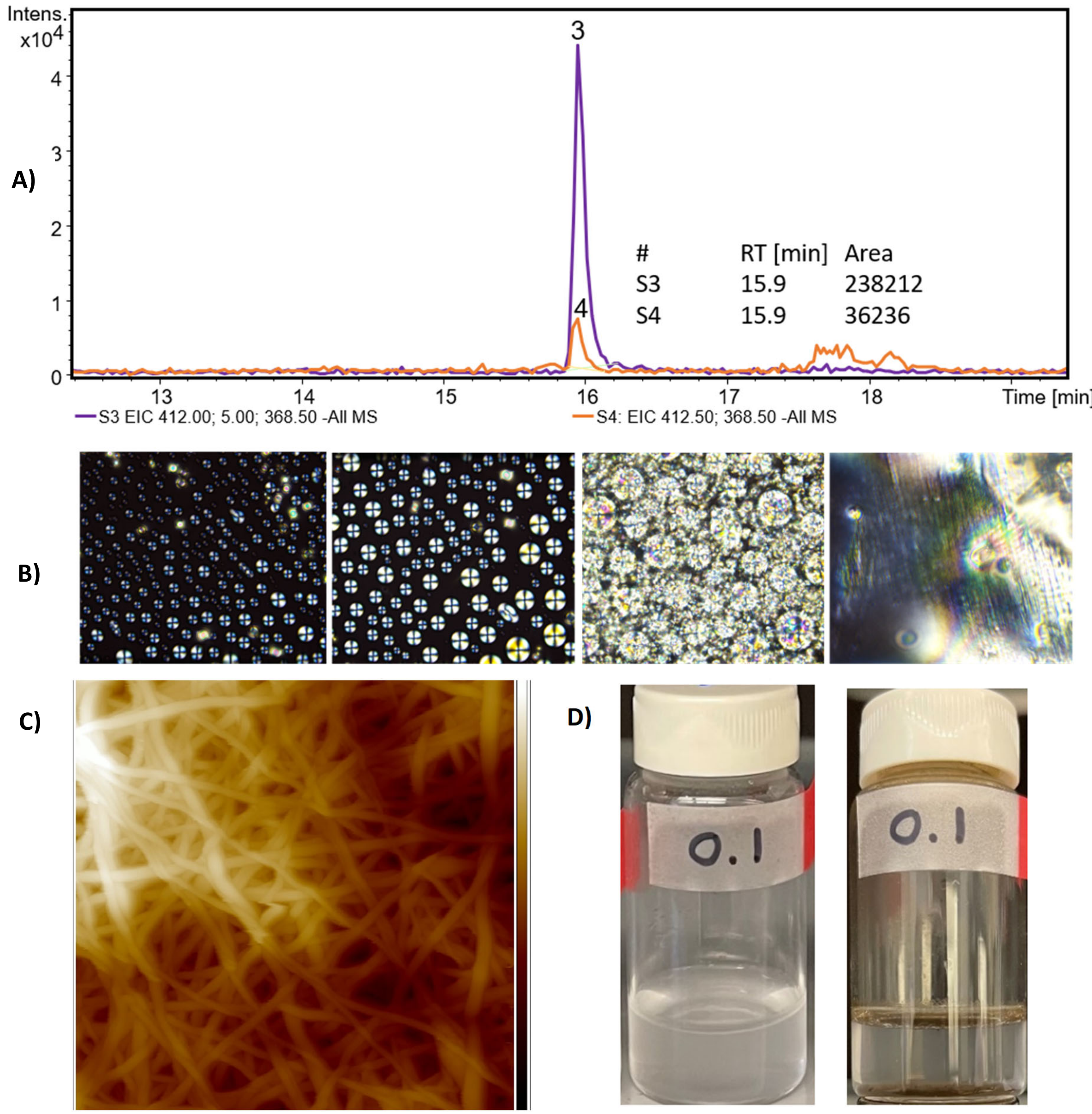

Figure 1. Collection of results obtained by both the REU and REM students. A) shows a liquid chromatography mass spectroscopy output reading the removal of perfluorooctanoic acid from drinking water. B) shows the transition of liquid crystal materials to the nematic phase under cooling. C) shows an atomic force microscopy of an electrospun nanofiber membrane. D) shows the removal of oil contaminants using modified magnetic nanoparticles.

successful examples of STEM research for a demographic that does not typically have them. This environment was crucial to the confidence REM students and the speed for which they were able to join their labs and start their projects. The program's first goal was to provide a quality research experience for these students to demonstrate STEM research is not outside of their capabilities. The impressive progress made by both the REM and REU students speaks to the development of the REM students over the course of the program. It was clear from both the end result and the improvements made between weekly meetings that the confidence of the REM students increased dramatically. In fact, one REM student commented this was her first time giving any STEM presentation, and the presentation received excellent feedback from the program managers. Therefore, the community atmosphere created by weekly meetings and working in pairs with REU students worked as intended to grow the confidence of the REM students, evident based on their final product and associated confidence in it. The second aim of the design of this program was to aid the minority community college students to transfer to the University of Arkansas and pursue careers in STEM. The trip to Longview TX was a successful enrichment activity even though many students planned to go into different fields of study. Students spoke to the value of experiencing the facilities and processes associated with industrial STEM companies and how that positively influenced them to continue to pursue STEM careers at the final meeting of the summer program. REM students are enthusiastic about continued mentorship and have already made progress toward transferring to the University of Arkansas. Results of the post program survey have not been made available at the time of submitting this report but are expected to mirror the overall positive feedback and substantial growth observed. Based on the success of this program, the program managers recommend other institutions running REM programs for minority community college students in parallel with REU programs when possible. In this case, along with high quality interaction and a community environment, this pairing was able to provide minority community college students with a quality summer research program that has increased their confidence and desire to pursue STEM careers in the future. The program managers hope that further efforts nationwide can be made to connect with this demographic of students, because from our experience it was clear that great talent can often go overlooked within this group that traditionally lacks the opportunities offered to students at four-year institutions.

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