TYPE Original Research
PUBLISHED 04 June 2024
DOI 10.3389/feduc.2024.1366063

OPEN ACCESS

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RECEIVED 05 January 2024
ACCEPTED 10 May 2024
PUBLISHED 04 June 2024

CITATION
McKean T, Bates L, Bates G, Wiersma-Mosley JD and Wickramasinghe SR (2024) A multi-tiered mentoring community approach to research experiences for local students from disadvantaged and underrepresented minority backgrounds.
Front. Educ. 9:1366063.
doi: 10.3389/feduc.2024.1366063

A multi-tiered mentoring community approach to research experiences for local students from disadvantaged and underrepresented minority backgrounds

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Introduction: A research and mentoring program was developed to provide local first-generation students, students returning to school after a professional experience, and underrepresented minority students resources and relationships to guide them toward a STEM degree from a four-year university.

Methods: A multi-tiered mentoring community was formed including direct mentoring from graduate students and faculty advisors, peer mentoring among undergraduate students from different colleges and universities, and high school students to increase the accessibility of research opportunities for this demographic. Local students were recruited from Northwest Arkansas Community College and Upward Bound to combine community college and high school students in a novel manner. The programs were integrated whenever possible to emphasize peer mentoring, including mentoring lunches, research meetings, presentation sessions, conference presentations, and professional development mentoring sessions.

Results: On the post-program survey, students indicated the community formed in the program supported their STEM identity development, provided them with quality relationships, and developed skills valuable to completion of a STEM degree. This identity development was further evidenced by the students presenting their work at a conference and obtaining additional research positions after the summer program ended.

Conclusion: The post-program scores and continued efforts of different demographics of students to pursue STEM highlight the versatility of the multi-tiered mentoring community model to serve students from different ages, backgrounds, and demographics.

KEYWORDS

research experiences, community college, underrepresented minority, high school, research, mentoring, research identity

1 Introduction

Most commonly, students who obtain four-year degrees in STEM are White cisgender men who often have access to others with experiences and resources that offer guidance throughout the process. Disadvantaged students with complex circumstances that fall outside of this demographic as an Underrepresented Minority (URM), first-generation college student, or student returning to school after pursuing a previous professional experience do not obtain four-year STEM degrees as often as others (Kingsford et al., 2022). The National Science Foundation (NSF) defines URM groups as "individuals of races or ethnicities whose representation in STEM employment and [Science and Engineering] education is smaller than their representation in the U.S. population. This includes Black students or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives" (National Science Foundation, 2023). First-generation college students are defined as students without a parent who has obtained a bachelor's degree and returning students are defined as students who are currently pursuing a degree after having spent a year or more away from school. It has been estimated previously that male and female URM students are 64 and 75% as likely to obtain a STEM degree, respectively (Hatfield et al., 2022). First generation students have been found to be almost half as likely to complete a STEM degree and almost twice as likely to drop out of school when compared to their continuing-generation counterparts (Bettencourt et al., 2020).

It is commonly accepted that STEM degrees lead to advantages in wages and job opportunities and that diverse environments lead to innovation and collaboration (Dika and D'Amico, 2015; Morgan et al., 2021). Therefore, there is great motivation to address the disparity between URM, first-generation, and returning students that receive degrees to better serve these communities in general. Further examining this disparity reveals this underrepresentation can be attributed to exclusionary constructs present within STEM. Ladson-Billings examines the exclusionary practices within education, explaining how historical inequities in the access to education, school funding, and involvement of URM participants in legislative and other decision-making processes related to education has resulted in an education debt. The consequences of this debt continue to result in social problems that contribute to the achievement gap between URM and majority students (Ladson-Billings, 2006). Similar historical inequities in the representation and support of URM at the forefront of STEM achievement had resulted in White men being the dominant force behind the formation of STEM culture. As a result, URM students are still subject to biases that limit their ability to confidently pursue and succeed in STEM. STEM is sometimes described as "color blind," meaning people in power may not be as receptive to the presence of specialized issues faced by URM participants (Miriti, 2020). This can result in URM participants feeling unable to address pertinent issues, and this lack of acknowledgement ultimately results in the issues becoming more severe (Ross and Edwards, 2016). These biases and "color-blindness" can result in devalued research contributions and resistance to studying the impacts of race, gender or socioeconomic factors in research projects (Turner et al., 2008; Leggon, 2011; Chapman, 2018). URM participants in STEM also face disproportionate duties, resources, and pay. Many of these URM participants are also first-generation and come from low-income backgrounds (Salehi et al., 2020). Participants from these backgrounds experience further difficulties balancing the time commitment of STEM with existing job or family commitments (Ries and Gray, 2018). In order to increase URM and first-generation participation and success in STEM, these specific issues of exclusionary bias and inaccessibility must be addressed.

An area where the inaccessibility of STEM manifests itself is participation in experiential learning experiences such as research experiences. URM, first-generation, and returning students are less likely to pursue these types of experiences than other students. Research opportunities are an effective form of experiential learning for URM, first-generation, and returning students because they provide students with technical experiences and connect them with mentors that lead to identity development within STEM (Prunuske et al., 2017; Kingsford et al., 2022; Taing et al., 2022). Students pursuing two-year degrees, who are commonly first generation or returning students, and URM students report finding experiential learning opportunities more valuable to them than their peers who start at four-year universities (Ezarik, 2022). Research experiences allow a student to build meaningful associations with technical concepts, faculty, graduate students and peers that contribute to the development of the student's STEM identity. Engagement theory describes the benefits of the personally meaningful associations to STEM created during research experiences, stating that they promote the retention and further application of new knowledge, traits urgently sought by industry (Kearsley and Shneiderman, 1998). Research experiences provide students with time, resources, and guidance to make these personal connections to STEM built through solving relevant and complex problems. The identity formed during this process is also a key component identified by Retention Theory as an indicator that strongly influences STEM retention (Tinto, 2016). Development of a STEM identity leads to persistence and resilience that allow students to navigate difficult events and circumstances that complicate completing a STEM degree, something that first generation, returning and URM students traditionally struggle with (Chang et al., 2011; Jowkar et al., 2014). URM, first-generation and returning students that complete research experiences consistently report growth in their STEM identity and cite the research experience as extremely important toward building skills necessary to complete a STEM degree (Balke et al., 2021).

Also essential to the development of a student's STEM identity and retention in a STEM program is the "border crossing" process through which the student enters the culture of scientific research. Border crossing highlights the difficulties any newcomer has becoming a part of a new community, acknowledging the process through which a newcomer builds an identity within their new community (Dewey et al., 2022). Border crossing can be difficult in STEM fields, given the complex cultural framework and typical lack of prior exposure for incoming students (Dewey et al., 2021). Direct mentoring relationships are one of the most effective means to guide students through this border crossing process, particularly for first generation, returning and URM students, who have reported that lab environments at major research universities do not always meet their expectations for inclusion and guidance (Morgan et al., 2021). Programs that successfully impact STEM retention highlight collaboration and community building as practices that aid in the border crossing for first generation, returning and URM and students (Dyer-Barr, 2014). Multi-tiered mentoring models that structure student interactions with peers, graduate students, faculty advisors, industry connections, and other administrative personnel are an effective way to both build the community that enables the border crossing process and ensure that mentors can provide quality mentoring to their mentees (Hayes, 2018). Cho et al. (2011) identified five traits of outstanding mentors: the ability to inspire enthusiasm, compassion, selflessness, and other qualities that benefit a mentee's self-efficacy, such as providing career guidance, emphasizing regular time commitments, promoting a healthy work/life balance, and empowering mentees. Multi-tiered mentoring models attempt to provide these qualities by connecting students to mentors best suited for each of these traits rather than rely on a single mentor to provide each. For example, graduate students are often more reliable at conveying their enthusiasm for research and connecting with students regularly, while faculty and industry mentors are often better suited to provide career guidance. Further, a multi-tiered mentoring model allows for finding optimal mentors based on the specific needs of the individual, which is a particular need for first generation, returning and URM students who require mentors who can relate to the issues they are experiencing (Morgan et al., 2021).

A need exists to address the deficit of URM, first-generation, and returning students that obtain STEM degrees and pursue experiential learning opportunities. Students from these demographics typically do not perceive these opportunities as accessible to them based on existing external commitments and biases and underrepresentation caused by historical inequities present within STEM. Therefore, providing a research experience targeted toward addressing these barriers faced by URM, first-generation, and returning students may offer an opportunity to increase the access to these valuable experiential learning opportunities. To do this, a research experiences and mentoring program was established that sought to form a multi-tiered mentoring community that provided mentoring and representation necessary for identity development within this demographic. It was hypothesized that this inclusive and supportive community would lead to the development of STEM identity crucial to pursuing future experiential learning opportunities and ultimately a four-year degree and career in STEM. To test this hypothesis, the following research questions were investigated:

- Research Question 1: Can URM, first-generation, and returning students from high schools local to Northwest Arkansas (NWA), Northwest Arkansas Community College (NWACC), visiting undergraduate students, University of Arkansas graduate students and faculty be brought together to form a diverse multi-tiered mentoring community? The formation of this highly collaborative environment will provide students with peer mentors, graduate student mentors, and faculty mentors and will promote an interactive, inclusive, and supportive community. The program predicted the formation of this multi-tiered mentoring community would be indicated by students forming strong mentoring relationships and reflecting positively on the collaborative elements of the program.
- Research Question 2: Does the formation of this multi-tiered mentoring community provide an environment where students from different demographics develop their identity within STEM? This STEM identity includes both self-efficacy within STEM and skills valuable to their pursuit of a STEM degree. Formation of this collaborative community where peers and graduate students lead by example would encourage the students to invest in the program and thus develop their STEM identity. The program predicted the students' identity development would be reflected in their post-program survey scores related to self-efficacy and skill development. Further, that this identity development would lead to the follow up action of the LSRM students presenting their research at a conference or pursuing an additional research opportunity after the program ended.

2 Materials and methods

2.1 Program design

The Membrane Applications, Science and Technology (MAST) center is an NSF Industry-University Cooperative Research Center (IUCRC) that connects four universities and about 20 companies to conduct industry-relevant membrane research. Since 1990 the center has worked with industry to perform salient precompetitive research in the fields of biopharmaceutical manufacturing, water purification, chemical separations, and membrane fundamentals. The center aims to provide students with access to unique research opportunities and career preparation through its partnerships with leading membrane companies and access to world-class facilities. Further, the center hopes to extend these resources to others in the university and local NWA communities. As part of this broader outreach, the MAST center and the Ralph E. Martin Department of Chemical Engineering at the University of Arkansas have expanded its Research Experiences for Undergraduates (REU) programs to offer local student research and mentoring (LSRM) programs for NWA students outside four-year degree programs. A multi-tiered mentoring community was formed that emphasized participation from URM, first-generation, and returning students to promote the environment necessary for these students to form STEM identities that lead to future success in a STEM degree and career.

The programs sought to build the STEM identities of these students by providing an accessible and positive introduction to research. The multi-tiered mentoring community attempted to combine students of different ages and backgrounds from similar demographics that face similar issues. For these students, accessibility refers to the development of an identity within STEM that transforms their perception of research from something outside of their capabilities to something more achievable. The sense of belonging that accompanies identity development is much more likely to contribute to these students pursuing future experiential learning opportunities within STEM, and ultimately a STEM career, than pressuring the students to produce top-quality results. This program focused on the development of this multi-tiered mentoring community to demonstrate successes in research through access to a wider variety of peer and senior mentors. These successes relate to the aspects of research outside of data collection that are necessary for the completion of a research project such as understanding the context of their project relative to the literature, planning and managing a project, analyzing data, and presenting their results. A key component of the development of research/STEM identity is feeling confident that one is capable of these tasks even if the desired result is not achieved. This is stressed to the students through the community environment that exposes them to the experiences of others similar to them, something particularly important for URM, first-generation, and returning students who typically have trouble relating to students outside these demographics.

Three concurrent programs were run: a Community College LSRM (CCLSRM) program for NWACC students, a High School LSRM (HSLSRM) for students attending NWA high schools, and a 10-week summer REU program for students visiting from out-of-state universities. The LSRM programs consisted of a 10-week summer experience consistent with REU formats and added additional mentoring sessions during the following academic year not provided in traditional REU experiences (Figure 1). This structure leverages the fact that the students are local to preserve quality mentor-mentee relationships that often fade once students in traditional REU programs return to their home institution. This design aims to work with students to tailor their experiences in the program to their specific set of circumstances through a multi-tiered mentoring model and mentoring sessions developed with direct input from the students. The program expects this extended involvement and emphasis on community will be instrumental to the formation of the students' STEM identities (Dewey et al., 2022).

2.2 Recruitment

The multi-tiered mentoring community included a combination of students local to the area and students participating in a concurrent REU program from out of state universities. This contrast between local students seeking to enroll in a 4-year STEM degree and visiting students already enrolled in such a program formed the first layer of peer mentoring in the multi-tiered mentoring community. Local students were recruited through partnerships between the MAST center and various organizations operating in NWA. Local students aged 16–32 in high school or pursuing a two-year degree were recruited from Upward Bound and NWACC. Community colleges offer two-year degree programs that provide students with technical and vocational skills applicable to the workforce. These schools are deeply rooted in the local community and often contain programs designed in partnership with employers in the area (Education USA, 2023). Community colleges traditionally contain more URM, first-generation, and returning students than four-year universities, making them an effective means of reaching these underserved demographics (Packard, 2012; Stofer et al., 2021). Upward Bound serves high school students of this same demographic (URM, first-generation and low income) in addition to students with disabilities, are homeless, or in foster care. The program prepares students for postsecondary education by providing programs such as tutoring, counseling, mentoring, work-study, and more in both STEM and non-STEM subjects (United States Department of Education, 2023). Both high school and community college students were targeted due to their shared goal of enrolling in a four-year STEM degree program despite their differences in ages and experiences. Doing so also maximized the age and demographic diversity of the program in a novel manner. The local Upward Bound program hosted the students on the University of Arkansas campus, allowing them to regularly attend the research experience as a group.

Partnering with these organizations allowed the program to reach its target ages and demographics. It was not a prerequisite for students to be URM, first-generation, or returning, though extra emphasis was made during recruitment to ensure prospective students from these demographics were aware of the opportunity by having individual conversations with prospective students from these groups. These conversations also helped bridge the initial confidence gap that may have dissuaded them from pursuing the opportunity otherwise. Representation of these groups is traditionally high in community colleges and Upward Bound only works with these students, so working with these organizations increases the ability of the program to connect with these students. More specifically, NWACC reports 24.6% of its student body is Hispanic or Latino, 5% is two or more races, 4% is Asian, 3% is Black students or African American, 2% is

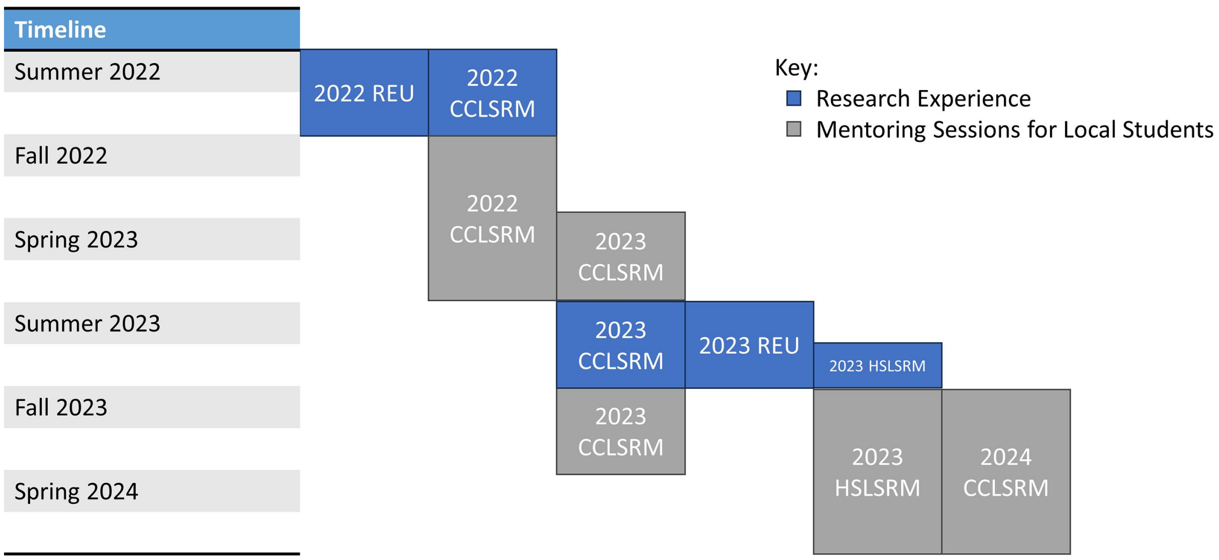

FIGURE 1
Timeline illustrating the overlapping of the REU, CCLSRM, and HSLSRM programs. The programs share research experiences (blue), whereas the mentoring initiatives (orange) were offered to the LSRM programs during the academic year. Research and mentoring sessions were run concurrently when possible to encourage the growth of the MAST center research community.

Unknown, 1% is American Indian or Alaskan Native, and 1% is Native Hawaiian or Pacific Islander (2023-2024 NWACC Fact Book, Northwest Arkansas Community College, 2023). NWACC does not report first-generation or returning student demographics specifically but does specify 6% of the students are "readmitted," or returning to an institution they previously attended, which encompasses a portion of the returning student demographic. The remainder of this demographic includes students who previously attended a different institution before resuming their education at NWACC.

The ideal candidate was someone who was engaged with and was successful in an introductory STEM course at NWACC or showed interest in a STEM high school course and was not aware of career paths outside of traditional STEM careers such as nursing. This type of student was ideal for their combination of potential to be successful in research and need for mentorship to maximize their ability and desire to pursue a STEM degree and career. This combination results in the highest likelihood of the students benefiting from and buying into the types of mentoring relationships the program aimed to establish. A competitive stipend was provided to allow the students to meet their obligations and acted as a recruiting tool.

2.3 Mentor training

Given the program's emphasis on mentoring, multiple levels of mentor training were incorporated into the program to maximize the quality of the mentor-mentee relationships formed. The program is built on a model where national NSF mentoring catalyst program leaders "train the trainers" and provide mentor training to the PI and lead graduate students. The training consisted of two parts, an eight-hour virtual seminar hosted prior to the arrival of the students and a follow-up in-person workshop that lasted 2 days. The activities and concepts at both sessions were similar. The in-person meeting after the program ended allowed the program to connect with other LSRM programs, share experiences and best practices, and reinforce the shift to post program mentoring from mentoring during the summer experience. The sessions consisted of presentations from the NSF mentoring experts, review and discussion of theory and case studies in small and large groups, and mock conflict situations where the participants acted as the mentor or mentee. Topics discussed related to how to ensure the mentees' research experience is valuable to them and how to navigate working with URM, first-generation, or returning students. Sessions relating to the technical portion of the research experience and career development included understanding the needs of the mentee, how to approach establishing appropriate boundaries and expectations, how to effectively communicate with mentees, how to promote the self-efficacy of mentees, how to foster independence, and how to provide mentees with professional development and skill awareness. Sessions were also incorporated to educate the mentors on the cultural awareness necessary to understand the unique experiences URM students may face relating to biases and cultural differences. Further, strategies to discuss these experiences in an appropriate manner were provided with the goal of supporting an equitable and inclusive community. Issues relating to first-generation and returning students were also discussed at these sessions, namely the importance of aligning expectations with these students. Mentors must be aware that the students are likely to have other commitments outside of the research experience, and the mentees may not understand how the lab environment may differ from other roles they have held outside of STEM. Examples of these case studies and mock conflict scenarios included discussion with a mentee on the merits of pursuing a PhD as a parent, how to encourage an underperforming mentee, and how to manage a conflict between two lab members that involved differences in opinion of the merit of studying implications of racial differences in a study. The mentor training concluded with instructions to discuss the importance of mentoring with the students at orientation. The value of mentoring relationships was emphasized to the students from the beginning to maximize their commitment to forming them as they progressed through the program.

2.4 Undergraduate research experience

Group work was a primary component of the program given the program's goal of forming a multi-tiered mentoring community that included peer mentoring. CCLSRM students were paired in labs with the visiting REU students based on research interests and ongoing projects of faculty members whenever possible. Efforts were made to connect the students in the program to mentors with similar backgrounds. Specific projects were decided on between the students and their advisor. Program activities outside the lab included weekly research meetings and an industry visit. Weekly research meetings were the primary tool used for the PI and lead graduate students to work with and check in with the students during the 10-week summer research experience. The purpose of these meetings was to provide a session students could use to develop and present a "quad" slide summarizing their progress to date. This format is standard to both industry and many areas of academia and includes an introduction/innovation quadrant, an approach quadrant, a results quadrant, and a conclusion/future work quadrant (United States Department of Veterans Affairs, 2023). Each student presented their update quad slide biweekly, alternating between the REU and the CCLSRM students. The industry visit involved touring Eastman Chemical Company (Longview, TX, USA) and Invista (Longview, TX, USA). The companies were selected to provide views of two different company styles, one much larger and more commodity based (Eastman) and one much more focused on research and product development (Invista). Professional development sessions know as 'dinner and dialogue sessions' were provided for both REU and CCLSRM programs which stressed professional development and graduate school preparation.

2.5 High school research experience

The high school students committed around 10 h per week to their research project at the MAST Center laboratories. This included a 1 h mentoring lunch. The projects were designed to both demonstrate relevant principles to membrane research as well as give the students the opportunity to contribute to their design as a researcher would. Each project consisted of an introductory day where the instructors taught some of the relevant theory and demonstrated the experiments, a learning day where the students practiced the experiments in one large group under heavy guidance and supervision from the instructors, and a research day where the students used the knowledge they gained over the first 2 days to make decisions about the project and interpret the change in results. The students were asked to describe the expected outcome after the first day of the project and asked to come up with a hypothesis after completing the second day.

2.6 Local student mentoring sessions following the summer program

A key component of the LSRM programs was to maintain contact with the students and provide ongoing mentorship for at least the next academic year. Facilitating connections between the 2022 and 2023 CCLSRM programs and the CCLSRM and HSLRM was a key component of this effort. The high school students were able to sit in on multiple undergraduate program research meetings and attended the final presentation session. Different types of professional development activities were planned for both groups, stressing industry-relevant topics as job seeking skills (i.e., resume building and interviewing), transfer and graduate school information, presenters from industry, local industry visits, etc. Speakers included MAST center alumni in industry and representatives from the University of Arkansas Undergraduate Recruitment Office who were experts in the transfer from a community college to University. Industry visits were also organized when possible. Formal mentoring concluded with guidance for presenting a poster at a local or national conference, notably the Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics (STEM). The conference is hosted by the American Association for the Advancement of Science (AAAS), Inclusive STEM Ecosystems for Equity & Diversity (ISEED) Programs and the National Science Foundation (NSF) Division of Equity for Excellence in STEM (EES). The conference is aimed at college and university undergraduate and graduate students including underrepresented minorities and persons with disabilities. A formal practice session was organized as a mentoring event the month prior to the conference. Finally, emphasis was also placed on including the families of students when possible. Research shows that community college and URM students place more importance on family than others, and it was important to communicate the value of the programs to the parents to enable them to assist in the formation of their child's STEM identity (Packard, 2012).

2.7 Data collection

Data for this study came from a Qualtrics survey of participants enrolled in the program; data were collected during the participants' last week of the summer program ($n=31$). Questions were developed internally based on the objectives of the REU program then further expanded to address components related to the mentoring relationships formed during the implementation of the LSRM program. All students volunteered to participate, and appropriate institutional approvals were obtained [institutional review board (IRB) protocol number 2203393399]. Statistical analyses include testing (1) differences between the groups using ANOVA, and (2) differences between group demographics (gender, race/ethnicity, first generation/non-first generation), using paired samples *t*-tests The survey contained approximately 50 questions asking students to rate themselves on a scale of one-to-five with regards to how much they gained from their participation in the program. Survey questions were divided into four categories: *development of STEM self-efficacy, formation of quality mentoring relationships with graduate student research mentors, formation of quality mentoring relationships with faculty advisors,* and *preparation for a university STEM degree program*. Each of the questions in the category were averaged to create a composite score used to compare across the programs surveyed. The *development of STEM self-efficacy* score was made up of questions assessing the students' confidence, comfortability, and understanding of principles relevant to conducting research in a lab, communicating results and scientific principles, and completing a STEM degree. *Mentoring relationships* scores included questions assessing the quality and quantity of mentor-mentee interactions, and assessing the impact of their relationship with their advisor may have on their likelihood to pursue future STEM experiences. Students described their relationships generally and responded to statements describing positive characteristics of mentoring relationships. *Preparation for a university STEM degree* included their STEM coursework, problem solving skills, project management, and data analysis that are valuable to industry and other STEM professions. *Research identity* and *preparation for a University STEM degree* questions were scored using "great gain" (five), "good gain" (four), "moderate gain" (three), "a little gain" (two), and "no gain" (one). *Mentoring relationships* questions were scored on two scales depending on the type of question asked. General descriptions of mentoring relationships were scored with "excellent" (five), "very good" (four), "good" (three), "fair" (two) and "poor" (one), and statements were responded to with "strongly agree" (five), "moderately agree" (four), "slightly agree" (three), "slightly disagree" (two), "moderately disagree" (one), and "strongly disagree" (zero). Students also rated their likelihood to pursue future STEM opportunities related to their research experience on the scale of "great gain" (five), "good gain" (four), "moderate gain" (three), "a little gain" (two), and "no gain" (one). In addition to the survey following the research experience, the program reached out to the students annually to continue tracking their progress toward completing a STEM degree. Data was validated through Cronbach's alpha reliability measurement. *Development of STEM self-efficacy* scored an alpha value of 0.92*, formation of quality mentoring relationships with graduate student research mentors* scored an alpha value of 0.90*, formation of quality mentoring relationships with faculty advisors* scored an alpha value of 0.93, and *preparation for a university STEM degree program* scored an alpha value of 0.90. Data was analyzed to understand the experience of URM, first-generation and returning to students in the program relative to the formation and impact of the multi-tiered mentoring community. URM was defined based on the NSF definition to include students who identified as Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives. Women were also included in this definition given their underrepresentation in engineering (Corbett and Hill, 2015).

In addition to student response survey data, data was collected describing the number of students in each program from each demographic, the types of projects completed worked on by the students, local student mentoring session outcomes, and feedback provided by the students. Students also identified their status as first-generation on the survey based on their parent's education, and community college students were asked about their status as returning at the start of the program. Student projects were categorized into bioseparations or water treatment based on their primary objective. Bioseparations focused primarily on biomolecules of industrial interest such as proteins, exosomes and viruses, and water treatment projects involved techniques to remove toxic substances such as per- and polyfluoroalkyl substances

(PFAS) and heavy metals from water. Local student mentoring outcomes related to student participation, family sessions, and conference presentations. Student participation described the number of students who attended two or more sessions. Family sessions measured parent participation by the number of students who brought at least one parent. Students who presented a poster on their summer research at a local, regional, national conference were said to have presented at a conference after the program ended. Lastly, feedback was collected from the students at the final group meetings, open response questions on the survey, and through post-program follow-ups. Students were asked about the format of the research meetings and trip specifically in addition to suggestions on general improvements to the program. Students also discussed the impact mentoring had on their future plans when asked open ended questions about their future plans on the post-program follow-up. 2022 CCLSRM students were also asked direct open-ended questions about the peer mentoring in the program in an additional follow up.

3 Results

3.1 Student demographics and mentoring community structure

The primary objective of the LSRM and REU programs was to provide an accessible introduction to research and a career in STEM through a multi-tiered mentoring community that addressed challenges faced by first-generation, returning and URM students. The typical size for each program was seven students, and the 2023 REU and 2023 HSLSRM programs supported six. This allowed the programs to be efficiently combined into a single group while remaining manageable. URM participation was emphasized in both the REU and LSRM programs (Table 1). The program was effective at reaching women and connecting with the growing Hispanic community in NWA. The program hosted a total of 14 students who identified as first-generation college students and seven students returning to school after pursuing a previous professional experience. Eight of the 13 REU students identified as URM, two of the 13 as first-generation, and one of the 13 identified as returning. In contrast, of the 20 LSRM students 13 identified as URM, 11 identified as first-generation, and 10 of the 14 CCLSRM students identified as returning. Three students did not indicate gender or race/ethnicity. This disparity demonstrates that the LSRM program's initiative to reach these demographics was successful. Overall, the program constructed an extremely diverse community that emphasized inclusion and successfully brought together many different students and faculty from different backgrounds. Figure 2 summarizes the tiers of the multi-tiered mentoring community, including faculty advisors mentoring all students, graduate student research mentors mentoring students in the lab, and peer mentoring that took place between the LSRM and REU programs. Peer mentoring was emphasized between the LSRM and REU programs by pairing them inside and outside the lab whenever possible to expedite the formation of the cohort community. The HSLSRM program was included in the undergraduate research meetings when possible to give the undergraduate students the chance to mentor the high school students. Other informal interactions between the programs were also encouraged between the HS and undergraduate students to support this peer mentoring.

3.2 Undergraduate student projects

Undergraduate student projects all investigated cutting-edge principles and techniques relevant to the research interests of the labs they were placed in. Broadly, the projects focused primarily on bioprocessing and water treatment. Bioprocessing focused on the purification of different biomolecules of value such proteins, exosomes, and viruses. Membrane filtration using electrospun membranes, membrane adsorbers, and column chromatography were also investigated for proteins of commercial interest such as green fluorescent protein, Annexin V, and Immunoglobulin M. Water treatment projects explored membrane fabrication using novel materials and solvents such as liquid crystals and gamma-Valerolactone. Processes such as magnetic nanoparticle removal and electrocoagulation were studied for the removal of salient contaminants such as heavy metals and per- and polyfluoroalkyl substances (PFAS). Table 2 provides sample project titles and abstracts from different programs.

3.3 High school student projects

The HSLSRM projects were designed to demonstrate relevant principles of membrane research. Membrane research is an effective topic for an introduction to STEM since students can easily visualize the process, the experiments are simple and efficient, and the field is

TABLE 1 Summary of participant numbers and demographics in each program.

	2022 REU	2022 CCLSRM	2023 REU	2023 CCLSRM	2023 HSLSRM
Total participants	**7**	**7**	**6**	**7**	**6**
URM	4	7	4	5	5
Women	4	5	4	4	4
Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives	1	4	2	1	3
Black students or African American, Hispanic or Latino, and American Indians or Alaska Native Women	1	2	2	0	2
First Generation	1	4	1	3	5
Returning	0	2	1	4	**N/A**

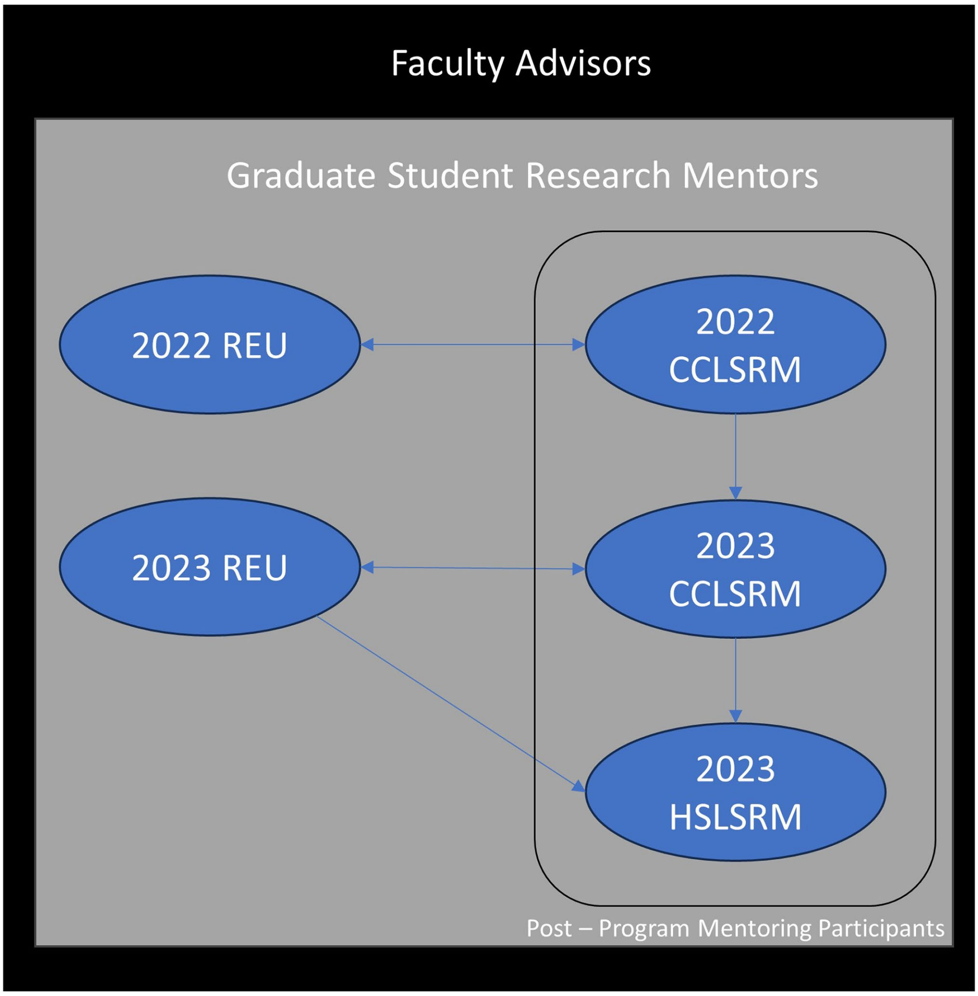

FIGURE 2
Layout of tiers present in the constructed multi-tiered mentoring community. Faculty advisors provided technical and career guidance for all students in the program. Graduate students provided research mentoring in the lab and personal experiences the students could use for guidance. The student programs were overlapped as much as possible, including between years, whenever possible to develop peer mentoring between the students.

highly interdisciplinary. Three types of membrane filtration techniques were explored: membrane chromatography, dead end filtration, and tangential flow filtration. The first project modeled tangential flow filtration using a cross flow membrane cassette (Sartorius Vivaflow 50, Germany) to separate food dye from watercolor pigment (Kaiser et al., 2017). A gel electrophoresis experiment (Flinn Scientific, Batavia, IL) was performed first to illustrate the size of dye molecules. The second project used a membrane adsorber (Cytiva Mustang Q Acrodisc, Marlborough, MA) to separate the thiocyanate anion from a potassium cation (Dizge et al., 2009). The final experiment used yeast cells to compare membrane fouling in dead end (Fisher Scientific Nalgene Rapidflow, Hampton, NH) and tangential flow filtration (Sartorius Vivaflow 50, Germany). The first and last experiment focused on calculating flux over time to quantify fouling and to observe the transport of each component through the process. The second experiment demonstrated the bind and elute process using a membrane adsorber and tasked the students with calculating the capacity of their membrane adsorber over multiple regenerations. The projects are further discussed in Table 3.

3.4 Local student mentoring sessions

A typical challenge mentoring relationships face involves the mentor and mentee growing more distant as both move on to different endeavors. The design of the LSRM program directly addressed this issue by targeting local students that were enthusiastic about continuing with the mentoring portion of the program. The program has successfully engaged five of seven 2022 CCLSRM students, all seven 2023 CCLSRM students and all six 2023 HSLSRM students to prepare for conference presentation. Each CCLSRM cohort participated in a session with the University of Arkansas transfer department, and the HSLSRM students had the chance to meet with alumni of the Upward Bound program that continued to the CCLSRM program. Industry speakers from companies such as Donaldson Membrane Solutions (Minneapolis, MN, USA), MilliporeSigma (Billerica, MA, USA), and Pel-Freez Biologicals (Springdale, AR, USA) were connected to the students, and a trip to Pel-Freez was organized. Another session connected the students to a representative in the career services office to discuss job search resources available to the students and a faculty member who described the graduate school admissions process to the

TABLE 2 Summary of REU and CCLSRM undergraduate student projects.

Research area	Example project titles
Bioseparations	Developing Hydrophobic Interaction Chromatography Membranes Using Electrospinning for Protein Separations (2022 CCLSRM) Purification of Recombinant Annexin V Using Immobilized Metal Affinity Chromatography (2022 REU) Evaluation of Exosome Isolation from 3 Different Mammalian Cell Lines (2023 CCLSRM) Isolation of IgM and C4BP from the Complex Structure for Academic and Industrial Applications (2023 REU)
Water treatment	Synthesis and Characterization of Magnetic Nanoparticles Fe_3O_4 for Water Purification (2022 CCLSRM) A Study of Coagulation Bath Composition to Improve Performance of Ultrafiltration Membranes Made with Gamma-Valerolactone (2022 REU) Electrocoagulation for the Removal of Perfluorooctanoic Acid from Water Solutions (2023 CCLSRM) Fabrication of Polymeric Nano Porous Membranes with Slit-shaped Pores via Synthetic Liquid Crystals as a Template for Water Filtration (2023 REU)

students. Two family sessions were also held, one for the 2022 CCLSRM program and one for both 2023 LSRM programs. Both sessions were well attended by parents, with greater than 50% of students attending brining at least one parent in both sessions. The sessions also hosted more than 20 people, highlighting the formation of the community brought by combining the different programs. The remainder of the sessions were devoted to providing guidance for developing posters to be presented at conferences and opportunities for the students to practice their presentations. The distribution of these sessions is summarized for each program in Table 4.

The culmination of post-program mentoring involved the students presenting their research at a local or national conference. Mentoring sessions leading up to the conference were devoted to helping the students prepare for these conferences. In addition to feedback on abstracts, reports, and presentations the students prepared, the students were also given advice on how to network and make the most of the opportunities available to them at a large national conference. Four of the seven 2022 CCLSRM students presented at the 2023 ERN conference. Presentations for the 2023 HSLSRM 2023 CCLSRM students have been arranged at the 2024 ERN and local conferences such as the Arkansas IDeA Network of Biomedical Research Excellence (Arkansas INBRE), the 2023 Membranes for Viral Purification (MVP) Center annual meeting, and the 2023 MAST center annual meeting, respectively.

3.5 Quantitative survey results

Survey data was collected from the participants to understand the student perspective of the formation of the multi-tiered mentoring community and the development of their STEM identity. Of the 33 students two did not complete the survey, resulting in a total sample size of 31 students. Questions were categorized into four composite scores *development of STEM self-efficacy, formation of quality mentoring relationships with research mentors, formation of quality mentoring relationships with faculty advisors,* and *preparation for a university STEM degree program.* First, to assess the program's ability to benefit URM and first-generation students, the scores were compared between women and men, White and Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives students, and first- generation and non-first-generation students (Figure 3). Returning students were not analyzed in comparison with non-returning students due to an insufficient sample size of returning students. In general, all scores were rated at least 3.8/5, indicating the program was able to provide a positive experience for students regardless of background. Significant difference was observed between males and females for the *formation of quality mentoring relationships with faculty advisors* score ($p < 0.05$), where females (4.43) scored higher than males (3.83). No significant differences in mentoring relationships were observed in white vs. BIPOC students, and no significant differences were observed in *development of STEM self-efficacy* or *preparation for a university STEM degree program* for both comparisons. No significant differences were observed among the four categories comparing first generation to non-first generation, though first-generation scores were slightly higher than non-first-generation scores.

Another key element in the formation of the multi-tiered mentoring community was bringing together the REU and LSRM programs to combine students from different ages, colleges/universities, and points in their STEM education timelines. Data for each composite score was tested for statistical difference between programs and no significant differences were found (Figure 4). This suggests the local students in the LSRM program had similar experiences to those in the REU programs visiting from out of state universities, and the formation of a thriving community where all parties were successful. The 2022 CCLSRM program had the highest scores on average, where the 2023 tended to be lower than the others. The HSLSRM program also showed comparable scores in all categories, despite the age difference and difference in program design. The high mentoring relationship scores for both graduate student mentors and faculty advisors of the HSLSRM program was also notable given the HSLSRM program's emphasis on regular interactions with these mentors. It also appears that mentoring relationships were not as strong in 2023. This could be related to the design change that moved away from placing the LSRM students in the same labs as the REU students. It is worth noting students reported "good" to "great" gains relating to partnerships and peer mentoring as well.

In addition to scores from the *development of STEM self-efficacy* and *preparation for a university STEM degree program* categories, STEM identity development also was studied by assessing how the program impacted their desire to pursue research in the future (Figure 5). A secondary goal of the program was to provide the students with an accessible introduction to research, so it was important to understand the students' perception on research after the summer program ended. Students consistently identified themselves as more likely to pursue research opportunities. No significant differences were found between women and men or White students and Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives students. It was found that first-generation students identified themselves as significantly more likely to work in a science lab ($p < 0.004$). The data was also compared across programs. Interestingly, the HSLSRM scores are consistently among the highest scores received. This

TABLE 3 Summary of HSLSRM Student Projects.

Experiment title	Abbreviated summary	Student design choice	Key results
Separation of Watercolor Pigment and Food Dye using Tangential Flow Filtration Cassettes	First, dye molecules were studied using gel electrophoresis, noting the relative size and charge of each dye molecule. Then, the dyes were mixed with watercolor pigments to form a solution with a third color. Colors in the retentate and permeate streams were observed.	Dye molecule and watercolor mixture design Flux test duration/ procedure	Permeate consistently pure dye color Similar behavior among dye molecules of different properties
Membrane Chromatography for the Binding and Elution of Thiocyanate	The function of the anion-exchange membrane adsorber was demonstrated by successfully isolating the thiocyanate anion. The thiocyanate ion acts as an indicator by forming a deep red complex with iron when added to an iron chloride solution. Initially no color change occurred as the potassium thiocyanate solution was passed through the membrane adsorber, demonstrating the membrane's ability to bind thiocyanate.	Thiocyanate and Iron Chloride solution concentrations Order of solutions tested for comparison	Average binding capacity calculated to be 33.6 μg Membrane can be effectively regenerated
Comparing Fouling and Dead-End and Tangential Flow Using Yeast Cells	Yeast cells were used to model cells and cellular debris in bioreactor effluent processing. Dead end filtration was tested using a custom-made, low cost apparatus. Fouling occurred quickly in the dead end configuration, and students were able to observe buildup on the membrane. A microfiltration cross flow cassette was used to isolate yeast cells much more efficiently, allowing the students to understand the utility of tangential flow filtration in industrial processes.	Yeast solution concentration Flux test duration/ procedure	Flux dropped much slower in tangential flow filtration Can be extended to protein purification

TABLE 4 Summary of the distribution of post-program mentoring sessions for each program.

	2022 CCLSRM program	2023 CCLSRM	2023 HSLSRM
University enrollment/transfer information	1	1	1
STEM career awareness (industry speaker, industry tour, graduate school representative)	2	3	1
Family social session	1	1	1
Conference presentation preparation	2	2	3

could also relate to having regular interactions with mentors with strong knowledge of research careers. Again, no significant differences were observed between the REU and LSRM programs ($p < 0.05$).

The program attempted to reconnect with the students from both the 2022 and 2023 programs for its annual check in during September 2023 (Table 5). The students were asked if they were still pursuing a STEM degree, if they had participated or were interested in participating in any learning experiences outside the classroom (i.e., research opportunities, internships, extracurricular activities), and what their future goals were. REU student data was less important to this study since they entered the program with formed goals of pursuing a STEM career. Of the five 2022 REU students that responded, three had held internships, one had started a Ph.D. program, and three mentioned they were part of professional societies (two served as president). The 2022 CCLSRM program maintained contact with five students of the seven students after the program finished. Of the five students, all were pursuing STEM degrees at the University of Arkansas, four had performed additional research after the program, four had presented at a conference, and three were considering attending graduate school. The 2023 program received more responses than the 2022 program, which was not surprising given the short time since the program had finished. This could also be related to the growth of the community between the 2022 and 2023 programs. Of these seven students, five were enrolled at the University of Arkansas in STEM and the remaining two still plan to transfer after completion of their associate degree. Five were working on an abstract or a poster to present at an upcoming conference. Four of the students also indicated were working in a lab during the following semester with a fifth heavily involved in professional societies. In total, eight of ten LSRM students that regularly participated in MAST center community and mentoring sessions have successfully obtained another research opportunity. Finally, all seven students specified they were at least considering attending graduate school after completing their bachelor's degree in STEM.

3.6 Undergraduate student feedback

The 2022 CCLSRM program emphasized peer mentoring by pairing NWACC students with REU students in the same group. These organic interactions early on effectively began the process of forming a community and establishing peer mentoring among the REU and NWACC students. The students spoke about the benefits of having a partner, namely that having the person to discuss the project with helped their understanding tremendously. This design change did not have a major impact on the students' experience in the program according to the 2023 CCLSRM student feedback. The students commented they had a great experience on the industry

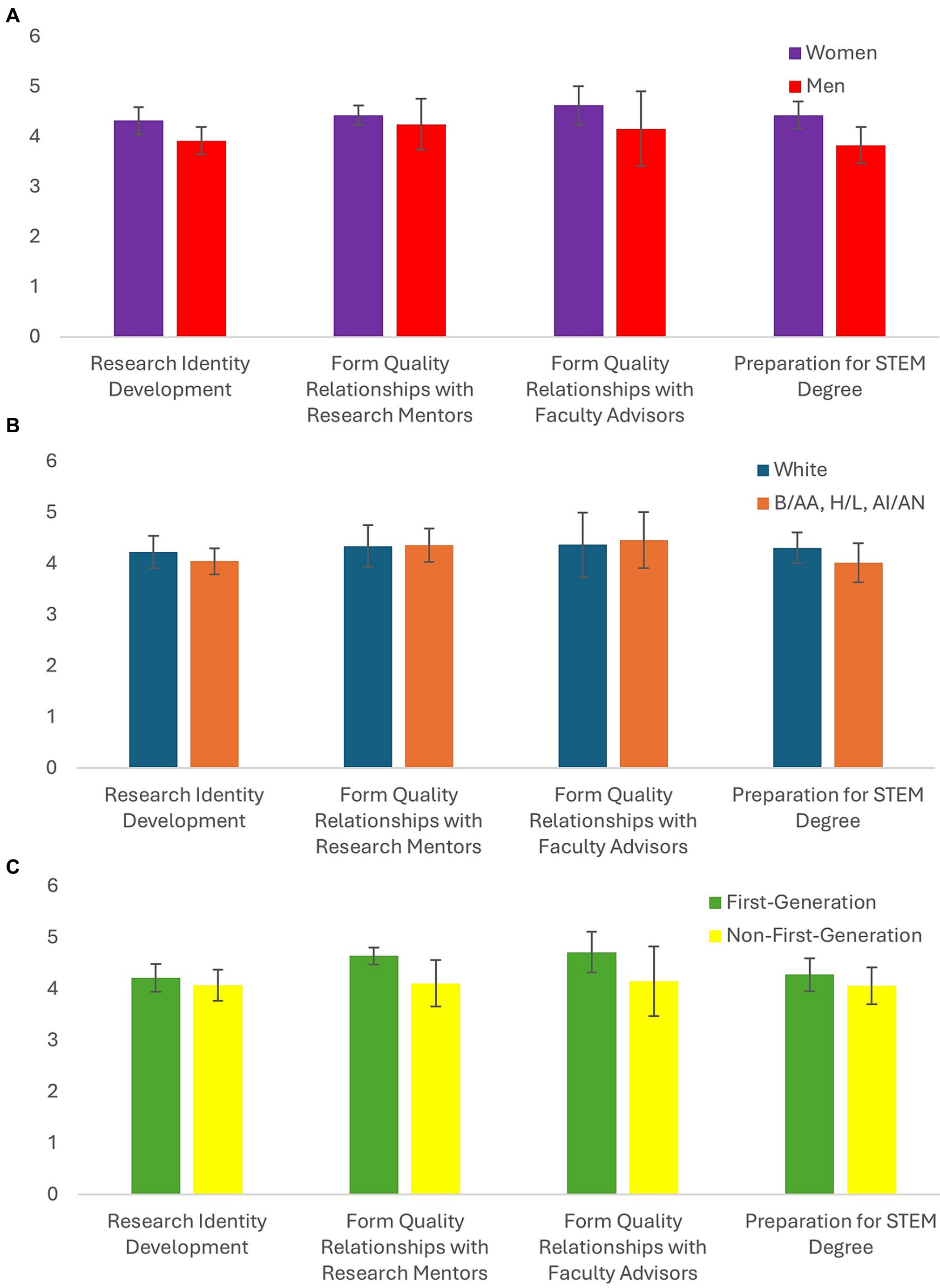

FIGURE 3
Summary of composite scores generated from student responses to the survey administered at the end of the research experience. Scores describing the STEM self-efficacy development, formation of quality mentoring relationships with both research mentors and faculty advisors, and preparation for a STEM degree are reported for different demographics: women vs. men **(A)**, White vs. Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives students **(B)**, and first-generation and non-first generation **(C)**. *Research identity* and *preparation for a University STEM degree* questions were scored using "great gain" (five), "good gain" (four), "moderate gain" (three), "a little gain" (two), and "no gain" (one). *Mentoring relationships* questions were scored on two scales depending on the type of question asked. General descriptions of mentoring relationships were scored with "excellent" (five), "very good" (four), "good" (three), "fair" (two) and "poor" (one), and statements were responded to with "strongly agree" (five), "moderately agree" (four), "slightly agree" (three), "slightly disagree" (two), "moderately disagree" (one), and "strongly disagree" (zero).

visit at the beginning of the program that helped integrate the two groups tremendously. In general, the students also spoke to the impact of the summer research experience on their confidence to work within STEM. One 2022 CCLSRM student said, "*The [LSRM] program gave me a huge confidence boost in comprehending research papers, journals, and articles in a way that I can now explain new*

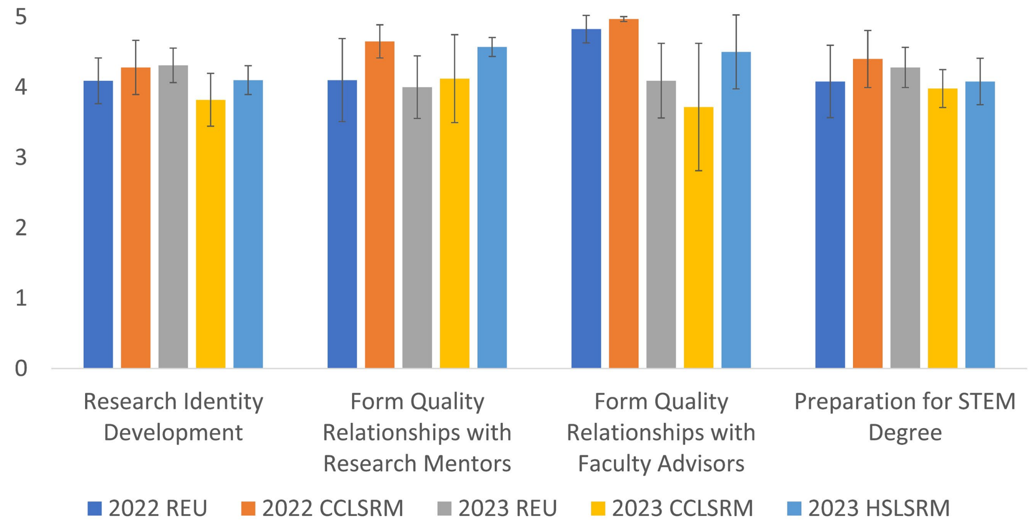

FIGURE 4
Summary of composite scores reported across different programs. High scores were obtained for each program, indicating the program provided a valuable experience for students from all programs. *Research identity* and *preparation for a University STEM degree* questions were scored using "great gain" (five), "good gain" (four), "moderate gain" (three), "a little gain" (two), and "no gain" (one). *Mentoring relationships* questions were scored on two scales depending on the type of question asked. General descriptions of mentoring relationships were scored with "excellent" (five), "very good" (four), "good" (three), "fair" (two) and "poor" (one), and statements were responded to with "strongly agree" (five), "moderately agree" (four), "slightly agree" (three), "slightly disagree" (two), "moderately disagree" (one), and "strongly disagree" (zero).

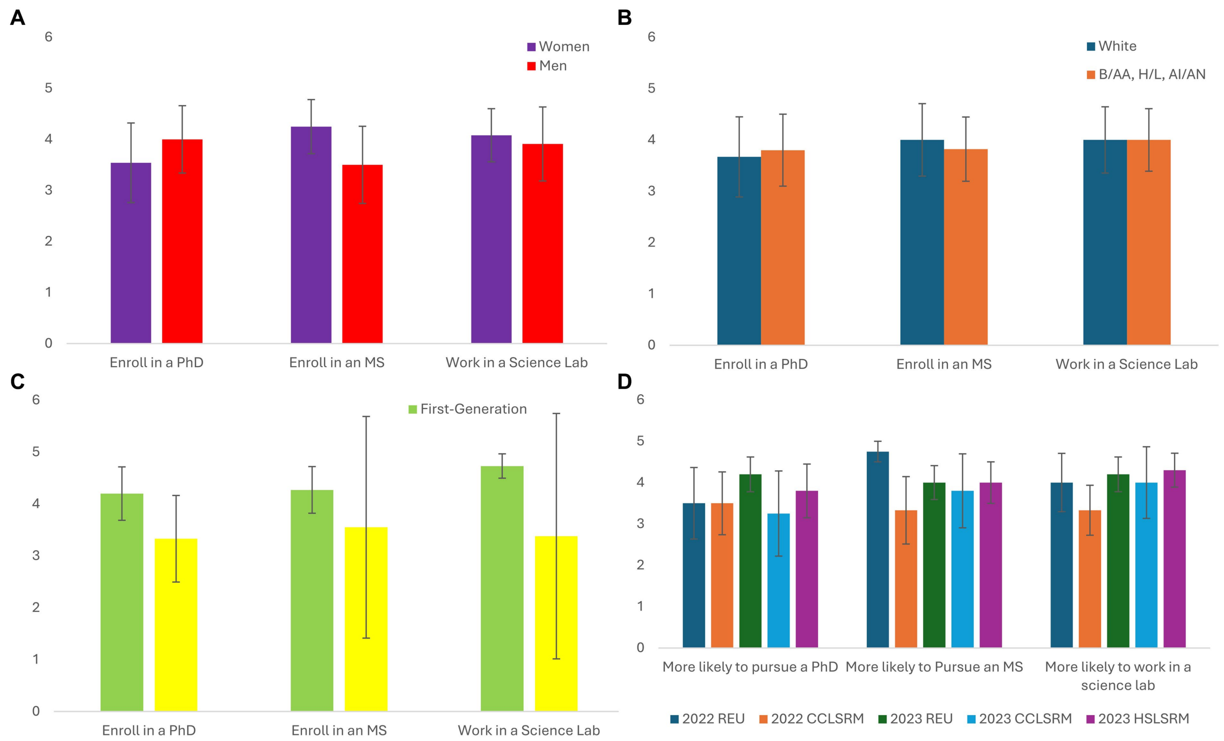

FIGURE 5
Data describing the impact of the various programs on the students' desire to pursue future research compared between women and men **(A)**, Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives students and White students **(B)**, first-generation and non-first-generation **(C)**, and across programs **(D)**. Scores corresponded to "great gain" (five), "good gain" (four), "moderate gain" (three), "a little gain" (two), and "no gain" (one).

ideas and concepts to people who are not familiar with the topic after I have read about it."

The 2022 CCLSRM students found the mentoring sessions useful and engaging. The students also spoke positively about devoting

TABLE 5 Summary of LSRM responses to follow up inquiry describing new goals after participation in LSRM program.

	2022 CCLSRM (n = 5)	2023 CCLSRM (n = 7)
Presented at conference after program	4	5
Continuing to pursue a STEM degree	4	7
Participating in additional research, internship, or experiential learning opportunities	4	5
Considering attending graduate school	3	7

sessions to conference preparation, commenting the sessions were extremely helpful in creating their first conference poster and navigating their first major conference. 2022 CCLSRM students who attended the ERN conference felt well prepared and that the conference was impactful, one of the URM students stated, "*I thoroughly enjoyed the conference as it gave me an excuse to chat about my research and learn in-depth about other people's work. It was inspirational to see such diversity in STEM and made me aspire to aim higher in my career. It was my first conference of that magnitude and I had never experienced such privileges before which most definitely made me want to pursue more conferences*." The sessions including family members were also very well received by the parents. One 2023 CCLSRM student commented that her family was skeptical about pursuing this opportunity over a more traditional nursing career, but after attending the family session at the MAST center their family had a much better idea of what she would be working on and was much more excited for them. Another 2023 student commented on the mentoring relationships formed in general, saying "*I would not have been interested in, or had the agency required to pursue [a subsequent research] opportunity with the experience of my summer internship, or the valuable mentorship*."

3.7 High school student feedback

The feedback collected from the high school students addressed both the design of the experiments and the mentoring activities during and after the research experience. Beginning with the experiments, the students enjoyed learning about membrane technology and the visual nature of the experiments. The visual effects, particularly those based on color changes, helped the students make connections between the explanations provided by the lead graduate student and faculty mentors. The students commented that further standardization of this experiment (i.e., assigning recorder role, creating standards to compare to) would have likely produced more consistent results. The students applied knowledge gained from the first 2 days of experiments within each project to choose parameters such as the volume and time intervals over which to assess samples to ensure maximum accuracy, concentrations of solutions to make when appropriate, speed of the experiment (i.e., pump or syringe), and ideas to troubleshoot when results did not go as expected (particularly with the third experiment). The students commented that having the ability to choose design components important to them, such as the concentration of the thiocyanate solutions and the color of the watercolor/dye solutions used, made the experiments more approachable and more impactful.

It was clearly valuable for the high school students to be around the MAST center community and fast-paced research environment of the dedicated research facility where the MAST center lab was located. Students who came into the program shy felt more confident conversing with peers. Some of the students even felt comfortable and interested enough in the undergraduate program research meetings they sat in on to ask the presenters questions. The lunch sessions were specifically mentioned as one of the most beneficial components of the program. Further feedback stated the students felt more prepared and more conscious of working to find their career after graduation and helped make their seemingly "outrageous" goals feel more achievable. In fact, two of the students quickly indicated they planned to pursue engineering at the University of Arkansas after the program and credited the program as their motivation.

4 Discussion

The LSRM program was constructed to address the need of providing more research opportunities to URM, first-generation, and returning students who typically lack the confidence and awareness to pursue them. The program sought to alter the perception of research and STEM in general to these students such that they found future opportunities and careers more accessible than before. While it was not a goal of the program to recruit students to engineering, the interdisciplinary nature of engineering research was an effective tool to bridge the divide between the concepts the students learned in their science classes and the techniques and processes used in industry. Exposing the students to relationships between science and engineering gave them a wider view of different career paths through STEM and the value of research to industry and academia. The positive feedback and survey scores regarding the research completed and future STEM aspirations suggest that these research projects were valuable to providing the students a meaningful introduction to STEM. This introduction can serve as a foundation that makes pursuing future opportunities more tangible and accessible. While it may seem counterintuitive to place students without advanced backgrounds or prior research experience in cutting-edge research projects, the outcomes of this program suggest that immersing them in the challenging research and community environment is an effective introductory experience. This can be further observed given the high success rate of LSRM students obtaining further research opportunities.

Mentoring was emphasized in this structure given the need for personal relationships to be formed when working with students from URM, first-generation, and returning backgrounds. Students from these demographics face complex issues they do not expect others in STEM to be able to relate to. The goal of the multi-tiered mentoring community was to provide the students with representation of others who are experiencing similar issues and provide training for mentors to be more capable of guiding these students through the issues they face. The first research question assessed the formation of this community. Community formation was assessed by observing mentoring relationship scores and listening to student feedback regarding the collaborative activities. Mentoring relationship scores ranging from "very good" to "excellent" on average for both graduate student mentors and faculty advisors provided evidence that the community was multi-tiered. The 2023 undergraduate programs did rate the mentoring relationships lower, but written feedback from the students does indicate quality relationships were still formed. The pattern may indicate the need for the program to provide structured interactions between the students and their advisors. Further, no observed significant differences among scores between women and men, White and Black students or African American, Hispanic or Latino, and American Indians or Alaska Natives students, and first-generation and non-first-generation students suggested the formation of a community where all participants benefitted. Age, college/university, and point in STEM education timeline were also not important to the students as evidenced by the lack of significant differences across programs. In addition to survey results that described the formation of this community, students in both 2022 and 2023 programs provided specific feedback that working with partners and peers from the MAST center community made research more approachable and interesting. Feedback collected from the LSRM programs described the community activities, such as weekly meetings and post-program mentoring sessions, as some of the most valuable parts of the program. Both feedback and survey scores are in agreement suggesting the mentoring initiatives were effective in forming an inclusive community no matter the students or program.

An accessible experience strengthened by a multi-tiered mentoring community was hypothesized to lead to identity development within STEM, a strong indicator for future success in a STEM degree and career. As such, the second research question addressed the larger goal of the program to develop the students' STEM identity during the program. The program observed increased self-efficacy and belonging within STEM that translated to the students pursuing the additional opportunities needed to maximize their competitiveness on the job market or a graduate school application. The survey results show this increase in self-efficacy directly through the composite score made up of questions relating to the students' confidence in their abilities in the classroom and lab. This development is also indirectly shown by the students reporting they have gained skills valuable to their future pursuit of a STEM degree since they feel they are more aware of what these skills are. This self-efficacy improvement was also indirectly evidenced by the majority of LSRM students following through on presenting their research and pursuing additional research after the program without incentive from the program to do so. High school students also reported an increased desire to enroll in a university STEM program in both the survey and anecdotal evidence. This improvement to self-efficacy and associated follow up actions were independent of URM, first-generation, or returning status. The STEM identity these groups begin to form in this program may help them overcome barriers they currently face or will face in the future and is expected to assist the students dramatically with their resiliency in their pursuit of a STEM degree and career.

4.1 Study limitations and future opportunities

Limitations of this study relate to the small sample size of the students who participated. A small pool to pull from plus limited lab spaces for students forces a small sample size that does not provide sufficient data in a short timeframe, nor power to statistically analyze groups. The change in structure for the LSRM program between 2022 and 2023 was another limitation of the study. While the change provided opportunities for the maximum number of students and a more robust mentoring experience, it is difficult to pinpoint the most impactful components of the LSRM structure. Both limitations are addressed by continuing to track the scores of students who participate over a longer period capable of producing a more adequate sample size. Continuing to track the alumni of the program will also be important for this data, and as such more formal procedures will be put in place to ensure maximum data is collected. Additionally, procedures to limit program management turnover and keep measures constant over an extended period will also be implemented.

Another limitation of this study was the lack of a presurvey. Implementing a presurvey will allow for better understanding the change in research identity and career plans the students undergo during the program. While the students did rate themselves based on "the impact the program had on…," a presurvey component will provide a clearer view of the backgrounds the students come from and allow for the program to identify additional trends relating to the success of students from different initial interests and circumstances. Additional areas of improvement relate to addressing lower relationship scores in 2023 and feedback from the LSRM students. To increase the quality of mentoring relationships formed, additional mentoring resources and individual development plan worksheet will be developed. The additional mentoring resources will consist of a series of modules created by the NSF for URM and nontraditional student mentoring and will be provided to the faculty and graduate students participating in the program prior to the arrival of the students. These modules will be similar to the topics covered by the general mentor training but will be selected to be most relevant to the mentor based on the mentee they will be working with. An individual development program will structure interactions between the mentors and mentees and facilitate regular check ins that maximize the experience for the mentee. Feedback from LSRM program noted that mentoring sessions could increase industry involvement, and in the case of the HSLSRM program more standardization could be used for the experiments. Efforts to create an internship component for the LSRM students are ongoing that would greatly increase industry involvement in the program. A more in-depth document will be constructed for the HSLSRM program, designed to resemble a chemistry lab worksheet with a clear procedure and straightforward questions. Standardizing and clarifying the procedure should improve the quality of the data collected by the students.

Collaboration with other LSRM programs at national meetings has led to further initiative to form a network connecting participants and administration between programs. More formal events, such as regional LSRM meetings, will provide more chances for quality post-program engagement with the students and offer them more opportunities for professional growth. Connecting with the administrators of other LSRM programs can improve procedures, measures to give students quality interactions with their advisors are of particular interest. Tools such as LinkedIn and Slack will be utilized to facilitate these connections remotely, both between students and alumni of the program as well as connections between programs themselves. Ideally, a "job board" can be constructed for alumni of the program, and a repository of successful LSRM program practices can be formed.

5 Conclusion

One strategy to address the gap between the number of URM, first-generation, and returning students who obtain STEM degrees is to take efforts to increase their participation in research experiences. Typically, research experiences are not accessible to these demographics due to a lack of representation and understanding of the complex issues faced by these demographics. The MAST center created the LSRM programs to address these deficiencies through a multi-tiered mentoring community environment. Through partnerships with NWACC and Upward Bound, students with different ages and demographics were brought together from high schools local to NWA, NWACC, and outside research universities to form a multi-tiered mentoring community alongside mentors from the University of Arkansas. The LSRM program leveraged the fact that the students were local to provide them with further mentoring sessions typically not provided by REU experiences. It was found that initiatives that focused on peer mentoring and post-program mentoring led to a community environment that developed students' identities within STEM. This identity development included actions taken by the students to present their research and pursue additional STEM opportunities. The LSRM program reported a particularly high percentage of students who obtained additional research roles after the program. This study demonstrates the impact that a mentoring-first program design can have on students who otherwise would not have the confidence to pursue a STEM experience or degree.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants in accordance with the national legislation and the institutional requirements.

Author contributions

TM: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft. LB: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. GB: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. JW-M: Data curation, Formal Analysis, Writing – review & editing. SR: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported by the National Science Foundation through (Research Experiences for Undergraduates Site) 2150436 and Membrane Applications, Science and Technology (MAST) 1822101, 2207153, 2232063, 2310837, 2333332.

Acknowledgments

The authors would like to thank the students, faculty and graduate students who participated in the program. The authors would also like to acknowledge the NSF-REM program initiative for their mentor training and efforts to form a national mentoring network. The companies that supported the students are also greatly appreciated. Lastly, the authors would like to thank MAST center coordinators Heather Pollard and Sarah Bonner for their great administrative contributions that allowed the programs to run smoothly.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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