Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #48418

Advancing Equity in Biomedical Engineering Education: Insights from Clinical Observations and Needs-Finding Courses

Alyssandra P Navarro, University of Arkansas
Miss Jacquelynn Ann Horsey, University of Arkansas for Medical Sciences

Jacquelynn is a graduate of the Department of Biomedical Engineering and is currently pursuing an MD at the University of Arkansas for Medical Sciences.

Thomas Hudnall McGehee, University of Arkansas
Bryce Williams, University of Arkansas
Timothy J. Muldoon, University of Arkansas

Dr. Timothy Muldoon is an Associate Professor in the Department of Biomedical Engineering at the University of Arkansas. Dr. Muldoon teaches the Clinical Observations and Needs Finding, the Biomedical Instrumentation, and the Biomedical Microscopy courses within the Department, and also serves as the Undergraduate Coordinator. Dr. Muldoon's research interests include engineering education, miniaturized optical imaging and spectroscopy approaches for endoscopy applications, and metabolic imaging of the tumor microenvironment.

Dr. Mostafa Elsaadany, University of Arkansas

Dr. Mostafa Elsaadany is a Teaching Associate Professor in the Department of Biomedical Engineering at the University of Arkansas. He received his Ph.D. in Biomedical Engineering from the University of Toledo. Dr. Elsaadany teaches Introduction to Biomedical Engineering, Biomechanical Engineering, Biomolecular Engineering, Senior Design, and Entrepreneurial Bioengineering. He is active in Engineering Education Research, where he studies different mentoring strategies to ensure the academic and professional success of historically marginalized groups. Further, he studies strategies for instilling the entrepreneurial mindset in engineering students as well as innovative approaches to teaching, such as using virtual reality.

Advancing Equity in Biomedical Engineering Education: Insights from Clinical Observations and Needs-Finding Courses

Abstract:

Identifying clinical problems and developing practical solutions is central to biomedical engineering. To prepare students, our department developed a junior-level clinical and industry immersion course as a prerequisite for Senior Design. This service-learning course emphasizes real-world clinical observations and needs finding, aiming to enhance students' confidence and skills in applying their learning to clinical applications. Given the demographic composition in STEM fields, this study focused on assessing the course's impact on historically marginalized groups (HMG), including women, Black/African American, Hispanic, Native American, and first-generation students, compared to non-historically marginalized groups (NHMG). The underrepresentation of certain demographic groups in STEM fields, particularly engineering, presents persistent challenges in education and the workforce. HMG students often face unique barriers that hinder their learning experience, such as unwelcoming classroom environments, limited mentorship opportunities, and a lack of belonging and community. These disparities contribute to lower retention rates and confidence levels compared to NHMG students.

This study evaluates the impact of our junior-level clinical immersion course on HMG and NHMG students. Surveys were conducted pre- and post-course to gather students' perspectives, focusing on skill development, self-efficacy, and perspectives on healthcare disparities. Quantitative results indicated significant gains in confidence and skill development across all students, with HMG students showing greater post-course growth despite lower initial confidence. Improvements in HMG students include an 8% increase in students selecting "Strongly Agree" and a 20% increase in students selecting "Agree" post-course regarding confidence in engineering design. Females also showed greater improvements compared to males post-course, including skills like understanding customer perspectives. Qualitative analysis done with NVivo software highlighted that students greatly valued clinical exposure in enhancing their understanding of engineering processes and healthcare disparities. By identifying these disparities in the classroom, we aim to inform strategies for creating inclusive curricula that better support historically marginalized students, ultimately advancing diversity and equity in biomedical engineering education.

Introduction:

Need identification and solution development are two core skills biomedical engineering students must develop during their undergraduate education. While needs identification may occur through literature reviews and background research, in-person clinical experience is often more valuable [1], [2]. To increase clinical exposure in the curriculum, we have developed a junior-level Clinical Observations and Needs Finding course as a prerequisite to the Senior Design course. Our course is designated as a service-learning course, requiring students to complete immersive clinical visits with local healthcare and industry partners. In a previous study, the effectiveness of this course was evaluated through pre- and post-course surveys that utilized the Likert scale and open-ended questions. It was determined that the course successfully increased students' self-efficacy regarding the engineering design process, their ability to connect with customers, and their understanding of value creation.

The field of biomedical engineering manifests demographics that are not necessarily representative of the general population [3], [4]. As a result of this, historically marginalized groups (HMG) may experience disparate learning challenges in higher education and the workforce. Research has suggested several reasons why HMG students do not enter engineering disciplines or choose to leave, including unwelcoming climates, negative interactions with professors and peers, and a lack of belonging [5]. While some professionals have adopted a "colorblind" mindset in an attempt not to discriminate between students of different racial backgrounds, this has been shown to produce the opposite effect. By attempting to see past race, professors of historically non-marginalized groups (NHMG) inadvertently advantaged students of their own background [6]. Some schools have developed programs attempting to increase the feeling of belonging for HMG, but most of these interactions occur outside the engineering classroom [3].

In particular, a service learning course may be the answer to decreasing educational disparities between engineering students. Service learning is a distinctive approach that enhances students' learning by engaging them in meaningful and active community involvement. [7]. By engaging in their communities and observing disparities directly, students are developing a more culturally attentive engineering mindset when solving problems and showing an internal change in attitude [8]. Research has shown that participating in project-based service-learning courses, particularly in lower-income areas, promotes a more inclusive and discerning attitude in engineering students, encouraging them to recognize and respect both similarities and differences in others [8]. Changing students' societal and moral awareness through community involvement could foster a more inclusive and welcoming environment for HMG students. This study aims to quantify and evaluate the efficacy of a clinical observation and needs-finding course for HMG students to create a more welcoming and equitable learning environment.

Methods:

The University of Arkansas Institutional Review Board approved the study (IRB Protocol #: 2209420237).

Likert Survey Questions: To evaluate students' perceptions before and after completing the course, a Qualtrics survey was administered with 5-point Likert scale questions with answers ranging from "Strongly Disagree" to "Strongly Agree" and open-response questions to gain insights into student perspectives. The survey, conducted during the first and last weeks of the course, was distributed to all junior-level undergraduate students through 4 iterations of the course. Demographic data—including gender, race, ethnicity, and first-generation status—were collected at the start of the survey. Key questions assessed students' confidence in areas like communicating engineering solutions and making connections to real-world solutions. The raw data was categorized into HMG and NHMG based on these different demographics for analysis. HMGs were defined and categorized in the data as students belonging to historically marginalized groups in STEM, particularly in engineering, such as Black/African American, Hispanic, Native American, or female students, while NHMGs referred to those outside these categories. Quantitative responses were processed and graphically represented using Microsoft Excel to identify trends.

Thematic and Sentiment Analysis: For qualitative analysis, generative AI combined with manual frequency analysis was used to conduct thematic analysis, while NVivo software facilitated sentiment analysis of open-ended responses, minimizing researcher bias.

The thematic analysis consisted of a user-focused scan of the open-response data for themes based on frequency, followed by precise thematic analysis via generative AI. The manual frequency analysis was cross-referenced with the AI analysis to confirm the accuracy of the themes. Sentiment analysis was performed to determine the moods of the students' responses utilizing qualitative analysis software called NVivo. NVivo categorizes positive, negative, and neutral sentiments by auto-coding each word and analyzing the sentiment in isolation without contextual interpretation. The software recognizes words with a preexisting sentiment score in very negative, moderately negative, neutral, moderately positive, and very positive ranges. The score for each word determines its place on this scale; however, the score can change if preceded by a modifier (like "more" or "somewhat"). Words with a neutral sentiment are not coded [7]. The University of Arkansas Institutional Review Board approved the study (IRB Protocol #: 2209420237).

Results:

Quantitative: The survey results indicate differences in engineering-related responses between historically marginalized groups (HMG) and non-historically marginalized groups (NHMG). Survey questions prompted students to assess their proficiency in various engineering-related skills to quantify their confidence levels. Overall, average confidence levels for both groups increased after course completion, indicating a positive effect on student outcomes.

For example, Figure 1 shows a comparison of students by race into HMG students (black, American Indian/ Alaskan Native, and other) and NHMG students (white and Asian students). For engineering design, HMG students showed lower initial confidence but a more substantial shift toward higher confidence levels compared to NHMG, with an 8% increase in students selecting "Strongly Agree" and a 20% increase in students selecting "Agree" post-course. While HMG students showed higher confidence after taking the course, both groups showed improvement in designing products to solve real-world problems.

I can design products to solve a real-world problem.

(A) HMG vs. NHMG **(B)** Averages of HMG vs. NHMG

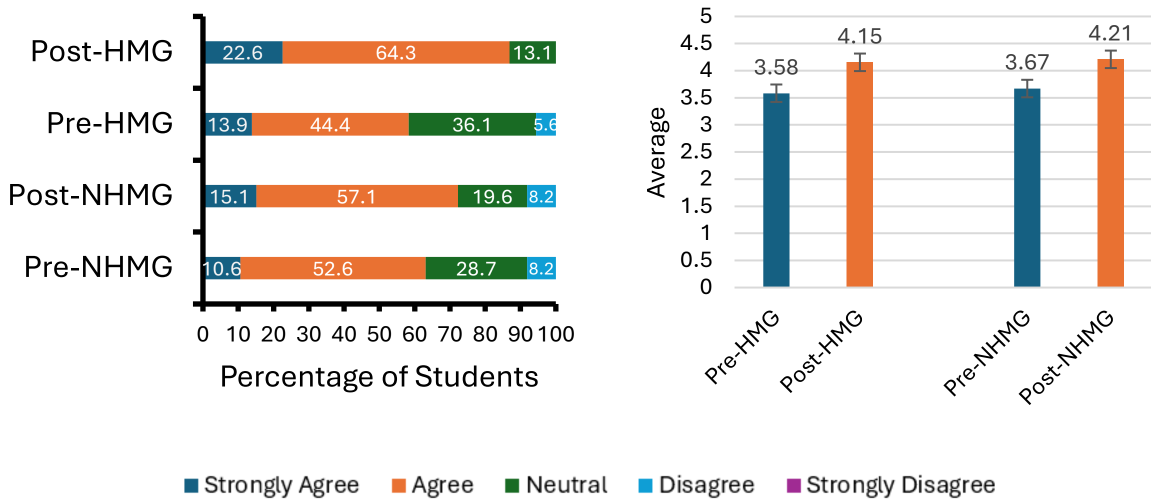

Figure 1. A) Confidence levels of HMG vs. NHMG students were categorized by race pre- and post-course regarding the design abilities of products that solve real-world problems. **B)** Overall average confidence level of HMG vs. NHMG students pre- and post-course on a 5-point scale. The error bars represent the standard deviation.

For the same question, HMG showed higher confidence increases compared to NHMG student groups post-course in other demographic comparisons. When looking at other marginalized vs. non-marginalized comparisons, the HMG groups post-course show larger differences in confidence regarding their design capabilities for producing products that could solve real-world issues. As shown in Figure 2, female students exhibited larger increases in confidence post-course than their male counterparts. Additionally, first-generation (FG) students demonstrated a more significant jump in highly confident responses and fewer "Disagree" responses post-course compared to continuing-generation students. HMG students' attitudes seem to shift to less neutral or disagreeing after the course, gaining confidence in their skills after being exposed to clinical or industry settings through the class.

I can design products to solve a real-world problem.

(A) Females vs. Males **(B)** FG vs. Non-FG

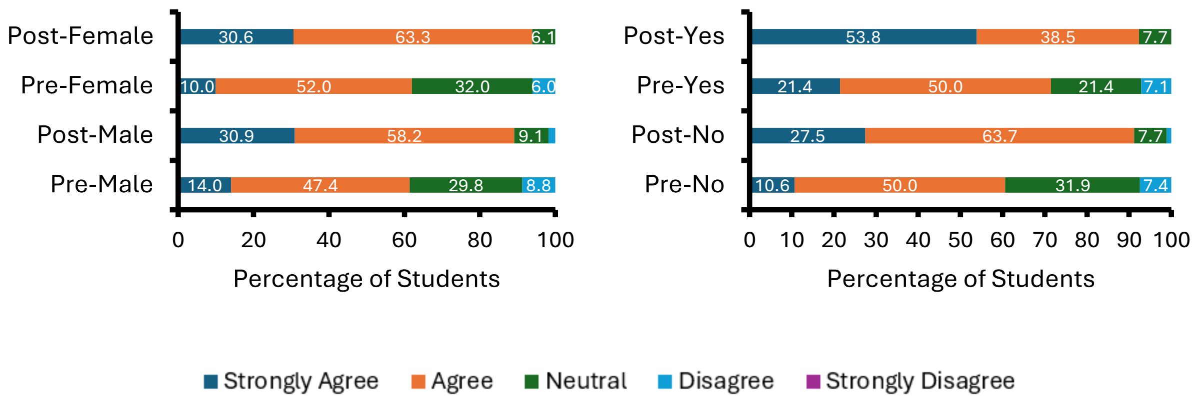

Figure 2. A) Confidence levels of Female vs. Male students pre- and post-course regarding design abilities of products that solve real-world problems. **B)** Confidence levels of First-Generation vs. Continuing students pre- and post-course regarding design abilities of products that solve real-world problems. The error bars represent the standard deviation.

Another area of improvement was understanding customer perspectives, shown in Figure 3, with HMG students showing the most significant growth. Female students outpaced male students in their improvements, with a higher increase in "Agree" and average confidence levels. In contrast, males remained relatively constant in higher confidence levels pre- and post-course, suggesting that the program promoted balanced skill development across gender lines. Females increased in "Agree" and "Strongly Agree" responses by approximately 22% as opposed to males, whose responses remained relatively unchanged.

I can understand the motivations and perspectives of customers.

(A) Females vs. Males **(B)** Averages of Females vs. Males

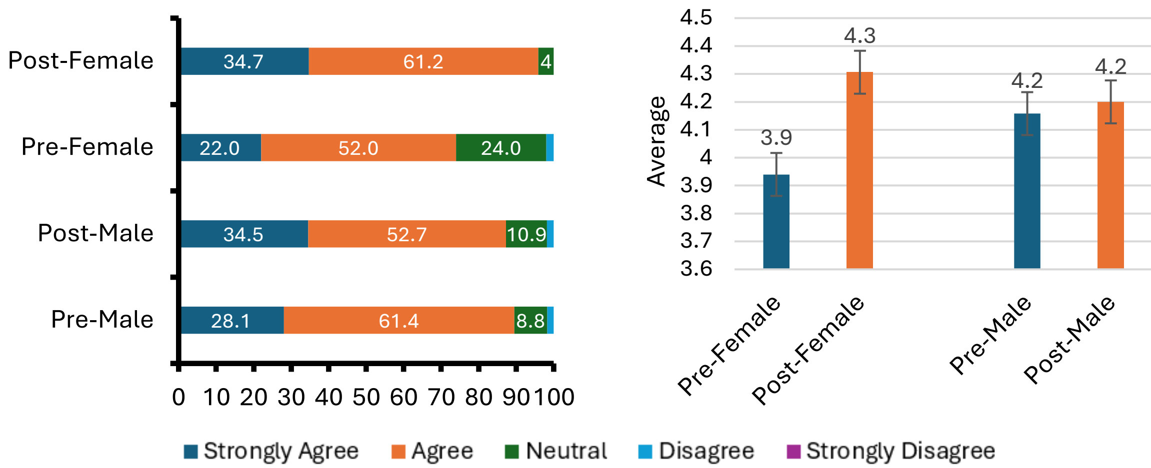

Figure 3. A) Confidence levels of Female vs. Male students pre- and post-course regarding understanding customer perspectives. **B)** Overall average confidence level of Female vs. Male students pre- and post-course on a 5-point scale. The error bars represent the standard deviation.

In team collaboration shown in Figure 4, although Hispanic students reported lower initial confidence, they reported a higher post-course confidence increase than non-Hispanic students. "Strongly Agree" responses for Hispanics increased by approximately 10% post-course compared to non-Hispanics, whose responses stayed relatively similar. FG students also exhibited a greater increase in collaboration confidence than continuing-generation students, despite lower initial levels, with 62% of FG students selecting "Strongly Agree" post-course, up from 42% pre-course.

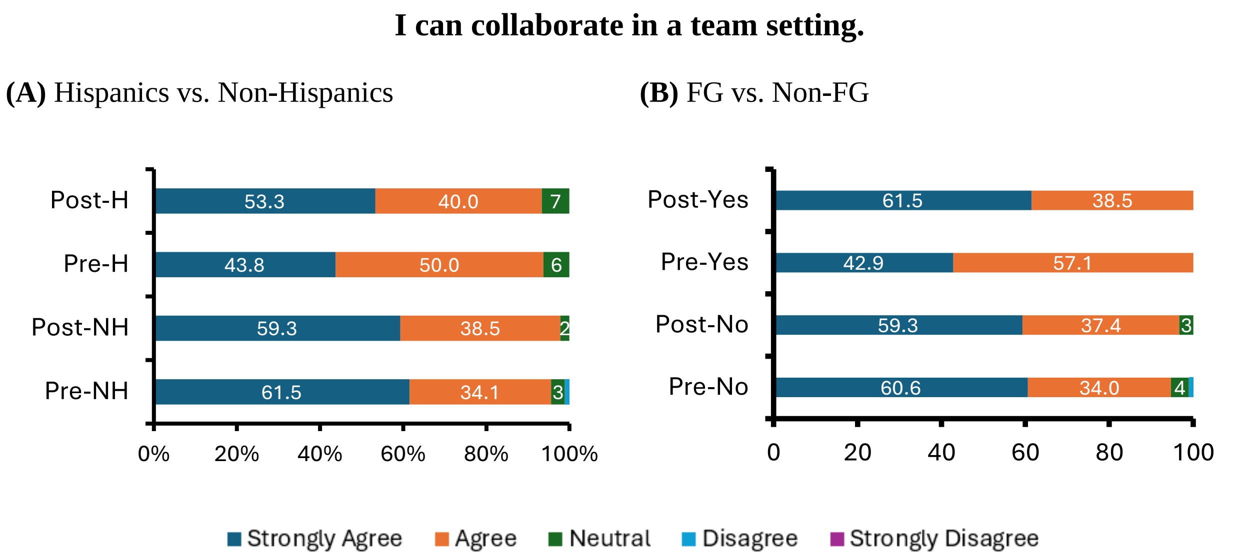

Figure 4. A) Confidence levels of Hispanics vs. non-Hispanic students pre- and post-course regarding team collaboration. **B)** Confidence levels of First-Generation vs. Continuing students pre- and post-course regarding team collaboration.

Qualitative: Three open-response questions were analyzed for common themes, and sentiment analysis was performed using NVivo, which quantifies positive, neutral, and negative sentiments of words, excluding context [9]. Question A asked the students how the course affected their knowledge/perception about implementing engineering solutions in clinical environments. Question B asked the students what they knew about service learning and its efficiency in biomedical engineering education. Lastly, Question C asked the students how they think the course can give back to the community and minimize local healthcare disparities.

<u>Thematic Analysis:</u> For thematic analysis, only the post-survey questions were analyzed to determine the course's impact on students.

The responses to Question A can be grouped into several common themes, including regulatory complexity and clinical integration. Many respondents indicated a greater understanding of the design and implementation process, including the engineering process's complexities, FDA regulations, and testing: "For an engineering solution to actually be implemented into a clinical environment, the process can be quite complex. I never realized the true complexity of FDA regulations/testing processes that are required for certain devices to be approved.". Students frequently cited gaining valuable real-world experience by visiting clinics, interacting with healthcare professionals, and identifying problems for themselves. One student mentions that the course "made me realize that the solutions we create are real and valuable in the clinics because they are based off problems from those clinics."

Overall, Question B's most common themes among respondents were binary, including a lack of awareness of service learning and service learning's potential. For those familiar with the concept, students concluded service learning as an effective tool for gaining hands-on experience, applying knowledge in a real environment, and interpersonal communication. One student's description of its effectiveness properly emphasizes this theme: "Service learning is a very effective tool in biomedical engineering. Medical devices/products are made to help people, so interacting with these people and getting their input on products is very important." Other responses signified the importance of service learning in understanding the needs of patients and clinicians. Students saw this as a way to bridge academic learning with practical, community-based applications, which could enhance their ability to solve biomedical engineering problems; however, most students claimed to be unaware of service learning in general.

Regarding Question C, the most commonly reported themes included identifying healthcare disparities and innovative solutions. Respondents noted that the course provides plentiful exposure to real-world problems. The course provided exposure to healthcare disparities by visiting clinics, shadowing healthcare professionals, and understanding the challenges faced by both providers and patients: "We see healthcare disparities firsthand by shadowing clinics in the community.". Another common theme was the improved ability to generate innovative solutions, a vital skill for creating cost-effective Senior Design projects that address healthcare disparities. Many students emphasized the importance of minimizing costs in healthcare solutions, as "one of the main things we focused on during this class with final projects is minimizing costs, which is extremely important in healthcare. By making things cheaper, healthcare might be more affordable to the surrounding community." Students recognized that affordability is key in making medical innovations accessible to communities facing disparities.

Sentiment Analysis: Sentiment analysis results using NVivo are shown below.

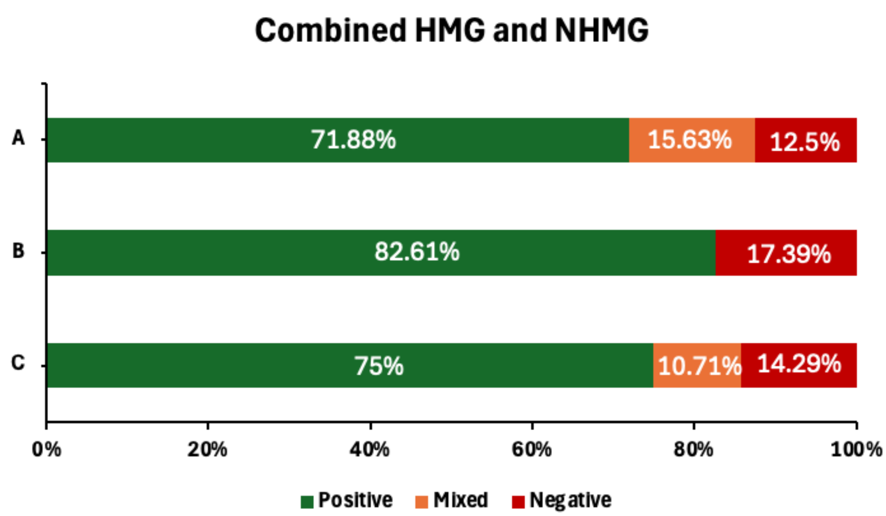

Figure 5: Comparison of sentiments among combined HMG and NHMG post-survey student responses to open-response questions A-C. **A)** How has the clinical needs finding course affected your knowledge/perception about how engineering solutions are implemented in a clinical environment? **B)** What do you know about service learning? If you know anything about service learning, can you comment on how it may/may not be an effective tool in Biomedical Engineering Education? **C)** How do you think the Clinical Needs Finding course can help with giving back to the community to minimize the local healthcare disparities?

Regarding the impact of this course on the students' knowledge of clinically applied engineering solutions, as shown in Question A, most respondents had a positive view, suggesting the course effectively increased their knowledge or improved their perception of how engineering solutions are implemented in clinical environments. The smaller portion of negative sentiment may correspond to gaps in the course's content or challenges in understanding the course's goals. When students were assessed on their knowledge of service learning in Question B, most responses were positive, implying that participants believe it is an effective tool in biomedical engineering education. The few indications of negative sentiment mostly correspond to a lack of awareness of service learning. Regarding the course's effect on giving back to the healthcare community in Question C, the overwhelmingly positive sentiment indicates that students see significant potential for this course to support these communities. The lack of negative sentiment supports this conclusion, as very few concerns exist. While these graphs do not compare the students' perspectives of the course before and after, they still provide relevant information about the general efficacy of the course. The majority of positive sentiment allows conclusions to be drawn that the course has positively affected students' perceptions of engineering solutions, provided knowledge of and about the benefits of service learning, and its impact on the healthcare community.

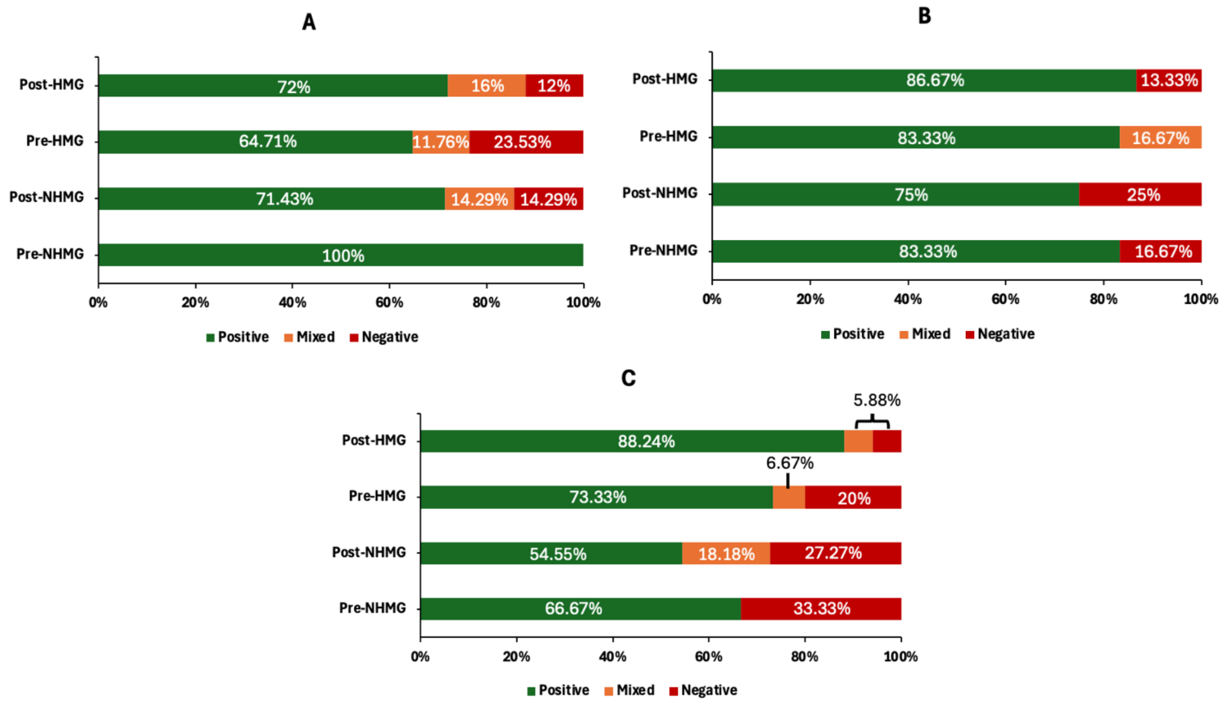

Figure 6: Comparison of sentiments between the pre- and post-survey student responses to individual open-response questions A-C, differentiating by HMG and NHMG groups.

For HMG students, analysis of question A shows that the increase in positive and decrease in negative sentiments suggests the course strengthened students' confidence and clarity regarding engineering implementation in healthcare. In question B, the growth in positive sentiment indicates an improved understanding of service learning's relevance in Biomedical Engineering; however, the transition from mixed to negative sentiment signifies a lack of awareness among a few students. Question C shows that the significant increase in positive sentiment and decrease in negative sentiment reflect the course's success in reinforcing appreciation for engineering's role in addressing healthcare disparities. For NHMG students, question A reveals that the decrease in positive sentiment and emergence of mixed and negative sentiments suggests students initially had strong perceptions of engineering in healthcare. Still, some struggled to connect course content to real-world applicability. In question B, the decrease in positive sentiment and increase in negative sentiment indicate an incomplete understanding of service learning among NHMG students. Finally, question C shows that the reduction of both positive and negative sentiments and the emergence of mixed sentiment imply the course may not have sufficiently addressed its impact on local healthcare disparities for this group.

Discussion:

This longitudinal study aims to track the effectiveness of the Clinical Observations and Needs Finding course over time. Current data suggests that while HMG students succeed in the course by growing in confidence, they enter with differing, less confident mindsets than their NHMG counterparts. This study sheds light on critical disparities in confidence levels between HMG and NHMG students, offering insights into the role of targeted educational interventions. The data illustrate that while the Clinical Observations and Needs-Finding course improves confidence and skill development across all demographics, it also highlights systemic gaps that require attention to ensure equitable outcomes. While these results demonstrate the course's ability to create opportunities for historically marginalized groups to excel, initial disparities suggest a need for additional support for HMG students before the course.

The study's limitations include small sample sizes for specific subgroups and reliance on self-reported data, which may introduce bias. Expanding this research to include multiple institutions would provide a more comprehensive understanding of these dynamics. Furthermore, longitudinal tracking of students beyond the course could offer insights into how confidence gains translate into career readiness and retention in biomedical engineering fields.

In conclusion, the course demonstrates its potential as a tool for fostering confidence and skill development among historically marginalized student groups. However, addressing the systemic disparities revealed in this study requires a holistic approach, including culturally responsive teaching practices, mentorship opportunities, and targeted outreach to historically marginalized communities. By implementing these strategies, biomedical engineering programs can better prepare all students for success while promoting diversity and equity in the field.

References:

[1] B. Przestrzelski and J. D. DesJardins, "The DeFINE Program: A Clinical Immersion for Biomedical Needs Identification," presented at the 2015 ASEE Annual Conference & Exposition, Jun. 2015, p. 26.1514.1-26.1514.16. Accessed: Jan. 18, 2024. [Online]. Available: https://peer.asee.org/the-define-program-a-clinical-immersion-for-biomedical-needs-identification

[2] M. Kotche, "Clinical Immersion Internship Introduces Students to Needs Assessment," presented at the 2016 ASEE Annual Conference & Exposition, Jun. 2016. Accessed: Jan. 18, 2024. [Online]. Available: https://peer.asee.org/clinical-immersion-internship-introduces-students-to-needs-assessment

[3] M. Ong, J. M. Smith, and L. T. Ko, "Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success," *J. Res. Sci. Teach.*, vol. 55, no. 2, pp. 206–245, 2018, doi: 10.1002/tea.21417.

[4] K. C. Thiem and N. Dasgupta, "From Precollege to Career: Barriers Facing Historically Marginalized Students and Evidence-Based Solutions," *Soc. Issues Policy Rev.*, vol. 16, no. 1, pp. 212–251, Jan. 2022, doi: 10.1111/sipr.12085.

[5] S. C. Davis, S. B. Nolen, N. Cheon, E. Moise, and E. W. Hamilton, "Engineering climate for marginalized groups: Connections to peer relations and engineering identity," *J. Eng. Educ.*, vol. 112, no. 2, pp. 284–315, Apr. 2023, doi: 10.1002/jee.20515.

[6] M. G. Eastman, M. L. Miles, and R. Yerrick, "Exploring the White and male culture: Investigating individual perspectives of equity and privilege in engineering education," *J. Eng. Educ.*, vol. 108, no. 4, pp. 459–480, Oct. 2019, doi: 10.1002/jee.20290.

[7] M. Jawaharlal, U. Fan, and S. Monemi, "Implementing Service Learning in Engineering Curriculum," presented at the 2006 ASEE Annual Conference & Exposition, Jun 2006, pp. 11.729.1 - 11.729.11. [Online]. Accessed: Feb. 17, 2025. Available: https:// https://peer.asee.org/implementing-service-learning-in-engineering-curriculum

[8] A. Bielefeldt, K. Paterson, and C. Swan, "Measuring the Value Added from Service Learning in Project-Based Engineering Education", *Int. J. Eng Ed.* Vol. 26, No. 3, pp. 535–546, Jan. 2010, [Online]. Accessed: Feb. 17, 2025

[9] "How auto coding sentiment works," NVivo 11 for Windows Help - How auto coding sentiment works, https://help-nv11.qsrinternational.com/desktop/concepts/How_auto_coding_sentiment_works.htm (accessed Jan. 5, 2025).