

BOARD # 24: Work In Progress: Health Disparities in Biomedical Engineering Curricula

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Introduction

There is a need for biomedical engineers to address health disparities (HD), which are defined as preventable health differences among historically marginalized groups (i.e., racial and ethnic minorities, women, rural communities, low-income individuals, older adults, etc.). A myriad of problems create HD, such as economic factors, healthcare access, environmental factors, education, and poor quality of care [1]-[4]. Although significant progress has been made towards improving people's health and well-being, the severity of the COVID-19 pandemic and world crises have further widened HD [5]. Biomedical Engineering (BME), which has always played a key role in the healthcare system, presents a solution to address HD by training engineers to understand HD and create engineering solutions to approach them [6], [7]. However, not all engineering solutions have equity in mind. For example, some pulse oximeters cannot accurately detect oxygen saturation in darker skin tones [8]. This highlights the importance of ensuring that future biomedical engineers are aware of HD.

In undergraduate BME education, students learn how to apply engineering principles and methods to address problems in the healthcare system. To prepare a BME workforce ready to solve modern-day healthcare problems, topics of HD should be accessible in the undergraduate curricula. Across the nation, faculty are incorporating HD into their courses, as evidenced by the literature [9]-[17]. However, much existing research focuses on a single course and, not all faculty have the capacity to share their work with the broader BME education community. Therefore, there is a need to examine the extent to which HD are incorporated across a wide array of courses, ensuring a more comprehensive understanding of how these topics are incorporated in BME undergraduate curricula.

This work in progress shares ongoing work from an exploratory case study investigating how existing BME courses incorporate HD. The research questions are as follows: 1) How do current BME undergraduate courses incorporate HD topics into their course content? And 2) From faculty perspectives, how are HD topics addressed in their courses

Literature Review

A scoping review found nine papers that examined how BME undergraduate courses addressed HD. The review revealed that the incorporation of HD often happens in a single course as opposed to multiple courses across the four-year curriculum. While two papers focused on incorporating HD throughout the four-year curriculum [9], [17] and one described a global health disparities minor [16], the remaining six papers focused on individual courses at different stages of the curriculum (first year [10], [15], middle years [12]-[15] and last year [11], [15]). Additionally, approaches to incorporating HD vary. Some studies introduced HD topics as additional modules in a course [10], [11], [15] whereas some studies incorporated HD topics in lesson plans and assignments [9], [13], [14], [17]. However, the specific topics and content included throughout the semester was rarely the focus of these papers, which can make it difficult for interested departments and faculty to update their own curriculum. This lack of information can be attributed to the motivations of papers assessing students' knowledge of topics rather than how students were taught HD. Lastly, three papers highlight cross-disciplinary courses that include both BME students with peers from other disciplines [11], [12], [15], suggesting there are diverse approaches to enhancing students' understanding of HD.

Theoretical Framework

This work is guided by Lanier and colleagues' [7] "Ten Simple Rules in Biomedical Engineering to Improve Healthcare Equity" (see Appendix A). These rules are guided by three main principles: 1) Improving diversity and equity in STEM; 2) Increasing research on underserved communities; and 3) Considering diverse communities in the research design process. The model was originally created to be used by biomedical engineers to give practical solutions for incorporating healthcare equity in their work. While it has not been used as a theoretical framework in educational research, it is useful in conveying topics related to HD. For this study, it will serve as guidance for what HD topics should be conveyed in BME courses.

In addition to knowing what HD topics should be conveyed, there is a need to define curriculum as there can be ambiguity. Lattuca and Stark [18] conceptualize the term as an "academic plan" where the curriculum is an intentional planning process that addresses the needs of students. Each element of the academic plan can be evaluated at a course, program, or college level [18]. For this study, evaluation will happen at the course level. Within an academic plan, there are eight components of curriculum that need to be considered: purposes, content, sequence, learners, instructional processes, instructional resources, assessment and evaluation, and adjustment [18]. Each component is incorporated into the research design.

Methods

Yin's [19] case study methodology was used to plan the research activities. There are six phases: 1) plan, 2) design, 3) prepare, 4) collect, 5) analyze, and 6) share (see Appendix B). The focus of this paper is on the first three phases.

Plan: The plan phase focused on determining if case study methodology is compatible with the proposed study and forming the research questions. Based on these findings of the scoping review, multiple-case study was chosen as the methodology. This study will examine a wide array of course types, focus on individual courses as opposed to the whole curriculum, and incorporate interviews of faculty of the courses examined. Given the varying types of engineering courses within the curriculum (i.e., first-year, technical, elective, design, etc.), this approach allows for a more complex and nuanced understanding of how different courses shape the curriculum, as each course type may require differing attention. Additionally, case study methodology involves in-depth examination of the phenomena, so both course material and interviews, are needed for data collection. Lastly, the main- and sub-research questions were informed by Lattuca and Stark's eight components of the curriculum (see Appendix C).

Design: The design phase focused on finalizing the research design, which entailed scoping the study, determining the cases that will be studied, and determining the units of analysis for each case. Lattuca and Stark's [18] framework was used to scope the study. The authors define an academic program as a group of courses and experiences designed for a specific subset of students [18]. In this study, an academic program is undergraduate BME, which serves students completing a Bachelor of Science in BME. Using this framing, eligibility criteria were created for the courses and faculty studied (See Appendix D). The embedded units of analysis are course content and faculty perspectives (See Appendix E).

Prepare: The preparation phase entailed developing the research protocol, completing the necessary research training, gaining the necessary IRB approval, and conducting preliminary

interviews. Informed by Lattuca and Stark [18], it was determined that the following data from each course will be collected: program descriptions, program requirements, course descriptions, course activity material, and syllabi. The material will collectively address RQ1. This data will be analyzed using content analysis [20], [21], which is commonly done in curriculum and case study design research [22]-[25]. Semi-structured interviews [26] will be conducted with faculty of the courses examined in RQ2 and will be analyzed using Braun and Clarke's [27] thematic analysis. A codebook was created using a priori codes guided by the theoretical frameworks (See Appendix F). This work was deemed exempt from further review by the Georgia Institute for Technology IRB. Information about preliminary interviews is in the following section.

Preliminary Interviews

To plan the study, preliminary interviews were conducted with BME faculty who have either a) worked on curricular change and/or b) have incorporated health equity topics into a course. These faculty were identified via snowball sampling. In the interviews, faculty were asked about their current work on incorporating health equity in their courses and/or curriculum, providing feedback on the study design, and BME faculty and departments who they know are doing similar work are currently doing health equity work, which will be used for sampling participants. Based on preliminary interviews, some changes were made to the study design.

Originally, the study aimed to examine four-year curriculums across different BME academic programs. However, faculty stated it was often difficult to get other faculty at their institutions on board with making changes to their courses. Therefore, it was decided to only look at individual courses and only sample courses that have successfully incorporated HD topics. This allows for a more in-depth analysis of individual courses and can provide examples for faculty who want to incorporate HD topics. From these preliminary interviews, approximately 20 people from 8 universities were identified as potential research participants for the main study. Lastly, the preliminary interviews helped refine the interview protocol (See Appendix G). Overall, these interviews were helpful in finalizing the research design.

Next Steps

Future work includes the last three phases of Yin's [19] case study methodology: collect, analyze, and share. The collect phase is collecting data for each case (i.e., documentation, interviews), creating a case study database, and establishing a chain of evidence to draw conclusions. The analyze phase is the data analysis, which focuses on developing the analytic strategy and analyzing the data for each case. Lastly, the share phase focuses on sharing the results with the necessary audiences, such as BME educators and education researchers.

Conclusion

The findings of this study will provide a deeper understanding of how BME faculty incorporate HD topics in their courses, providing a blueprint for how to include these topics in course design. As a product of this work, a publicly accessible guidebook will be created for BME programs and educators to assess if their own courses effectively incorporate HD topics, along with providing best practices for ways to incorporate HD. By incorporating HD in BME courses, we can aid in developing engineers who are socially conscious and driven to make an impact in society. These engineers will then be better prepared to address HD, improving not only representation in BME, but also emphasizing equity in healthcare industries and research.

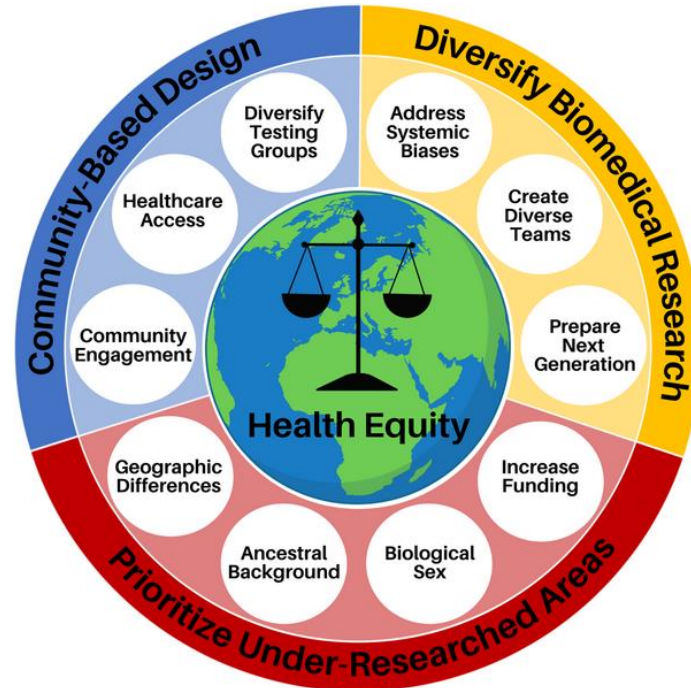
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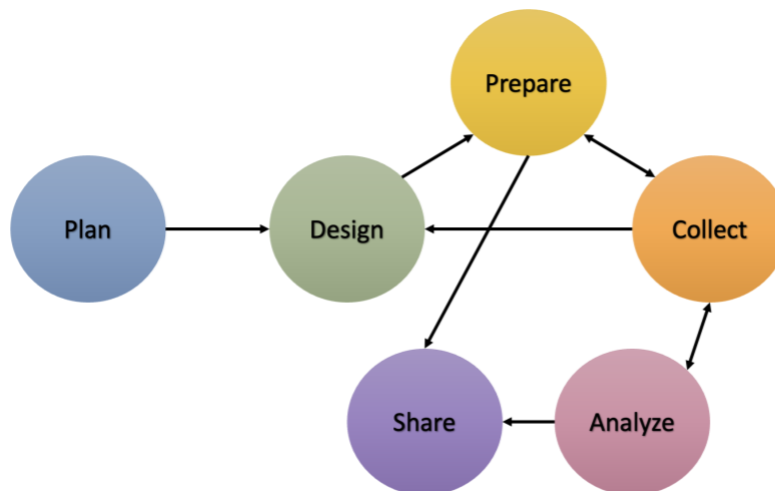
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Appendices

Appendix A: Lanier and colleagues' [7] “Ten Simple Rules in Biomedical Engineering to Improve Healthcare Equity”

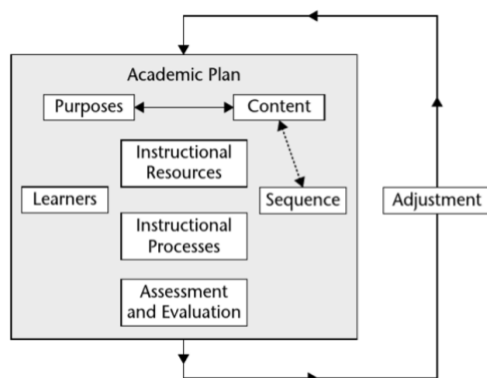


Appendix B: Yin's [19] process for conducting a case study



Appendix C: Sub-research questions along with diagram showing how each research sub-question incorporates elements of the academic plan

- **RQ1.1:** What learning objectives and missions related to HD are in BME coursework?
- **RQ1.2:** How is the subject matter arranged in courses to facilitate learning of HD topics?
- **RQ1.3:** How are HD topics incorporated into the content and instructional resources of BME academic programs?
- **RQ2.1:** How do faculty incorporate HD topics into their instructional processes?
- **RQ2.2:** How do faculty evaluate and assess their courses to increase students' knowledge of HD?
- **RQ2.3:** From the perspectives of faculty, what educational outcomes related to HD should be achieved by BME students because of their academic plan?

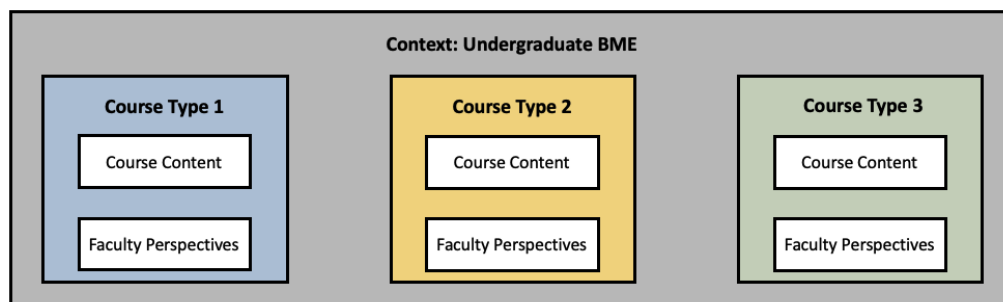


Research Sub-Question	Academic Plan Element(s)
<i>RQ1.1</i>	Purpose
<i>RQ1.2</i>	Sequence
<i>RQ1.3</i>	Content & Instructional Resources
<i>RQ2.1</i>	Instructional Processes
<i>RQ2.2</i>	Evaluation & Adjustment
<i>RQ2.3</i>	Learners

Appendix D: Eligibility criteria for study participants

- Are a faculty member (tenure-track or non-tenure-track) teaching in a BME department.
- Have taught an undergraduate BME course.
- Have incorporated topics related to health disparities, including healthcare disparities or health equity, in your course.

Appendix E: Diagram illustrating the case study design, specifically the context, cases, and units of analysis.



Appendix F: Preliminary codebook created using theoretical frameworks

Health disparities	Discusses health disparities more broadly and the problems that need to be addressed
Systemic biases	Communicates systemic biases (i.e., racism, sexism, heterosexism, ageism, ableism, classism, etc.) that contribute to health inequities and
Diverse teams	States there is a need to have diverse teams that reflect the patient population and create inclusive environments
Next generation of engineers	Discussion of preparing the next generation of engineers to address health disparities
Historically marginalized groups	States there are diseases that affect historically marginalized groups. Can also talk about the research on this topic and the need to increase funding for this research
Biological sex differences	Biological sex-based determinants of health
Ancestral origins	Ancestral genealogical origins as a tool to study health outcomes
Environmental effects	The impact of geographical and environmental effects on overall health and health disparities
Community engagement	The importance of community engagement and research designs that promote community engagement
Access in design process	Considers access to healthcare in the design process
Diversity in testing populations	The need for diversity in testing populations in research

Appendix G: Final semi-structured interview protocol

Thank you for taking the time to participate in this interview. This study explores how health disparities are incorporated into biomedical engineering (BME) courses. The goal of this interview is to understand what BME faculty perspectives on health disparities in relation to biomedical engineering curriculum are.

With your permission, this interview will be recorded and transcribed for accuracy. Do you consent to being recorded? Do you have any questions before we begin?

Interview Questions:

1. Course and Teaching Background

- Can you briefly describe the course you teach that includes content on health disparities?
- What motivated you to incorporate health disparities into your course?

2. Teaching Strategies and Learning Activities

- a. What learning activities do you use to integrate health disparities into your course?
 - b. Can you provide an example of a specific lesson or project you use?
 - c. How do you engage students in discussions or critical thinking about health disparities in BME?
- 3. Challenges and Barriers**
- a. What are some challenges you face when incorporating health disparities into your course?
 - b. Have you encountered any resistance from students, faculty, or administrators? If so, how have you navigated these challenges?
- 4. Assessment and Evaluation**
- a. How do you assess and evaluate student learning related to health disparities?
- 5. Student Impact and Outcomes**
- a. Based on your experience, what are your perceptions of students' knowledge of health disparities as a result of taking your course?
 - b. Have you noticed any changes in students' attitudes, engagement, or understanding over time?
 - c. What key educational outcomes related to health disparities do you believe students should achieve in a BME curriculum?
- 6. Closing and Additional Thoughts**
- a. Is there anything else you would like to share about your experiences incorporating health disparities into your teaching?
 - b. Do you have any recommendations for other faculty looking to integrate these topics into their courses?

Conclusion:

Thank you for sharing your insights. Your perspectives are valuable in understanding how health disparities are incorporated into BME education. If you have any questions or would like to follow up, please feel free to contact me via email.