Work in Progress: A Multi-level Undergraduate Curricular Approach to Exploring Health Equity in Biomedical Engineering Solutions

Jennifer M Hatch, Indiana University-Purdue University Indianapolis

Jennifer Hatch is a Lecturer of Biomedical Engineering at Indiana University-Purdue University Indianapolis (IUPUI). She earned her BS and MS in Biomedical Engineering from IUPUI.

Dr. Steven Higbee, Indiana University-Purdue University Indianapolis

Steve is a Clinical Associate Professor of Biomedical Engineering at Indiana University-Purdue University Indianapolis. He received his PhD in Bioengineering from Rice University (Houston, TX) in 2013, after earning his BS and MS degrees from Purdue University (West Lafayette, IN).

Ms. Danka Maric, Indiana University-Purdue University Indianapolis

Danka Maric is a Research Associate at the STEM Education Innovation and Research Institute (SEIRI). Her research interest center around how psycho-social factors interact with student learning and promoting diversity and inclusion in STEM education. She has expertise in quantitative research methodology and has developed a special interest in measurement during her time at SEIRI. She also works on faculty development through several of SEIRI's initiatives. This includes acting as the grant facilitator for the SEIRI Seed Grant program and supporting STEM faculty on STEM education research projects.

Dr. Sharon Miller, Purdue University

Sharon Miller, PhD, is an Associate Professor of Practice in the Weldon School of Biomedical Engineering at Purdue University. She received a BS degree in Materials Science and Engineering from Purdue University and MS and PhD degrees in Biomedical Engineering from the University of Michigan. Her educational efforts focus on biomedical engineering discipline-based educational research, including design self-efficacy, project-based learning, critical reflection in ethics, and high-impact practices.

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Introduction

Motivation: Health equity entails reducing health disparities to provide all people an equally high standard of health [1]. Biomedical Engineering (BME), with further emphasis on health equity throughout the design process, is well-positioned to produce medical innovations that improve health and address inequities. Specifically, medical innovators and educators are called to include consideration of health care access at all stages of design [2]. As such, BME educators have begun to identify ways to integrate health equity throughout undergraduate curricula ([3], [4]). Outlining broad integration of health disparity modules within core courses may impel programs to consider curricular revision, though this can also be limiting without detailed examples on how to implement in the classroom. Alternatively, case studies may identify medical innovations, such as wearable devices in digital health, that introduce health inequities [5], but may not be enough for students to engage in broader integration of health equity consideration during the design process. Few have reported easily adopted curricular approaches for BME students to explore health equity in biomedical engineering solutions that have demonstrated efficacy through evidence-based research.

In our role as undergraduate BME educators, we aim to help students build cultural and social competencies in tandem with integrative engineering skills. To initiate this work, we strive to identify baseline student knowledge of health equity and design using a discipline-based research approach. This work in progress shares our curricular approach to address the guiding question: *How do students describe health equity considerations when exploring engineering design?*

Pedagogical Approach: Our multi-level undergraduate assignment, grounded in Universal Design and Biodesign principles, engages first- and third-year BME students with health equity in design. Universal Design (UD), as defined by Ronald Mace, is a process that aims to create products and systems that are accessible and usable by as many people as possible [6]. The UD characteristics of usable, accessible, and inclusive [7] are encompassed in seven design principles: equitable use; flexibility in use; simple and intuitive use; availability of information; tolerance for error; low physical effort; size and space for approach and use; and aesthetic and minimalist design [8]. Biodesign is a method of training future health technology innovators that was founded at Stanford University [9]. This approach engages medicine, engineering, and business in a curriculum that challenges participants to identify (needs finding and screening), invent (concept generation and screening), and implement (strategy development and business planning) [10]. A recently developed diversity, equity, inclusion, and justice (DEIJ) toolkit for the Biodesign process provides curriculum developers and instructors with information on diverse team building, challenges in developing medical technologies for all, and techniques to implement DEIJ in the design process [11]. Our work leverages principles of UD and Biodesign to introduce first-year BME students to accessibility and equity vocabulary and to challenge third-year BME students to integrate health equity as a necessary component of biomedical design.

Methods

We are evaluating coursework and focus group responses from BME students to capture their baseline knowledge of health equity in design. Our multi-level assignment introduces first-year students to the terms used in discussions of health equity and encourages them to engage with the

idea of health equity as a critical component of design. Third-year students are challenged to build upon work from first-year students by implementing the design process through the lens of health equity. Below, we outline further details of the assignment, student focus group, and outcomes. All data were collected with student consent, with approval from the [University Redacted] Institutional Review Board (#20607).

Student Assignment – Exploring Health Equity in Biomedical Engineering Solutions: A two-part assignment, rooted in principles of UD and informed by the DEIJ Biodesign toolkit, guides students through an exploration of health equity in engineering. Part One is delivered in a first-year introductory engineering course. After instruction on Universal Design, teams of 2-3 students research the history, function, and fabrication of a biomedical device or therapeutic, and then each student analyzes the strengths and weaknesses of product design with regards to social, cultural, economic, and environmental considerations. Part Two is delivered in a third-year professional development and design course. The background research generated by first-year students in the fall semester is handed off to groups of 2-3 third-year BME students in the spring semester who explore the device or therapeutic through the lens of Biodesign. Using the online resource 'A Student Guide to BIODESIGN' [12] students research medical device classification, prior art, and cycle of care for their device, then perform stakeholder and gap analyses. 'Consider statements' are used as points of reflection to push student teams to think about all stakeholders, to document if proposed solutions reach underserved populations, and to consider underserved communities during market research and analysis.

Student Focus Groups: Student focus groups led by an external evaluator were used at three timepoints to assess student exposure to, and knowledge of, health disparities. Twenty, first year BME students aged 18 – 20 participated after completion of Part One of the assignment. Twelve, third-year BME students aged 20 – 23 participated in the remaining two focus groups. The focus groups were conducted during class, audio recorded, and transcribed for analysis. Students who arrived late, or were under the age of 18, were not allowed to participate.

Measured Outcomes: First-year students are evaluated on their ability to recognize groups which may be excluded from use of a product/therapy, cost differentials and their causes, and barriers to use in response to prompts. Third-year students will be evaluated on their abilities to scope and refine a user need, evaluate an entire cycle of care to identify stakeholdersand to determine to what degree proposed solutions address the user need.

Preliminary Results & Future Directions

In fall 2023, first-year student groups researched the history, fabrication, and function of ten biomedical devices/therapies ranging from the Band-Aid® to the X-ray machine. When reflecting on existing inequities in the history, fabrication, or function of the device, students identified that groups may be excluded from use of a device by mobility limitations, lack of insurance or money for treatment, insufficient time off for treatments and trainings, limited access to specialists or facilities, or cultural social stigma. Students recognized that cost of treatments varied by level of insurance and by country of residence and that other barriers to care were listed as concerns about danger of treatment, inability to read or understand directions based on language or literacy, and lack of access to follow-up care. Table 1 summarizes student responses, including representative quotes and the frequencies with which students adequately addressed the given prompt.

Preliminary analysis of the first-year focus group mirrored the assignment reflections, as six key themes were identified: the role of biomedical engineers, defining health equity, defining health disparities, identifying reasons for health disparities, promoting health equity in BME, and identifying underlying biases in BME design. Students shared that a biomedical engineer's role in society is to improve patient care and quality of life, optimize human health, and ensure safety regulations. Health equity was defined by students as equal access to proper health care for all people no matter their race, gender, financial status, religion, country of residence, or sexuality. Another student defined health equity as health care resulting in equitable outcomes. Students defined disparities as different groups of people experiencing unequal health care access or unequal quality of health care received. A lack of consideration for differing experiences between groups was also noted. One illustrative example that was shared was the higher childbirth deathrates among Black mothers. Students noted myriad reasons for health disparities, including discrimination, bias, stereotyping, limited exposure to the issue, the insurance system, the lack of diversity in medical research, and policy. There was agreement that biomedical engineers play a role in promoting health equity and it is embodied in several ways, such as by creating devices that work and are optimal for all people. Considering the effects of patients' environments and cultures, access to resources needed to use a device, and recovery times were also cited as ways to promote health equity. When asked to identify underlying biases in BME design, students cited a simple lack of knowledge on certain issues, engineering teams lacking diversity, and one's internal biases.

Table 1. First-year Student Responses to Part-one of Health-Equity Assignment

Reflection Prompt	Frequency	Representative quotes from first-year student assignments
Are there specific groups the device will not work for?	(13 of 18) 72%	*"People with allergies to acrylic adhesives or natural resins might have a reaction to Band-Aids and might mean that those group of people couldn't wear Band-Aids®."*
Does [the cost] vary for different populations?	(9 of 13) 69%	*"The price can also vary depending on if a person has insurance, and how much of the cost a person's insurance is able to cover…In other countries around the world [EpiPens®] cost anywhere between 50 dollars to 150 dollars. This is a very big difference between the United States and any other country in the world."*
What other barriers to use might exist for different groups of users?	(6 of 7) 86%	*"Infants, very ill, old, or patients who have a hard time using their hands may find using an inhaler a challenge. Pushing down on the canister may pose a problem."*
Are there options on the market to overcome these barriers?	(5 of 7) 71%	*"Implementing telemedicine and remote consultation can improve access to X-ray interpretations, particularly in remote or underserved areas. Advances in technology have led to lower radiation doses during X-ray procedures, reducing potential risks to patients. There are also portable machines that allow for imaging in various healthcare settings, including mobile units that can reach underserved areas."*

Through the assignment and focus group, over 70% of first-year students demonstrated abilities to identify stakeholders, consider which communities may be underserved or not served by an engineering solution, and document how well existing products serve different communities. Our next steps involve assessing third-year student literacy on health equity issues through a baseline focus group, execution and evaluation of Part Two of the assignment, and completion of a final focus group to contextualize student work and to compare with results from first-year students.

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