Get in the Middle of it: A Study of Minoritized Engineering Student Experiences in a Solid Mechanics Course

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Rawan Aqel is an accomplished academic and professional in the field of civil engineering and mechanics. She earned her bachelor's degree in civil engineering with a minor in Business Administration. Her passion for engineering led her to pursue further studies, and she obtained a master's degree in civil engineering. She is currently a Ph.D. Candidate in Civil Engineering and Mechanics, demonstrating her commitment to advancing the field. Rawan has a strong foundation in the industry, with six years of valuable experience. Her expertise has been acknowledged by publishing multiple top journal papers, contributing significantly to the field's knowledge and development. Beyond her academic and professional pursuits, Rawan enjoys exploring the world through travel, which broadens her horizons and provides new perspectives. She also practices yoga, which not only promotes physical well-being but also fosters mental and spiritual balance. Rawan Aqel's journey in the world of civil engineering showcases her dedication to academic excellence and her contributions to the industry. Her passion for learning and her diverse interests make her a well-rounded individual who strives for excellence in her personal and professional life.

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Introduction

Minoritized students in engineering often encounter unique challenges and hurdles. These difficulties arise from numerous factors, including societal biases, lack of representation, and administrative barriers. The push for supporting students will not endure if we do not consider every student throughout our course curriculum.

This work-in-progress study will examine the supports and barriers for minoritized students enrolled in a fundamental engineering course at an urban, access-oriented, R1 university. Solid mechanics is one of the fundamental engineering courses at this institution and is crucial for the success of students pursuing careers in various STEM fields. However, minoritized students frequently encounter difficulties and barriers that can hinder their academic progress and success.

University and Course Context

The University of Wisconsin-Milwaukee (UWM) is an R1, urban, access-oriented university. Admitted undergraduate students are often from the surrounding city and state region. Additionally, students who graduate from this university get jobs in the area and promote regional prosperity. The solid mechanics course at UWM has undergone notable changes in the past two years. Originally, there were two distinct courses: statics and material mechanics. These two courses were identified to be combined because faculty in higher-level classes didn't think students needed the details from the material mechanics course to be successful. Additionally, the engineering departments were actively working to reduce the required number of course credits to complete an engineering degree. In this climate, the change to collapse two courses into one was made.

The new course, Solid Mechanics, covers a truncated version of statics and material mechanics to prepare students for higher-level dynamics and structures courses in their junior and senior years. Students are required to attend a lecture taught by a professor and a lab taught by a graduate teaching assistant (GTA) each week. Since the transition to one course, instructors, students, and TAs have noticed otherwise talented students are struggling in the new course. Our overall research project focuses on the student experience in this course through the grounded theory methodology. It aims to provide actionable feedback for GTAs and professors teaching the course, data the college can use to apply widely in engineering courses and provide the groundwork for future grants to improve the engineering curricula at this university to improve its access mission.

For this work-in-progress paper, the goal is to discuss the results through the lens of one case study using the question: *What supports and barriers exist for minoritized students in a solid mechanics course?*

Sampling for this project included 50 students who took the course during the Fall 2021-Spring 2023 academic years. The case study unit is the students who took the course at this time with the same teaching assistant.

Literature Review

For the purposes of this study, we explored literature related to second and third-year engineering courses and the success of minoritized engineering students. Literature shows that successful engineers require a diverse range of knowledge and skills that extend beyond what is typically taught in engineering programs [1]. Future engineers should have professional practice opportunities in real-world team-based settings to become collaborative and engineering experts [2]. For long-term impact, studies on enhancing engineering education and integrating real-world team-based practice to foster collaborative expertise should be considered. Research indicates that engineering students frequently drop out of engineering programs [3]. There are numerous explanations for this phenomenon, and a comprehensive examination of existing literature has pinpointed six commonly cited factors. These factors include classroom and academic climate, grades and conceptual understanding, self-efficacy and self-confidence, high school readiness, interest and career ambitions, and race and gender.

Existing literature indicates that minoritized students in engineering courses encounter various barriers, such as issues related to representation, stereotype threats, and administrative inequalities. The lack of representation among faculty and peers can lead to feelings of isolation and imposter syndrome, while stereotype threats can undermine students' confidence and performance. Administrative inequalities may result in limited access to educational resources and opportunities [4], [5]. These barriers can significantly impact students' experiences and outcomes in engineering courses. The feelings of isolation and imposter syndrome resulting from the lack of representation can affect students' mental well-being and academic performance. Additionally, stereotype threats can further compound these challenges by influencing students' confidence levels and ability to succeed in their studies [4], [5]. Administrative inequalities, such as restricted access to resources and opportunities, can pose additional obstacles for minoritized students in engineering courses. These disparities can impede students' full engagement with the material, participation in extracurricular activities, and access to support systems crucial for their academic success.

Studies show that the instructor enhances each student's intellectual growth by assigning difficult application exercises and providing timely, insightful comments [2]. Enhancing student motivation in the classroom can help with a variety of other aspects essential for long-term performance, in addition to the academic success of the students in a specific course of study [3]. An analysis of anecdotal data from the flipped sophomore design engineering course indicated that students' perceptions of engagement activities and learning enhancements differed from those of the traditional, lecture-based version [2]. Findings from this work in progress project will be used to make similar decisions about course change and fuel faculty motivation to change.

The Mechanics Project is a comprehensive initiative that reimagines traditional mechanics courses for engineering students, focusing on statics, dynamics, and deformable solids. It introduces a student-centered engaged learning environment with flipped recitation sessions [6]. A simple grading rubric and feedback system provides students with timely and detailed feedback on their progress. This approach not only transforms the courses but also influences course content and materials development, highlighting the importance of rethinking assessment strategies in engineering education for improved student learning outcomes. The outcomes of these studies will be underscored to recognize the intellectual capacity of students in solid mechanics courses.

Existing course structures in universities also feed into this work. Engineering education's push to change first-year and senior-year experiences has resulted in many capstone and project-led courses. The Clemson University department of Civil Engineering experimented on the new courses in civil engineering called "Springers" because they serve as the foundational stones of the transformed curriculum. The Springer course sequence aims to provide students with a comprehensive understanding of civil engineering while fostering their professionalism, communication, and teamwork skills through practical projects and hands-on activities. By doing so, students will gain a holistic perspective of the field while being able to apply their knowledge to real-world scenarios [7]. These research findings will help with curriculum transformation and retention strategies, as well as improve student success in civil engineering.

Capstone experiences in the civil engineering undergraduate curriculum at Clemson University, involve immersive projects intended to provide students with essential competencies and insights for their future careers [7]. Research From Virginia Tech University's Rising Sophomore Abroad Program showed that participating in the summer program helps students develop their interests, increase their knowledge, and strengthen their bonds with instructors and peers. The implementation of this present research will help understand the hurdles to the existing courses and how to work on them.

To address these challenges, this research will discuss students' experiences at institutions, and instructors should implement inclusive teaching practices, increase diversity in faculty and student populations, and provide tailored support systems for minoritized students. This research contributes to a broader understanding of the complex dynamics at play in solid mechanics education, highlighting the importance of fostering an inclusive and equitable learning environment for all students, regardless of their representation.

Methods

The goal of this overall project is to answer the research question: *What supports and barriers exist for minoritized students in a solid mechanics course?* To answer this question, we are starting the research with a grounded theory methodology. This means that, as researchers, we will acknowledge and take note of our prior understanding and biases of these students and classrooms in order to fully understand the course context through the lens of students who take the course and the teaching team that gives the course.

The grounded theory methodology we leverage will consist of interviewing students and faculty in the solid mechanics course who have taken or taught the course from Fall 2021-Fall 2023. Students will be interviewed in person and through teleconference using semi-structured interviews.

The questions in the semi-structured interviews are to understand student experiences and give them a chance to delve into their understanding of themselves and the course. Questions are open ended in order to give the student a chance to answer the question however they feel is appropriate without feeling like there is an obvious "right answer" that is expected by the interviewer.

Questions include:

- What were your thoughts about solid mechanics before taking it?
- Please share about your experience in solid mechanics.
    - Share about a time you were supported in class? Outside of class?
    - Share about a time you encountered a barrier in class? Outside of class?
- What thoughts do you have about the class now that it is over?

Researcher Biases

It is important to recognize existing researcher bias when doing this detailed, qualitative work. To increase transparency and trustworthiness of this work, we as researchers wrote our individual bias statements as they relate to this work.

[First author] I am originally from the Middle East and identify as a white, cis-gender woman. My undergraduate education took place in an urban university in my home country within a conflict zone, where diversity was limited. However, relocating for work purposes to the United Arab Emirates and immersing myself in a multinational company comprised of over 20 nationalities and backgrounds has shaped my perspective on diversity and inclusion. During this time, I pursued my master's degree in a diverse urban institute, further expanding my understanding of diversity. Currently, I am pursuing my doctoral studies in engineering at an urban, access oriented, R1 university. Throughout my academic journey, I've served as a teaching assistant for first- and second-year engineering courses. I had the opportunity to engage closely with students from diverse backgrounds, gaining valuable insights into their academic challenges and support needs. This experience further fueled my interest in understanding and advocating for underrepresented students in engineering education. Despite these experiences, I am still exploring the nuances of diversity, particularly in urban universities, especially those situated in segregated areas. My research aims to delve into students' experiences and provide actionable recommendations to engineering schools on enhancing support for underrepresented students.

[Second author] I am a cis-gender, able-bodied woman originally from Bangladesh. I'm currently pursuing my master's in the Department of Civil and Environmental Engineering at an R1 University in the USA. Prior to this, I completed my undergraduate studies at an institute in Bangladesh. With almost two years of experience as a Research Assistant back in my undergraduate university, I'm now continuing my academic journey. Passionate about academia, I aim to make meaningful contributions while embracing the opportunities and challenges of international education.

[Third author] I am a white, cis-gender, able-bodied woman from the United States. I attended a small, private, specialty university for my undergraduate engineering degree. For graduate school, I attended a large, primarily white, R1, land-grand university. I am now an assistant professor at an urban, access oriented, R1 university. I served as a TA for coding classes when I was in undergrad while learning about and engaging in engineering education research. Additionally, I served as a TA and co-teacher for a first-year engineering course during graduate school. I primarily teach senior design courses as a professor and am working on creating a graduate course on engineering education at my current university. Throughout my experiences teaching and

learning in engineering, I have had extensive experience with students from many backgrounds but am still learning about the segregated and underserved nature of my current university. My goal for this research is to understand student experience so I can use my power as a faculty to support their success.

Future Research Directions & Concluding Remarks

Future steps for this research include carrying out the analysis and thematically coding the data to understand supports and barriers. Using these supports and barriers as a way to talk to faculty, we plan to work with faculty, TAs, and our research group to work on a grant to support change efforts in the department and the college.

The future of higher education needs to be considered by everyone in the classroom including students, TAs, and instructors. This study will help us understand, in this particular context, what supports our students and how we can design better courses in the middle years of the engineering degree.

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