# Computation, Gender, and Engineering Identity Among Biomedical Engineering Undergraduates

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***Abstract*— This study explores interactions between computational thinking, gender and engineering identity among biomedical engineering undergraduate students. Biomedical engineering enjoys higher rates of women's enrollment than other engineering disciplines, but nevertheless has gender disparities in persistence within the field. Additionally, trends towards greater incorporation of computation into biomedical engineering have the potential to recreate the gender inequities seen in more computationally intensive engineering disciplines. Recently, 'engineering identity' has emerged as a powerful analytic lens to understand persistence in engineering, particularly for underrepresented groups such as women. However, there is limited work examining how experiences using computational methods influences engineering identity formation in undergraduate biomedical engineers. Further, it remains unclear to what extent gender differentially mediates the effects of computational practice on engineering identity formation. In order to explore the intersection of these issues, we study a thermodynamics course in the biomedical engineering department of a large Midwestern public research institution in the United States. The thermodynamics course includes in-class computational modeling group activities and has an enrollment of more than 120, primarily sophomore year, undergraduate students. We use a qualitative study approach that includes gathering data through classroom observation and detailed semi-structured interviews. We analyze classroom observation data to try to understand student experiences of learning and participation during in-class computational modeling exercises. Specifically, we look for evidence of gendered differences in task sorting and engagement with the exercise. Classroom data is complemented by semi-structured interviews. Thematic analysis of semi-structured interviews gains student's perspectives on how gender has influenced their learning experience and their identity as engineers.**

***Keywords—computation, engineering identity, gender.***

## I. Introduction

Women are critically underrepresented among undergraduate engineering students. This is a serious problem which needs to be addressed for reasons of persistence in gender equity. Biomedical Engineering (BME) is often described as a success story for women in engineering due to the higher representation than other engineering disciplines [2]. However, women's participation in BME undergraduate programs is lower than their share of the overall undergraduate population (~35% vs over 50%) [3]. Studies of women persistence in engineering suggest that engineering identity maybe more important for persistence in engineering for women than for men [4]. Additionally, the connection of computational skills in regard to gender and identity are overlooked in BME students. The study seeks to understand how binary gender mediates the effects of computational practice on engineering identity formation.

## II. Literature Review

There are many different meanings of the term 'identity' found in the literature. Our research is based on the space of 'engineering identity' and what role 'gender' and 'computation' play in the formation of students' engineering identity.

In our study, engineering identity is considered through a sociocultural perspective taking into consideration the cultural and social aspects of how "engineering identity" is formed in undergraduate engineering students. Engineering identity formation is an ongoing process and is dynamic with respect to how a person interacts in the engineering environment with other people [6][8]. The sociocultural theory of identity [6] is used as a framework to explore how students form their engineering identity. According to sociocultural theory of identity, someone's identity is how they are recognized as a certain 'kind of person' (in our case an engineer) in a given context. Social interaction in the community of practice helps in "engineering identity" formation [8]. The concept of communities of practice (group work) can help us understand how "engineering identity" is constructed in an engineering classroom environment.

Gender plays an essential role in engineering identity development in engineering education. Some engineering education researchers have identified ways that male students are privileged, and women are sidelined [12][13]. The phrase "acting like men" describes a not so silent standard in engineering to which engineering students often must conform. In the presence of such views many women have learned to put up with oppressive treatment. This oppressive treatment can affect a women's sense of belonging in engineering [7]. Women's participation is found to be excellent when it comes to performing actual 'engineering' tasks regardless of gendered perceptions [12]. The condition of being male was conducive to constructing an engineering identity [13]. Hence, gender plays a role in influencing the

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extent to which an individual is able to successfully develop an engineering identity. Research has reported that one of the reasons women are choosing pathways away from STEM fields of study and STEM careers is because women are bombarded with socialized ideas and negative stereotypes, specifically about women's subpar math abilities [13]. However, some studies suggest providing women valuable problem-solving experiences can prove to be a factor for their retention in STEM fields [9][14].

It was reported by [10] that when students feel a sense of support from peers it develops in them a sense of motivation towards pursuing academic success in STEM-related courses. As students advance from the first year to sophomore year during undergraduate engineering, they develop skills and with those skills, a sense of engineering identity is developed [12].

Our study aims to understand engineering identity development through the lens of social interaction, computation and gendered socialization. The scope of our study is limited to classroom-based interactions within student groups while BME undergraduate students participate in computational tasks assigned to them. We also observe if student gender mediates any effects with respect to computation. We seek to explore how increased exposure to computation contributes to engineering identity development. Based on the socio-cultural, gendered, and computational lenses for investigating engineering identity formation we have developed the following research questions.

## III. Research Questions

Question 1: How do experiences using computational methods influence engineering identity formation in undergraduate biomedical engineers?

Question 2: How does computational practice influence engineering identity in tandem with student gender?

## IV. Data Collection & Analysis

We study a thermodynamics course in the biomedical engineering department of large Midwestern public research institution in the United States. The thermodynamics course includes in-class computational modeling group activities and has an enrollment of more than 120, primarily sophomore year, undergraduate students. We use a qualitative study approach that includes gathering data through classroom observation and detailed semi-structured interviews. We analyze classroom observation data in order to understand student experiences of learning and participation during in-class computational modeling exercises. Specifically, we look for evidence of gendered differences in task sorting and engagement with the exercise. Classroom data is complemented by semi-structured interviews. Semi-structured interviews have proved to be a particularly useful method for collecting data for engineering identity. A set of questions were designed to record student experiences in and out of class settings. We conducted semi-structured interviews with six voluntary participants from the thermodynamics class. Interviews were conducted at locations that were convenient to each participant. All interviews were audio recorded for the purpose of review by the researcher. Six participants volunteered for the interviews, where five out of the six participants were women and the gender of participants was binary. The students were in the sophomore year of the biomedical and biological engineering discipline.

We chose to conduct a thematic analysis to analyze our data due to its flexible approach of working with the richness of qualitative data. To conduct thematic analysis, we work through a series of phases that result in a set of emergent themes [1]. Thematic analysis helps researchers gain insight and knowledge from data gathered. This analytic procedure is a useful method for examining different research participants' perspectives, highlighting similarities and differences, and generating unforeseen insights. Thematic analysis is also useful in summarizing the key features of a large data set, since it forces the researcher to adopt a well-structured approach to data handling. Thematic analysis helps in organizing a clear final report [5]. A deductive coding approach was used during data analysis based on the research questions to generate new theories that emerge from the data. The finding presented in the study are based on thematic analysis of interviews as well as classroom observation data.

## V. Findings & discussion

**Theme 1 - Problem Solving and Computation activities are essential skills to achieving engineering identity.**

It was observed that students associate problem solving, design, computation, and innovation abilities with engineering identity formation. They feel like an engineer when they participate in these activities. Also, students reported computational modeling activities to be an essential skill for professional development as an engineer.

**1A – During the interviews, students reported that participating in activities involving problem-solving, designing, and innovating makes them feel like an engineer.**

One student reported that *"using my engineering skills that I've learned as far as, computational modeling, all the job, um, problem solving, especially at real life problems. Um, and also as far as professional development goes, uh, allowing, being able to communicate with others effectively, uh, is a large part of being an engineer (sic)"*. The student believes that being able to learn and apply problem solving and computational modeling in realistic situations are an essential part of being an engineer and such activities provoke the engineering identity in the student.

In another interview, a student said, *"I really felt like an engineer because I was able to really be innovative and work on my own."*. We analyze that engineering identity is provoked in this student when they are able to come up with an innovative solution individually.

**1B – Students reported computational modeling to be an essential part of their academic and professional journey.**

When a student was asked about views on computational modeling, the student said *"I think it's necessary. ... it's not really something I would say is like a fun part of engineering.*

*Um, but definitely is necessary and like useful in order to be able to analyze what you're doing. (sic)"* Computational modeling is not an easy task, but it helps the student in understanding the problem-solving process and the problem in a thorough manner. Computational modelling gives a new dimension in order to understand and solve the problem.

One student reported computational modeling is important because *"I can imagine a decade from now it's all going to be about computational modeling. So, understanding that it's something that's so important. (sic)"*. The student believes that computational modeling is an essential skill of the current and future engineer.

A student compared the analytic procedure of solving equations in high school with the computational modelling procedure used in the thermodynamics class by saying *"back in high school, we did not know coding. Like we didn't, we were not even introduced to it or anything related to computational modeling. So, there were so many redundant calculations are so many procedures that we had to do it on the paper. So being able to just code it and like something that's so error free. Oh, it makes me feel like we can have so many better results at the end of the day. (sic)"*. According to this student, computational modelling is helpful because it provides a way to solve the problem more efficiently with a reduced chance of error in the solution.

We analyze from student comments that in or out of class authentic experiences of problem-solving, designing, and using computational tools created a sense of engineering identity in them and made them feel like a "real" engineer. Hence, our finding suggests that computational experiences are valuable to create a sense of belonging in engineering for undergraduate BME students.

**Theme 2 - Working with peers on activities involving computational processes creates a sense of confidence towards the attainment of engineering identity. Confidence in problem solving increases over time.**

It was observed that students felt a sense of confidence and independence when they participated in peer collaboration during classroom activities which involved computation. The sense of confidence and independence creates in students trust in their own skills and abilities which helps in engineering identity formation.

One student reported computational modeling to be a difficult task in the problem-solving process. However, working in a group helped the student figure out how to do it, *"with like creating the equations just on paper from the problem…. we (group) really are independent workers…. And then when it goes to actually coding, um, I'd say we're all pretty much mediocre with our experience, but we're able to just work together and figure it out. (sic)"*

Another student explained that motivation was a core part of her' team's ability to complete the computational modeling tasks:"*when my group is motivated to solve the problem, for example, the computational modeling part, then we are able to do it fairly efficiently within the allotted time."*. The team was struggling initially but over time they gained computational modelling skills which improved their confidence: *"I feel the computational modelling problems are straight forward because we work on similar method to solve it time and again. It was challenging and we as a group were struggling in the beginning but with time and practice, I believe now I need less help with the computational modelling part."*

Another student mentioned that peer to peer interaction makes it easier to perform computational modeling.*" Um, what happens is mostly we try and contribute equally and we tried to come up with a solution because nowadays what does that, …, we would just go to her and she would like instruct us what she's thinking (sic)"*.

We determined from the student comments above, that group work has positive effects on learning and students' abilities to work independently. Students reported that they were able to learn from one another in groups especially during computational modelling components. After learning how to perform better in this component students feel more proficient and confident. When we connect this back to our previous theme, we find further evidence that computational modelling skill is helpful in acquiring engineering identity.

**Theme 3 - Women students who depict technical proficiency while participating in computational processes are recognized by other peers as confident.**

While observing classroom interaction in student groups and analyzing student interview responses it was observed that the women students who were proficient in their knowledge of using computational tools showed confidence while interacting with others. They also self-identified as being able to perform proficiently in the thermodynamics course.

One woman talked about using a computational tool in group work during the class *"In this class I use the computational tool when the problem requires it… I usually help other people in how to work with it."* She also identified herself positively *"I am very hardworking, dedicated, and focused. I like to pay attention in class because of active learning*." We analyze that because this student knows how to work with the computational tool, she feels confident in helping other members of the group and feel positive about her identity as a BME engineering student.

When we asked another woman about problem solving strategies and working in a group, she stated, *"I started the problem by, uh, looking at the professor's previous example and uh, doing the coding. And when I got stuck, I took a break and came back (sic)"*. The student reported that in order to solve the problem she just took some time off during the parts of the problem where she got stuck and later discussed with her group. *"I also asked people from my group, um, what they got (as an answer) …. We really discussed why we thought, um, that solution was the solution. So, we came up with our consensus."* This depicts the student's ability to solve problems independently and then collaborate to validate the solution approach.

At another instance, a woman student recognized one of her peers to have exemplary computational modelling skills*" I would say my group in general, there's only like one girl who knows how to code for like three years now. So she is well equipped with it (sic).*

During the semester we collected data for this study, the instructor made changes to the lessons to provide more scaffolding for computation. This allowed some students with less technical experience to participate fully in computational activities. One student shared that she struggled with activities which were not scaffolded activities, but was able to participate more as changes were made to the instruction: *"initially…we were supposed to just write the code from scratch…but now that we've been using the whole method of, you know, inserting our code in place of question marks in the given quarter and it's much easier. So now doing it on my own and then discussing with the group and going about it as much more easier than it was the beginning of the class (sic)"*.

The same student further said, "*Most of the times I'm not going to lie, it is that one girl that has been like, like she's been doing code and for quite a while. So she's the one who helps us usually (sic)*" we observed that because a women peer in the in the interviewee's group is technically proficient in coding, she is confident and vocal about helping other group members with the computational coding part. It was also observed during classroom group interactions that a good number of students would choose to be in single-gender groups. In women comprised groups, women were seen to be actively participating. It was noted that these women were confident about their computation-based problem-solving abilities. Having knowledge of computational skills is associated with confidence in women students.

## VI. Limitations

There are four primary limitations involved in the current study: 1) the single-site design, 2) restricting the study to participants who have persisted in their sophomore year of undergraduate engineering, 3) the sample size for interviews was based on six participants where 80% of participants were women students, 4) the participants were limited to binary gender. This research primarily relates to the experiences of traditional, full-time college students at a single institution. The sample of participants for this study was limited where the gender of participants was binary. While the purpose of this study was not to generalize to a larger population, there is an acknowledgment that the sample population did not represent a diverse population.

## VII. Future Directions & Recomendations

Our preliminary findings suggest the importance of problem solving and computational activities in helping students develop an engineering identity. However, more in-depth understanding is needed on the incorporation and design of these activities so they can be inclusive to all students. Also, students reported positive attitude towards learning from classroom group interactions. Performing computational activities in groups can help students learn computational skills and participating in these activities increases confidence towards student's attainment of engineering identity. Investigating how the group dynamics play a role in learning effectively can help manage engineering classrooms more efficiently and make learning thermodynamics more inclusive. Finally, our findings suggest that women who are proficient in computational abilities depict confidence. Recent engineering identity research [15] suggests the importance of making engineering experiences more personalized for students so they can connect with them to develop a sense of belonging. However, personalizing engineering experiences in courses like thermodynamics can be a daunting process. We recommend analyzing the experiences of the women who show proficiency and confidence in working with computational tools. Designing similar in and out of class experiences will promote a sense of belonging in engineering amongst the students. The analysis also provides a foundation for researchers working in engineering identity development in identifying authentic experiences which define how underrepresented groups in engineering can feel more included in engineering environments.

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