

Factors Influencing Researcher Identities in Minority Gender Students in Electrical Engineering

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Abstract—This research full paper explores the intersection of gender and researcher identities in electrical engineering students. Minority gender (i.e. women, transgender, and nonbinary) students make up very little of the electrical and computer engineering higher education population, at both the undergraduate and graduate level. To remain in this field, particularly through graduate school, the establishment of a researcher identity is particularly important for minority students. In an effort to establish how minority gender electrical and computer engineering students at a public, Midwestern R1 institution gain an identity as a researcher, a survey was sent via email to the electrical and computer engineering student body. Additionally, links to the survey were presented at the end of events run by a minority-gender-focused student group in the same department. This research paper describes a survey of 179 students, including 117 undergraduate and 62 graduate students. Within the survey, students were asked to answer the question, “Do you see yourself as a researcher?” using the Likert scale, where 1 was “Strongly disagree”, 2 was “Somewhat disagree”, 3 was “Neither agree nor disagree”, 4 was “Somewhat agree”, and 5 was “Strongly agree”. Students who ranked themselves 3-5 were asked why they identify as a researcher, and those who ranked themselves 1-2 were asked why they didn’t identify as a researcher. Their responses were then labeled with common codes, and these codes categorized into relevant themes. Graduate-level minority gender students ranked themselves on average a 3.52, graduate-level cisgender men ranked themselves on average at a 3.7, undergraduate-level minority gender students ranked themselves on average a 2.81, and undergraduate-level cisgender men ranked themselves on average a 2.54. Minority gender students were found to more often than cisgender men rank themselves in the 3-5 range while writing they did not identify as a researcher. The most common theme found in the students’ responses to why they did or did not identify as a researcher was research, primarily through the code of research experience. The second most common theme among minority gender students was applied

curiosity; for example, literature review and synthesizing ideas. While for cisgender men applied curiosity tied with personal characteristics for their second most common theme; characteristics include self-identifying some innate capability and working hard. Insights from this paper can influence practice in how to best support students in establishing a researcher identity and improve retention of marginalized students.

Index Terms—gender, identity, student experience, survey, underrepresentation

I. INTRODUCTION

Electrical engineering was first established as a discipline in the United States in the early 1880’s to reflect the rapidly growing electrical manufacturing industry, branching off from the existing physics departments [1]. This field has since continued to evolve, and now often exists in a joint electrical and computer engineering (ECE) department [2]. This field has a continued importance due to the electrical and computer engineering’s applications including in consumer electronics, defense capabilities, and commercial data centers. This importance has been emphasized in recent years through the passing of the CHIPS Act in the United States [3]. A critical aspect of preserving and improving this field is generating a capable and diverse researcher force to become leaders in industry and academia, who can establish cutting-edge technology and teach future generations of the workforce.

A. Gender Diversity

It has been well-established that diversity is a boon for STEM (science, technology, engineering, and math) fields; from being more likely to identify problems in existing models and having an improved ability to generate new research questions [4], to improved health-care outcomes and improved financial performance [5],

diversity is important to have a strong STEM workforce. It is additionally important to pursue diversity for the sake of morality and social justice, to right historic marginalizations and injustices [4].

While women make up about 48% of the total workforce in 2021, women only make up 35% of the STEM workforce in the same year [6]. In 2021, for engineering and engineering technology degrees, women made up only 24.6% of undergraduate enrollment, 29.6% of masters enrollment, and 28.6% of doctoral enrollment [7]. Despite these numbers still being low, they have been gradually climbing in recent years. However, if one focuses on the electrical engineering discipline, a bleaker picture is painted. After increasing from approximately 1% women in the 1970's to approximately 13% in 1987, the percentage of women in electrical engineering has stayed relatively steady in the 13 - 16% range through 2021 [8], [9], [7]. Thus, there is a critical challenge in establishing gender diversity in the electrical engineering field. There are many aspects in electrical engineering that can be pursued to improve diversity, including recruitment and attrition. This paper will focus on the attrition issue, whereby women in engineering have a larger attrition rate than their male peers [10], [11].

While the discussion of Historically marginalized or Underrepresented Genders (HUG) typically focus on cisgender women, where cisgender refers to women who were assigned female at birth - i.e. not transgender, it is widely understood that transgender people also face intense gender-related challenges [12], [13]. These transgender students have also been found to have 10% worse attrition rates than their cisgender peers [14], indicating a need to explore their attrition. Additionally, while the discussion of gender equity and equality in engineering has historically focused on women and men, it has been established that gender goes beyond this binary to include nonbinary persons [15]. Thus, this paper aims to address some of the gap in the discussion around transgender and nonbinary students in engineering, and they are included within the discussed HUG group.

B. Researcher Identity

Identity theory asserts that people establish a series of identities which creates their self-perception. These identities are dynamically constructed through one's experiences and will affect how one interacts with other people, how one imagines their future, and influences their behaviors. This theory posits that people are more likely to pursue behaviors that reflect one of their own identities, and these identities impact how one interprets

and reacts to challenges. If an identity is related to a challenge, people are more likely to interpret the challenge as important rather than impossible [16], [17].

This identity theory is supported by studies that have indicated that establishing an engineering identity improves persistence rates for undergraduate engineering students [18], [19], [20], and having identity congruence with one's doctoral program improves motivation for the work and motivation to overcome challenges [21]. Thus, it is reasonable to presume establishing a researcher identity will improve persistence rates for students, particularly HUG students, in electrical engineering through undergraduate/ graduate education and through academic/ industry work.

This paper aims to look at electrical engineering students through the lens of identity theory and address the following research questions:

- 1) RQ1: How do electrical engineering undergraduate and graduate students develop a researcher identity?
- 2) RQ2: How does researcher identity development differ between HUG students and cisgender male students?

II. METHODS

Participant recruitment was pursued during the Fall 2022 semester for a Institutional Review Board-approved survey (IRB #23267). The survey was disseminated via email, through digital and printed flyers, at the end of events run by a minority-gender-focused student group in ECE [22], and before/after select lectures, potentially reaching all ECE students, including both undergraduate and graduate students. Some of this program's results have been previously published discussing the background and structure of the research program [23], exploring the effects of panel discussions on minority gender students' sense of belonging and research-career interests [24], and investigating how to improve motivation in minority gender students to attend graduate school [25], however, the questions, responses, and results discussed herein have yet to be disseminated.

As part of the disseminated survey, student respondents were asked "Do you see yourself as a researcher?", and students were able to respond using a Likert scale where 1 was "Strongly disagree", 2 was "Somewhat disagree", 3 was "Neither agree nor disagree", 4 was "Somewhat agree", and 5 was "Strongly agree". This self-identified score will hereby be referred to as the "researcher identity score". Students who ranked themselves positively, with scores of 3 - 5, were asked "When

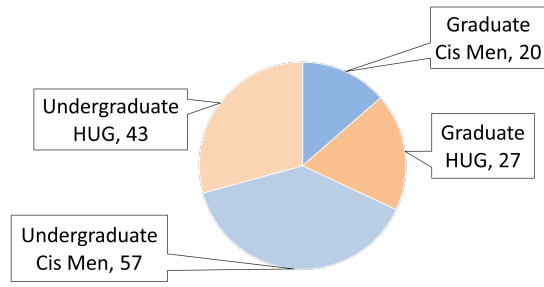


Fig. 1. Self-identified undergraduate/graduate status and gender of student respondents who provided a reflection. HUG includes cisgender women, transgender students, and nonbinary students. Cis men are cisgender men.

did you start feeling like a researcher? Please describe a scenario/experience in which you felt recognized as a researcher. (If you haven't had a scenario/experience where you have been recognized as a researcher, state so.)", and were able to respond in short-answer form. Respondents who ranked themselves lowly, with scores of 1 - 2, were asked "Why don't you see yourself as a researcher?", and the students were able to respond in short-answer form.

In the survey responses, 179 students identified their researcher identity score, consisting of 32 students who did not identify their gender, 43 undergraduate HUG students including 31 cisgender women and 12 transgender/nonbinary students, 57 undergraduate cisgender men, 27 graduate HUG students including 23 cisgender women and 4 transgender/nonbinary students, and 20 graduate cisgender men, as summarized in Fig. 1.

Out of the 179 respondents, 150 students also answered the follow-up open response question. Of these respondents, 26 students did not identify their gender, 38 identify as undergraduate HUG students, 49 as undergraduate cisgender men, 20 as graduate HUG students, and 17 as graduate cisgender men. There was a small difference by gender of the rates at which students responded to both their researcher identity score and short-answer question: 14% of cisgender men did not answer the short-answer follow-up, and 17% of HUG students did not answer the short-answer follow-up.

Thematic analysis was performed on short answer responses to label the qualitative data with codes by 3 researchers. Discussions were made to determine a set number of 27 codes to cover every response. The responses were then individually re-categorized using these codes, with each response having one or more codes attached to it. Each of the 3 researchers code assignments were compared, and where there was disagreement, the

researchers discussed until unanimously agreement was met. Due to the large number of codes, these 27 codes were then categorized into 7 relevant themes by the researchers. A summary of these codes and themes can be seen in Table I.

III. RESULTS

A. Researcher Identity Score

For all 179 surveyed students, the average researcher identity score was 3.04. For all HUG students, this average raises to 3.09, and for all cisgender men the average drops to 2.84. Undergraduate students on average rated themselves a 2.74, while graduate students averaged 3.63. Thus, graduate students average towards viewing themselves as a researcher while undergraduate students average towards not viewing themselves a a researcher. This discrepancy between undergraduates and graduates is likely due to graduate students having more opportunities to pursue research. Undergraduate cisgender men averaged a score of 2.54, while undergraduate HUG students averaged 2.81. For both gender categories, the average undergraduate does not view themselves as a researcher; however, HUG students tend to be slightly more confident in their researcher identity. For graduate students, cisgender men averaged a score of 3.7, while graduate HUG students averaged a score of 3.52. In the graduate student case, both gender categories view themselves as researchers; however, cisgender men are more confident than HUG students in their researcher identity. These averages were the same for the subset of 150 students who also responded to the short-answer question. These results are summarized in Fig. 2. This switch from undergraduate HUG students having a stronger researcher identity than undergraduate cisgender men, to graduate cisgender men having a stronger researcher identity than graduate HUG students may indicate that HUG students are quicker to gain initial, small confidence in their researcher identity, however, to then establish a more robust, confident researcher identity is slower for HUG students.

B. Students Short-Response: Themes & Codes

To investigate how students establish a researcher identity, one can explore the codes and themes found in the students short-answer response. Across all students, the most common theme in establishing a researcher identity was research. 64% of HUG students' responses and 64% of cisgender men's responses were identified using one or more research-related code. For HUG students, the second most common theme was applied

TABLE I
SURVEY RESPONSE THEMES, CODES, AND AN EXAMPLE OF A RESPONSE.

Themes	Codes	Example
Characteristics	Capability/ Innate characteristics Having general (i.e. not applied) curiosity Being creative/ innovative Exerting effort (short-term, <1 month) Working hard (long-term, >1 month) Having communication skills	"I haven't been involved in any formal research, but my general curiosity and approach to life (and ECE) makes me consider myself a researcher"
Applied Curiosity	Analyzing/ comparing Confirming what is known Asking questions Studying unknown Constructing knowledge Developing something novel/new Synthesizing ideas	"I've had to find information on electronics through extensive research on a robotics team as nobody had the previous knowledge. I wasn't finding "new" information, but it was new to the robotics team."
Research	Wanting to apply knowledge/ theory Interest in research Don't know how to get involved in research Research experience Identify specialization Working independently Improving process/ product	"I viewed myself as a researcher as a sophomore when I was working in a lab and contributing."
Coursework	Coursework	"When I had taken some lab classes that required me to follow a procedure and report what I found."
Conference (attendance)	Conference (attendance)	"First time to attend conference"
External Acknowledgement	Presenting to others Authorship Acknowledgement by researchers/ mentors Getting paid to do research	"Once my paper got accepted for a well-known journal."
Finances	Finances	"Not enough money"

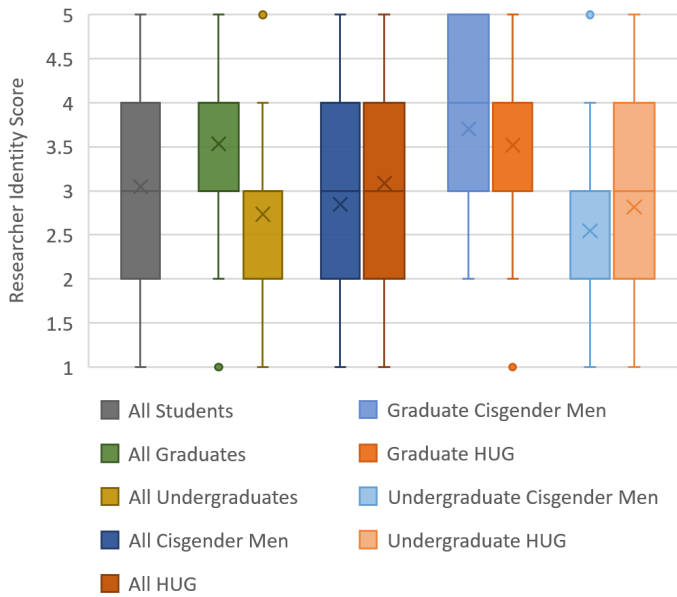


Fig. 2. Students response to question "Do You See Yourself as a Researcher?" 1 : no, 5: yes.

curiosity, with 26% of HUG students responses having an applied curiosity-related code, while for cisgender men this was only 18% of their responses. For men, applied curiosity and characteristics tied for the second most common theme, both being found in 18% of cisgender men's responses. Only 14% of HUG students, however, had characteristic-themed codes. This data is summarized in Fig. 3. The less popular themes were external acknowledgement which was identified in 19% of HUG student responses and 14% of cisgender men, coursework which was identified in 9% of HUG student responses and 11% of cisgender men, and finances which was not identified in any HUG student responses and was in 8% of cisgender men's responses.

When comparing graduate and undergraduate students, research remains the primary theme in students responses, however, the frequency is significantly less among graduate students at 50% than undergraduates at 64%, despite these students presumably having easier access to research. For graduate students, external acknowledgement becomes particularly important, seen at 38%

frequency in their responses versus only appearing in 7% of undergraduate responses. Among graduate students, there are discrepancies in HUG students versus cisgender men. Firstly, graduate cisgender men reference research 37% less than graduate HUG students, and graduate HUG students reference applied curiosity 38% less than graduate cisgender men; where graduate cisgender men are identified using the research theme 41% of the time versus 60% for HUG students, and graduate cisgender men are identified using the applied curiosity theme 29% of the time versus 20% for HUG students. Both characteristics and coursework are referenced by cisgender men approximately twice as often than with HUG students, while both gender categories reference external acknowledgement at similar rates of 35%. Conferences and finances are both minimally reference by both gender groups, at rates <6%. Among undergraduate students, it is seen that both gender groups reference research at much more similar rates, with only a difference of about 6%. Characteristics are again more similar among undergraduate students than with graduate, with HUG students referencing it 10% more often; where graduate cisgender men reference characteristics 14% of the time versus 16% for HUG students. Greater differences are seen with coursework being referenced 25% more by HUG students and external acknowledgement being referenced 53% more by HUG students, however with a rate difference of only 2% and 4% respectively (coursework referenced 10% versus 8% and external acknowledgement 10% versus 6%), these differences may be less impactful than what is seen with applied curiosity, which is referenced 29% of the time by HUG undergraduate students, while only being referenced 14% of the time by undergraduate cisgender men. This difference of 15% is a 68% more frequent referencing by HUG undergraduate students than undergraduate cisgender men. Conference attendance and finances are infrequently referenced by undergraduate cisgender men at rates of 2% and 8% respectively, and are never referenced by undergraduate HUG students. The frequency of response by theme and graduate level/ gender category is summarized in Fig. 4.

Another aspect of these codes and themes is which students are using which themes: those who did not identify as a research or those who did? This may be analyzed by comparing the average researcher identity scores. While the research theme was the most common theme, it was primarily used to explain why students felt they were not a researcher, with an average researcher identity score of 2.80 for students with this theme in their response; students indicating that they “haven’t

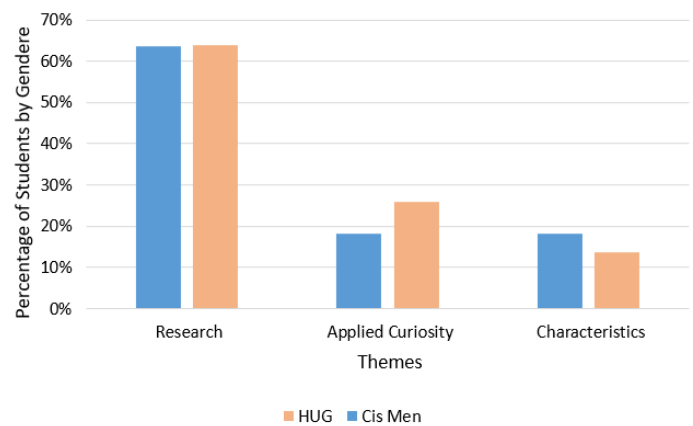


Fig. 3. Most common themes in students discussion around their responses summarized in Fig. 2. Both HUG students and cisgender men students identified research experience as the most common reason they did or did not identify themselves as a researcher. For HUG students, the second most common reason was due to experiences in applying their curiosity. For cisgender men, their second most common reason was also in applying curiosity, but to a lesser proportion of students, and this theme was tied with the theme of characteristics.

done much research” was common. Characteristics were similarly used to primarily indicate why students did not feel they were a researcher, with an average researcher identity score of 2.79. Applied curiosity was the most popular theme with a >3 average researcher identity score (3.67). External acknowledgement, coursework, and conference attendance all have >3 scores, with average researcher identity scores of 3.88, 3.61, and 3.25 respectively. The last theme, finances, had another <3 score of 2.8.

Due to the nature of the survey questions, wherein students who rated themselves a 3 (“Neither agree nor disagree”) were grouped with those who scored themselves a 4 or 5 (“Somewhat agree” and “Strongly agree” respectively) asked the positive-related follow-up short-answer question (“When did you start feeling like a researcher? Please describe a scenario/experience in which you felt recognized as a researcher. (If you haven’t had a scenario/experience where you have been recognized as a researcher, state so.)”), there were several students who indicated that they do not identify as a researcher or did not have a scenario/experience. 12% of HUG students and 8% of cisgender men indicated that despite rating themselves in the 3-5 range, they did not identify as a researcher and/or did not have a scenario/experience. As this phenomenon is seen more often in HUG students, this may be part of the source for HUG undergraduate students on average rating themselves

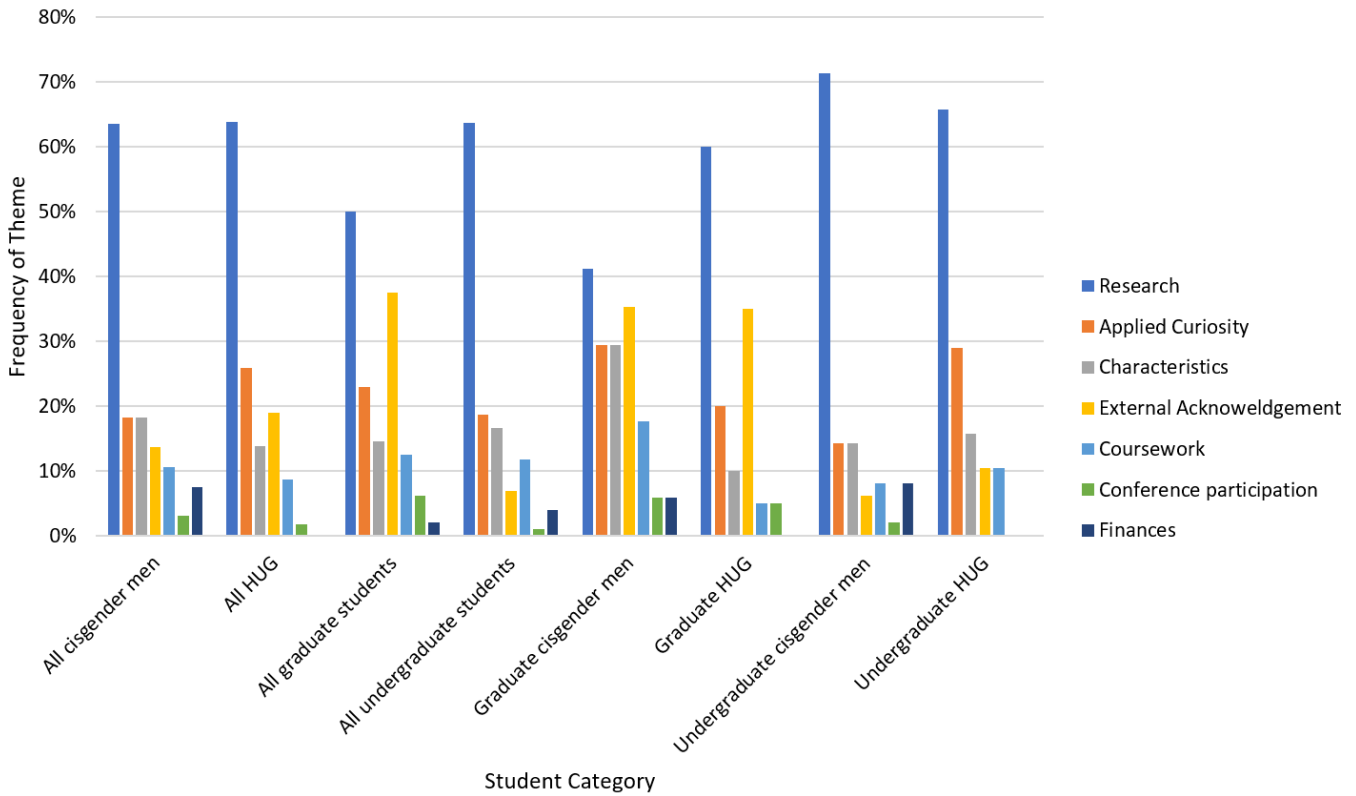


Fig. 4. Frequency of themes found in different student subgroups.

higher on their researcher identity score than cisgender men undergraduates. If the students who gave a negative response despite ranking themselves in the 3-5 scale are removed, the undergraduate HUG average becomes 2.71, a 0.10 decrease, and undergraduate cisgender men's average becomes 2.50, a 0.04 decrease; indicating again that this is a larger issue HUG students than cisgender men, and HUG students average score drops by 3.6% while cisgender men's average score drops by only 1.6%. This is also primarily an undergraduate phenomenon, with 87% of the affected students were undergraduates. Additionally, while most students who this affected rated themselves a 3, the only students who ranked themselves above a 3 and identified negatively to the short-answer question were undergraduate HUG students.

IV. DISCUSSION

The results of this study indicate the importance of student involvement in research, particularly at the undergraduate level, to establish a strong researchers identity. Thus, creating easier pathways for students to engage in research at the undergraduate level, such providing internal funds for student researchers and a central board for research positions, can allow for

improved researcher identities amongst students. This stronger researcher identity will in turn increase student retention throughout their academic and industry career as previously established [18], [19], [20]. Beyond research experience, it is important for undergraduate HUG students to apply their curiosity. This could be brought to praxis through implementing things like term papers in courses where students are able to pick a topic and explore the literature surrounding it. For graduate HUG students, external acknowledgement through things like praise by mentors and authorship of research are particularly important. Incorporating this in praxis could be through formalizing more of the mentorship process of professors and established graduate students with new graduate students in the department, and incorporating minimum publication requirements for students, particularly Ph.D. students, graduation. For minimum publication requirements to be implemented, a strong support network of faculty and staff may be necessary to ensure success.

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