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HUG Initiative: Overcoming roadblocks on a research career roadmap of individuals from historically marginalized or underrepresented genders

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The underrepresentation of students of Historically marginalized or Underrepresented Genders (HUGs) in STEM departments results in the low representation of HUG researchers in the space science community. This paper reviews relevant literature to explore the potential barriers that prevent HUG students from staying in STEM fields, including few opportunities to develop STEM identities, experiences with professional devaluation, and chilly campus climates. Thus, HUG students are more likely to feel excluded in STEM programs. To address the disparities, our HUG Initiative, a student-led research initiative, is proposed and piloted at a large research institution. This initiative promotes the pursuit of research careers among students who self-identify as HUG in the department of electrical and computer engineering. By holding panel discussions, interactive workshops, and networking luncheons, HUG Initiative aims to demystify what it means to be a researcher and provide resources on research opportunities and support for HUG students. The influence on the HUG students' career choice and their accessibility of information will be evaluated by pre-study and post-study surveys. The research outcome will offer suggestions to create a safe and supportive departmental environment for HUG-identifying students to pursue research careers.

KEYWORDS

research career, gender minority, initiative, chilly climate, STEM identity

1 Introduction

The field of space physics is interdisciplinary, combining both engineering and science. Researcher affiliations include departments of planetary science, physics, astronomy, and electrical engineering among others. Demographics of Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) community presents a drastic decrease in women populations from students (38.7%) to early career scientists (17.9%), implying that women are more likely to leave the space physics field once obtaining the degrees (Jones Jr and Maute, 2022). The result is aligned with the AGU Section Membership Demographics report in 2018, which indicates that the percentages for women students, early-, mid-, and senior-career scientists in the section of Space Physics and Agronomy are 35.8%, 29.86%, 21.05%, and 10.73% respectively (AGU, 2018). The phenomena might be partly explained by "the leaky

pipeline" (Seymour and Hewitt, 1997; Lovitts, 2002; Grogan, 2019), which will be detailed in the following section.

Over the past several decades, while there have been multiple efforts to study the systemic gender biases women face in STEM fields, the binary gender narrative does not include the people who are non-binary, genderqueer, genderfluid, *etc.* Moreover, women-only spaces often exclude transgender and non-binary people, especially with anti-trans rhetoric of trans-exclusionary radical feminists (TERFs) on the rise since the start of the COVID-19 global pandemic (Pearce et al., 2020). The experiences of people who identify as lesbian, gay, bisexual, transgender, and/or queer (LGBTQ+) in STEM are seldom addressed in studies and reviews (Kersey and Voigt, 2021; Maloy et al., 2022). For instance, all the surveys American Geophysical Union (AGU) distributed before 2019 only had three choices, "female," "male," and "prefer not to answer." It was not until 2021 that AGU Diversity and Inclusion Advisory Committee officially updated the gender categories to include "non-binary" (AGU, 2021). While few efforts have focused on analyzing the academic and workplace experiences of transgender scientists (Kersey and Voigt, 2021; Maloy et al., 2022), prior studies have shown that queer and transgender students and professionals in STEM face various microaggressions in academic settings, such as being subjected to cis-normative language or incorrect pronouns (Campbell-Montalvo et al., 2022b). Moreover, transgender and non-binary students are often forced to use their deadname—the birth name they no longer use—due to interpersonal or institutional reasons, leading to increased mental health issues (Russell et al., 2018; Cooper et al., 2020). In addition, STEM fields often present a chilly climate to women and people who identify as LGBTQ+ (Settles, 2014; Campbell-Montalvo et al., 2022b), and the prevalence of cisgender culture within STEM that alienates those who identify as LGBTQ + as well as cisgender women (Miller et al., 2021).

For a more comprehensive coverage of genders, this study includes individuals of Historically marginalized or Underrepresented Genders (HUGs), including cisgender women and anyone who identifies with transgender and non-binary groups. In this paper, we review past efforts in understanding the difficulties and potential solutions for STEM students and professionals of underrepresented genders. We also provide a framework, HUG Initiative, for supporting and motivating HUG students in pursuing research careers. **Section 2** discusses the obstacles HUG students face in research and proposes possible solutions to mitigate the barriers. **Section 3** details the workings of HUG Initiative, including a pilot study survey, panel events, and a student mentoring program. **Section 4** concludes the paper.

2 Obstacles and possible solutions

The underrepresentation of HUG students in STEM fields is possibly caused by the lack of awareness of diversity when recruiting HUG students as well as the fact that HUG students have higher attrition rates than non-HUG students, so called "the leaky pipeline," as shown in **Figure 1**. While numerous studies focus on the recruitment of HUG students in STEM fields, this section discusses why HUG students leave STEM fields. In this section, we explore the possible barriers HUG students face when pursuing STEM degrees along the career research roadmaps. While studies have shown that non-binary and transgender people have similar experiences as cisgender women, they face augmented difficulties (Blackburn, 2017; Conrad et al., 2021; Miles and Naumann, 2021; Campbell-Montalvo et al., 2022a). Challenges and compounding difficulties will both be addressed in this section.

2.1 Lack of opportunities to develop STEM identity

STEM identity is a quantitative indicator for measuring students' behaviors on educational and professional persistence in STEM field (Carlone and Johnson, 2007; Hazari et al., 2010, 2013; Unfried et al., 2014). This indicator is developed based on four dimensions, including interest, competence, recognition, and performance, and was found to accurately predict students' intentions to complete and choose a STEM career. HUG undergraduates have lower STEM identities when compared with non-HUG peers, and thus they had lower interests in STEM careers and did not recognize themselves as engineering or physics students (Hazari et al., 2010; Godwin et al., 2013). The Persistence Research in Science and Engineering (PRiSE) survey project on undergraduate identities showed that 50% of men considered themselves as physicists, compared with only 30% for women (Hazari et al., 2013). One factor contributing to this disparity is identity regulation. Students are more likely to connect with disciplines that fit their actual or desired identity and avoid areas that they consider different from themselves. Since STEM fields are often associated with masculinity (Master et al., 2016; Cheryan et al., 2017), HUG students are often perceived as being a misfit between their gendered self-concept and the image of STEM (Kessels et al., 2014). Another factor for low STEM identity is due to the low self-efficacy beliefs of HUG students, that is, they possess lower confidence in their ability to conduct a STEM project or research (Miles and Naumann, 2021; de las Cuevas et al., 2022; Andrews et al., 2021). Women in physics class have lower science self-efficacy than their men counterparts. Moreover, women with "A" grades often had comparable physics self-efficacy perceptions to men with "C" grades (Marshman et al., 2018).

The fact that HUG students possess lower STEM identity and efficacy beliefs is most likely due to the lack of opportunities to develop their STEM identity. HUG students tend to be more passive in answering questions during lectures and are less likely to be encouraged to become researchers by faculty (Hazari et al., 2010). Kahle et al. (1993) indicated that men students engaged more in the typical classroom interactions, such as asking and answering questions. Thus, women typically received less attention and recognition from lecturers, and had fewer prior experience on conceptual understanding than their men counterparts (Kahle et al., 1993; Chambers and Andre, 1997). In addition, negative stereotypes play a key role in the students' motivation to pursue a STEM career. For instance, women students' self-confidence is likely to be influenced by beliefs that men generally perform better in STEM than women (Maries et al., 2018). Therefore, women students are more likely to assume that they need to make extra efforts to succeed in STEM fields and undergo stress to demonstrate their skills in order to be valued equally as men students (Marshman et al., 2018).

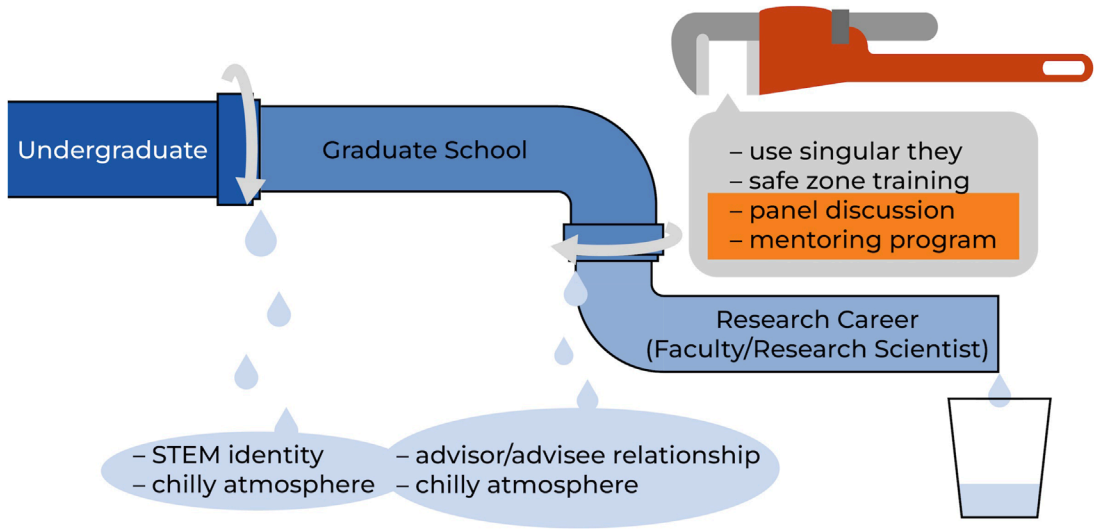

FIGURE 1
Conceptual diagram of obstacles HUG students face while pursuing a research career. The highlighted text under the pipe wrench indicates the scope of HUG Initiative.

2.2 Chilly climate

Department climate is shaped by the nature and quality of interactions between students, faculty members, and staff. The "chilly climate" refers to the inequities that may seem trivial, but frequently occur. However, cumulatively, these inequities can lead people to doubt the value of their contributions (Lee and Mccabe, 2021). HUG students usually face additional difficulties of integration with their academic community and experience chilly department climates. They—especially those who do not fit in the cisgender binary—experience more harassment, discrimination, and professional devaluation in their departments (Cech and Waidzunas, 2021). STEM departments seldom provide the environment for students to feel safe to be out about their gender identities, including the lack of gender-neutral bathrooms and binary gender options (man or woman) on school forms (Woodford et al., 2017). Moreover, since STEM is primarily dominated by cisgender men, the nature of cis-normative language within the department causes people from underrepresented groups to make additional efforts to blend in or resist the culture (Miller et al., 2021). An interview study revealed that HUG students felt uncomfortable about gender-specific language, such as often addressing each other as "bro," "dude," or "guy" in casual conversations and having male-dominated jokes (Vaccaro, 2012). HUG students further reported that they tend to dress less feminine to avoid harassment from their peers, and believed this made them easier to fit in to the departments (Miller et al., 2021). Overall, this unwelcoming and chilly atmosphere and pressure to conform gives HUG students the impression that "STEM is not for me." The failure of integrating with the academic community decreases the motivations of HUG students to stay in STEM fields.

The difficulties HUG graduate students face are similar to HUG undergraduates. However, advisor–advisee relationship is one of the aspects that differs between HUG undergraduate and graduate students. Unlike undergraduates, graduate students have few opportunities to meet peers through lectures and student organizations. Instead, they spend more time and effort being involved in professional organizations, participate in seminars, and on- or off-campus social events. Since these activities vary between research fields, the research career roadmaps of graduate students are typically guided by their advisors. Building a strong and bonding advisor–advisee relationship introduces additional opportunities and interactions to integrate with the academic community and helps keep HUG graduate students in the STEM field. Studies have shown that students who are advised by a faculty member with close research interests or who share similar personal interests tend to form more successful advisor–advisee relationships (Lovitts, 2002). Since HUG faculty members are also underrepresented in most STEM departments, they usually spent 2 hours more per week on mentoring students than their colleagues (Misra et al., 2011). Therefore, HUG students have difficulties finding an advisor who has the time and experience to help them overcome the challenges they face.

2.3 Result: Lack of psychological safety

The lower STEM identities of HUG students and their experiences with a chilly atmosphere lead to HUG student difficulties in constructing their research career roadmaps when pursuing STEM degrees. These roadblocks also limit their opportunities to build their networking villages in departments, professional organizations, and meetings throughout their research careers. Therefore, HUG students may feel disappointed by the learning experiences and explore opportunities outside STEM fields. Moreover, HUG students were reported to experience health difficulties, including insomnia, stress from work, and depression, more frequently than their non-HUG peers due to chilly atmosphere (Cech and Waidzunas, 2021). HUG students felt less like they "fit in" in STEM fields as they faced more severe, frequent, and

often invisible microaggressions when interacting with others, such as professional devaluation, additional harassment, and discrimination during conversations (Campbell-Montalvo et al., 2022b). Consequently, HUG students exhibit lower persistence and sense of belonging to STEM fields than their non-HUG colleagues. For example, around 30% of HUG students and faculty were not comfortable with STEM department climates, and seriously considered leaving their institution due to negative experiences and perceptions (Farrell et al., 2017; Conrad et al., 2021). Moreover, non-binary and transgender students were 7% more likely to transfer to non-STEM programs (Hughes, 2018), and a longitudinal survey study on the degree completion of graduate students showed that HUG graduate students in the typically-men PhD programs (with less than 38.5% women students in the average cohort) are ~12% less likely to graduate from the PhD program than men students (Fouad et al., 2017; Bostwick and Weinberg, 2022; Maloy et al., 2022).

2.4 Additional impact during global pandemic

The COVID-19 pandemic placed additional challenges on HUG students because of online learning and working environments. During the pandemic, HUG students, especially LGBTQ + students, were constantly discriminated against and harassed by their peers due to the rise of TERF wars (Pearce et al., 2020), or isolated with their unsupportive families (Fish et al., 2020). However, access to supportive systems within the university, such as interaction with affirming friends, therapists, advisors, teachers, and student organizations, largely decreased (Thanawala et al., 2022). For example, 30% of HUG students felt unsafe and missed at least 1 day of school monthly, according to a School Climate 2022 survey, and suffered from psychological distress four times greater than non-HUG students (Salerno and Boekeloo, 2022). Furthermore, women reported more disruptions to publishing academic papers and focusing on their research studies than men due to their expected family responsibilities (Shah et al., 2021). They are likely to cut their work hours to take care of sick family members or help their children with homework and keep them focused during school hours (Modestino, 2020). Studies showed that the research productivity of women, especially early-career HUGs, has been affected more than non-HUGs (Squazzoni et al., 2021; Paul et al., 2022). The proportion of first authors who are women on COVID-19 related papers was 20% lower than on papers published before the pandemic in medical journals (Andersen et al., 2020). This phenomenon has not been observed in the space science community yet, and may require additional statistical analysis in future studies (Wooden and Hanson, 2022).

2.5 Possible solutions: Take actions

Considering the challenges that HUG students face when pursuing a career in STEM fields and the additional burdens caused by the COVID-19 pandemic, it is extremely important for us not only to detail the disparities between HUG and non-HUG students, but also to implement pragmatic solutions and take actions for a more inclusive and supportive environment in our academic community. These actions should take place not only at events held by professional organizations, departments, and student organizations, but also at lectures and during office hours. Liemohn (2022) suggested stopping using bro language and stoping having male-dominated jokes in casual conversations. Instead, we use gender-neutral language, such as using "singular they" in publications and presentations.

Several other actions were recommended in supporting HUG students, including panel discussions, safe zone training, and mentoring programs. Surprisingly, Hazari et al. (2010) pointed out that inviting HUG speakers and introducing HUG scientists during lectures had little impact on the increase in STEM identities. It would be beneficial to have an explicit discussion of the issues of underrepresentation faced by minorities in HUG, such as the gender-bias experienced by HUG scientists (Hazari et al., 2010). A mini workshop series of panel discussions was reported to have a significant impact on underrepresented students by providing resources and opportunities that were not accessible individually (Artiles et al., 2021; Connor et al., 2021). Furthermore, holding safe zone training sessions within departments or professional organizations educates people about terminologies of gender minorities and the biases they experience, as well as the coming out process (Farrell et al., 2017; Miles and Naumann, 2021). The training sessions are meant to engage everyone to be aware of the difficulties HUG students face and form a supportive structure and culture of allies for HUGs (Miller et al., 2021). In addition, students who used support and mentoring services were found to have lower attrition rates (Madara and Cherotich, 2016). Meeting with a STEM professional who shared similar backgrounds greatly encouraged HUG students to pursue a STEM career, and helped them feel like they belonged in their academic community (Kricorian et al., 2020).

3 Plan of action: HUG Initiative

To close the knowledge and resource gaps between HUG and non-HUG students while providing a sense of community for HUGs, the HUG Initiative is formed to promote the pursuit of research careers among both undergraduate and graduate students of historically marginalized or underrepresented genders alike in the Department of Electrical and Computer Engineering at the University of Illinois Urbana-Champaign (ECE Illinois). This student-led research-based initiative includes a pilot study that identifies the difficulties HUG students in ECE Illinois face compared to their non-HUG counterparts, and addresses the roadblocks through panel discussions and student mentoring. Our plan of action and research outcome provide a framework for how to motivate HUGs to involve in the space science community and create a safe and supportive environment to continue their research career pathways.

There are 327 women undergraduate and 117 women graduate students in ECE Illinois, which are ~15% and 17% of the total ECE student populations. The HUG Initiative aims to help these HUG students develop their researcher identities and attain research positions. We envision three key elements that lead to a

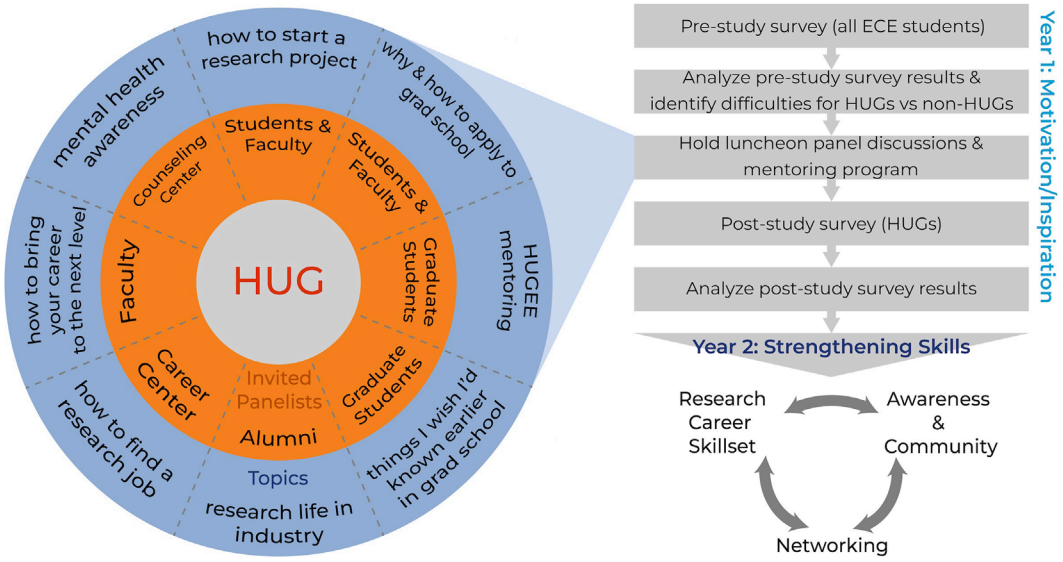

FIGURE 2
Diagram for HUG Initiative makeup and activities.

successful HUG researcher: research career skill sets, networking, and community awareness. These elements are meant to help HUG students construct their research career roadmaps while pursuing their STEM degrees, and provide additional opportunities for them to integrate with the academic community. A flowchart for HUG Initiative is on the right side of **Figure 2**.

3.1 Pre-study survey

We distributed an institutional review board approved pre-study survey to all ECE students in the first week of the Fall 2022 semester to identify the difficulties HUG students face compared to non-HUG students. The survey is designed to collect students' current states regarding their STEM and research identities, knowledge of available research resources and opportunities, attitudes toward STEM careers, and psychological safety in the department. Results will provide the department with insight into how to better direct HUG students towards STEM research careers. To evaluate the impact of the HUG Initiative, a similar survey will be distributed to HUG students at the end of the academic year to assess how the panel discussions and networking events impact their understandings of research career pathways.

3.2 Event planning

HUG Initiative will hold panel discussions, mentoring program, and town hall meetings, which will accommodate 20–30 students at each event. During the panel discussions, HUG Initiative will invite panelists to give advice on how to find research opportunities, and share their experiences in research skill development, especially the challenges they have encountered before. Various topics, including undergraduate research opportunities, graduate school application, graduate student orientation, research job searching in academia and industry, and mental health will be addressed. Planned topics and corresponding panelists are detailed on the left side of **Figure 2**. These panel discussions aim to help HUG students gain understanding and motivation toward having research careers, and further build connections with panelists for future opportunities of advancement. Similarly, the mentoring program was launched during the semester to pair graduate students with undergraduates for one-on-one near-peer mentoring on graduate school applications and research experiences.

4 Conclusion

HUG undergraduates are suggested to be 10% more likely to leave the STEM field compared to their non-HUG peers, while HUG graduates are suggested to be 12% less likely to complete a PhD program. This high attrition rate of HUG students may be credited to the fact that they experience additional professional devaluation and chilly campus climates. Therefore, they suffer from low psychological safety and feel excluded from STEM programs. To address the disparities, we designed the HUG Initiative to increase the representation of historically marginalized or underrepresented genders in STEM research through community building and informative workshops. The initiative not only investigates in why HUG students are more likely to leave STEM field, but also takes actions by holding panel discussions and mentoring program for HUG students and studying how to better support their pursuit of research careers. The survey findings and event evaluations will provide insights on how to increase gender representation in the space science research community from the students' perspectives.

A student-led research initiative is critical to promoting a more diverse research community. It is necessary to include

voices from different stages of education level to construct a career roadmap. The experience of education research strengthens students' research skillsets and gives them additional chances to interact with administrative staff in the departments as well as their peers in the academic community. The entire research team of HUG Initiative is led and operated by graduate and undergraduate students from ECE Illinois, and thus, a good example. With the support from experienced faculty members and the Institute for Inclusion, Diversity, Equity and Access in The Grainger College of Engineering, HUG Initiative can conduct educational research that focuses on the experiences of students in the department, in addition to their technical research projects.

5 Citation diversity statement

Recent work in several fields of science has identified a bias in citation practices, such that papers from women and other minority scholars are under-cited relative to the number of such papers in the field (Maliniak et al., 2013; Mitchell et al., 2013; Caplar et al., 2017; Dion et al., 2018; Bertolero et al., 2020; Dworkin et al., 2020; Chatterjee and Werner, 2021; Fulvio et al., 2021; Wang et al., 2021). Here we sought to proactively consider choosing references that reflect the diversity of the field in thought, form of contribution, gender, race, ethnicity, and other factors. First, we obtained the predicted gender of the first and last author of each reference by using databases that store the probability of a first name being carried by a woman (Dworkin et al., 2020; Zhou et al., 2020). By this measure (and excluding self-citations to the first and last authors of our current paper), our references contain 43.94% woman (first)/woman (last), 14.91% man/woman, 25.72% woman/man, and 15.43% man/man. This method is limited in that a) names, pronouns, and social media profiles used to construct the databases may not, in every case, be indicative of gender identity and b) it cannot account for intersex, non-binary, or transgender people. Second, we obtained predicted racial/ethnic category of the first and last author of each reference by databases that store the probability of a first and last name being carried by an author of color (Ambekar et al., 2009; Sood and Laohaprapanon, 2018). By this measure (and excluding self-citations), our references contain 9.64% author of color (first)/author of color (last), 18.21% white author/author of color, 13.65% author of color/white author, and 58.50% white author/white author. This method is limited in that a) names and Florida Voter Data to make the predictions may not be indicative of racial/ethnic identity, and b) it cannot account for Indigenous and mixed-race authors, or those who may face differential biases due to the ambiguous racialization or ethnicization of their names. We look forward to future work that could help us to better understand how to support equitable practices in science.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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