Illuminating Growth Among Women in Engineering: A Retrospective on ASEE Data

Ms. Kristin L Schaefer P.E., University of Houston

Kristin Luthringer Schaefer is a licensed professional engineer (PE) and a certified secondary teacher (grades 6-12), both in Texas, as well as the owner of her own consulting firm, Schaefer Engineering. She obtained both her bachelor's and master's degrees in Mechanical Engineering (ME) from Texas A&M University (TAMU) and earned a doctorate in Mechanical Engineering at the University of Houston (UH). Her Ph.D. research interests are in STEM education, especially with underrepresented students of all ages, STEM mentors, and their motivations and/or persistence. The first part of her career was spent designing residential split system HVAC equipment and Indoor Air Quality (IAQ) unitsfor Trane in Tyler, TX. Kristin has taught about design, engineering, and manufacturing to students of all ages in various places including to preschoolers via Schaefer Engineering's STEM outreach, to senior mechanical engineering undergraduates at TAMU, to eighth graders in KatyISD at Beckendorff Junior High, and to freshmen mixed major undergraduates at UH and at TAMU. Kristin is also the mom of one smart teenage boy whose journey through learning differences and Type 1 Diabetes (T1D) has enabled her to connect with and support students with a broad spectrum of learning preferences.

Dr. Jerrod A Henderson, University of Houston

Dr. Jerrod A. Henderson (”Dr. J”) is an assistant professor in the William A. Brookshire Department of Chemical and Biomolecular Engineering at the Cullen College of Engineering at the University of Houston (UH). He began his pursuits of higher education at Morehouse College and North Carolina Agricultural & Technical State University, where he earned degrees in chemistry and chemical engineering as a part of the Atlanta University Center's Dual Degree in Engineering Program. While in college, he was a Ronald E. McNair Scholar, allowing him to intern at NASA Langley. He also earned distinction as a Phi Beta Kappa member and an American Chemical Society Scholar. Dr. Henderson completed his Ph.D. in Chemical & Biomolecular Engineering at the University of Illinois at Urbana-Champaign. As a graduate student, he was a NASA Harriet G. Jenkins Graduate Fellow and mentor for the Summer Research Opportunities Program. Dr. Henderson has dedicated his career to increasing the number of students on pathways to pursue STEM careers. He believes that exposing students to STEM early will impact their lives and academic pursuits. He, along with Rick Greer, co-founded the St. Elmo Brady STEM Academy (SEBA). SEBA is an educational intervention that introduces underrepresented and underserved fourth and fifth-grade students and their families to hands-on STEM experiences. Dr. Henderson is the immediate past Director of the Program for Mastery in Engineering Studies (PROMES, pronounced ”promise”), a program aimed at increasing engineering student achievement, engagement, and graduation rates. His research group seeks to understand engineering identity trajectories and success mechanisms throughout lifespans using action-based participatory research and novel methodologies such as photovoice, IPA, and draw-an-engineer and the development of research-informed interventions to improve student success. He was most recently recognized by INSIGHT Into Diversity Magazine as an Inspiring STEM Leader, the University of Illinois at Urbana-Champaign with the College of Liberal Arts & Sciences (LAS) Outstanding Young Alumni Award, Career Communications Group with a Black Engineer of the Year Award for college-level promotion of engineering education and a National Science Foundation CAREER Award in 2023 to advance his work that centers engineering identities of Black men in engineering.

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1 Introduction and Purpose

The U.S. education community has fixated on Science, Technology, Engineering, and Mathematics (STEM) content, including computer science, in PreK-20 levels since President Roosevelt in 1944 requested scientific research and development, "for the improvement of the national health, the creation of new jobs, and the betterment of the national standard of living," [1, p. 106]. Thus, educators, researchers, and practitioners at all stages of the STEM pipeline, especially in engineering pathways, have grappled with how to develop an engineering literate society [2], [3], [4], [5], [6], [7].

Further, over the past 40 years, there has been a national U.S. focus on broadening the participation of those underrepresented and underserved in engineering, including women [8]. Countless outreach programs, both coeducational and single-sex and at all PreK-20 levels, have encouraged students to pursue engineering and persist through an engineering degree program[1]. Yet, we do not know the full impact of this focus, especially as the typically reported aggregated data does not appear to shift over time. Specifically, women in engineering numbers of degrees awarded are increasing, yet the total representation remains around the commonly reported 20% proportion of degrees awarded [9], [10]. Recent research by our team found indications that there have been shifts in female representation in engineering, and this work seeks to further investigate those trends [11]. Our disaggregated infographics illuminate if the changes over time have drawn underrepresented and underserved students into particular engineering disciplines.

1.1 Background

Engineering is a field where industry not only accepts the bachelor's (BS) degree for entry, but also does not legally require all engineers to obtain a license to practice. The industry exemption allows for one engineer in the firm who has a license to supervise the work of other career engineers without one [12]. However, some engineering disciplines and careers do require additional education [13], either as a master's (MS) or doctoral (PhD) degree (e.g., collectively known as graduate degrees). In 1973, Biglan described academic subjects by three dimensions of

[1] The PreK-20 education range indicates prekindergarten to grade 5 as elementary, grades 6 to 8 as middle school (sometimes referred to as junior high), and grades 9 to 12 as high school; with the optional educational years 13 to 14 as an associate's degree or 13 to 16 as a bachelor's degree (e.g., undergraduate degrees), and years 17 to 20 as graduate degrees, where 18 would indicate obtaining a master's degree and 20 indicates a doctoral degree.

hard-soft, pure-applied, and life-nonlife clusters in order to shine a light onto the organization and output characteristics that are typical for specific subjects [14], [15], [16]. The traditional, paradigmatic disciplines such as civil engineering, mechanical engineering, and computer science (inside engineering) can be identified as hard-applied-nonlife, while the contemporary, biology-based disciplines such as biomedical engineering, biological/agricultural engineering, and environmental engineering can be identified as hard-applied-life. Additionally, the managerial-based disciplines of industrial/manufacturing/systems engineering can be identified as soft-applied-life. While all engineering disciplines require rigorous education, these analysis adjectives tend to be unfairly simplified and colloquially the more social, science-based "life system" disciplines are described as "soft" and the more computational, math-based "nonlife system" disciplines as "hard" [17]. Thus, we wanted to understand the anecdotal musings that women are avoiding the "hard" engineering disciplines, like aerospace or electrical engineering, for "soft" engineering disciplines, like chemical engineering or engineering management [18], [19].

Additionally, we sought to disaggregate the graduation data over time by biological identities of race and sex in ways previously unpublished by the American Society for Engineering Education (ASEE) annual reports. Prior work established the conceptual framework behind why our infographics are formatted in the ways shown here [11].

1.2 Engineering Disciplines and Levels

ASEE has a self-reported database called the Engineering Data Management System (EDMS). Member institutions' degrees awarded data at the bachelor's, master's, and doctoral levels for twenty-two different disciplines are recorded in the EDMS, listed alphabetically in Table 1, and used for annual reports [20]. However, annualized reporting creates difficulties in spotting trends and these reports do not disaggregate the information sufficiently [11].

Table 1: Options for Engineering Degree Disciplines in ASEE EDMS

Order	ASEE Disciplines	Order	ASEE Disciplines
1	Aerospace Engineering	**12**	Engineering (General)
2	Architectural Engineering	**13**	Engineering Management
3	Biological Engr. and Agricultural Engr.	**14**	Engr. Science and Engr. Physics
4	Biomedical Engineering	**15**	Environmental Engineering
5	Chemical Engineering	**16**	Industrial/Manufacturing/Systems Engineering
6	Civil Engineering	**17**	Mechanical Engineering
7	Civil/Environmental Engineering	**18**	Metallurgical and Matrls. Engineering
8	Computer Engineering	**19**	Mining Engineering
9	Computer Science (inside engineering)	**20**	Nuclear Engineering
10	Electrical Engineering	**21**	Other Engineering Disciplines
11	Electrical/Computer Engineering	**22**	Petroleum Engineering

1.3 Research Question

What are the top and bottom performing ASEE-reporting institutions' engineering disciplines in terms of gender representation?

This important research question begs a corollary data investigation into how the gender and racial distribution of degrees awarded has changed over time for the 22 ASEE-reported disciplines for the institutions that provide their data to the EDMS database.

2 Methods

For inclusion and exclusion criteria, the EDMS database was queried for all reported information at the three degree levels for all engineering degree disciplines, plus computer science within engineering. The sex-specific records were not kept reliably until 2005, thus our infographics start from that year and proceed through 2021, which was the last date available when access to the data was purchased by the authors' institution. The gender choice of "Other" was excluded due to the limited number of degrees awarded, reported only for 2019. Our "Native" category reflects combining the racial reporting options of "American Indian/Alaska Native" and "Native Hawaiian/Other Pacific Islander." Similarly, our "Multi" category reflects combining "Foreign," "Multiracial," and "Unknown." Other racial categories are used as reported by ASEE (e.g., "Asian," "Black," "Hispanic," and "White").

Procedurally, the data was first downloaded into a CSV file. A self-generated Jupyter file was created to clean the data and create the tidy format [21] XLSX files needed by Tableau for creating the infographics [11]. Once the charts were styled with shapes, colors, and categories chosen for visual distinction and contextual discernment, the total degrees awarded and those disaggregated by each discipline were saved to PDF files [22], [23, Ch. 4, 6, 8]. Excel was used to create summary tables.

The primary contribution of this work is further disaggregation by ASEE discipline and the addition of numeric details within the charts rather than separate wide-format tables [11]. To understand what disciplines women are migrating towards over the others, we discuss the EDMS data by discipline as well as race and sex for each degree level. However, since the intention of this paper is to compare top and bottom performing disciplines, and since a BS degree is sufficient for practice, the discussion is limited to that level. All infographics generated in the course of this study are provided as supplementary materials to this paper and include the remaining disciplines and degree levels. The intention is still for the use of these infographics to

justify research into why degrees awarded to women and minorities are increasing, yet the total percentages appear to be stagnant.

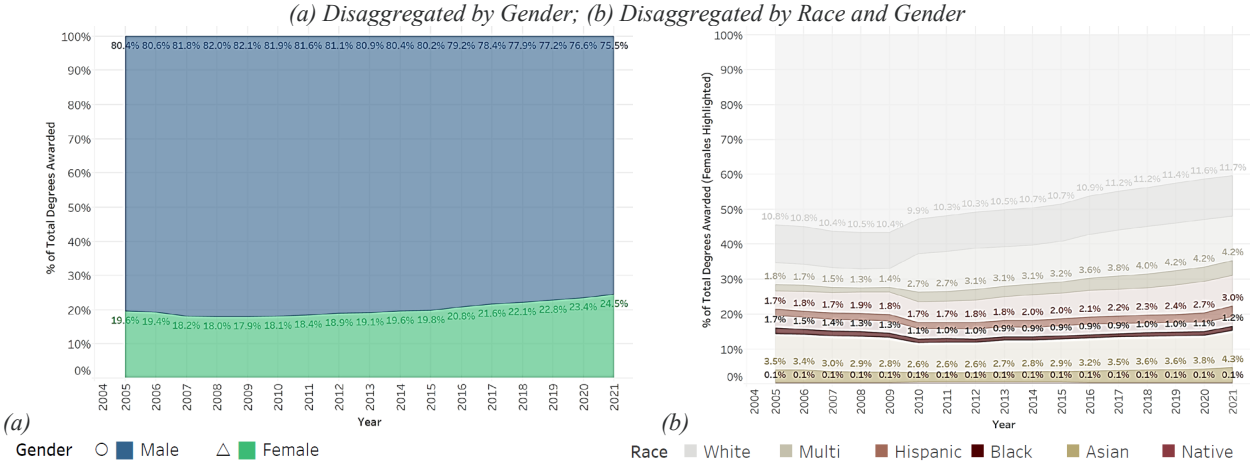
3 Results and Discussion

These infographics will only showcase the choices made by the women and minorities within the ASEE member-reporting institutions between 2005 and 2021. They cannot disclose motivations behind the various year-to-year shifts, however some logical inferences may be made when considering the US recession in 2008, the changes in US immigration policy in 2018, and the COVID-19 lockdowns in 2020 [24], [25], [26]. For example, according to US Census Bureau, the US population for the traditional college age range shows a lower increase from 2010 to 2020 than was shown in 2000 to 2010, which could indicate that any recent growth in the disciplines is not due to population growth [27], [28]. These infographics therefore contrast discipline-specific information with the commonly lamented inference from total engineering charts that "no" progress has been made in broadening participation in engineering at each degree level beyond one-fifth female. We start with the total infographics by degree level, as they are useful for understanding the context of the broadening participation lament. We then move to the EDMS data disaggregated by discipline to discuss the bottom and top five percentage female representation for the BS degree level.

3.1 Bachelor's degrees (BS)

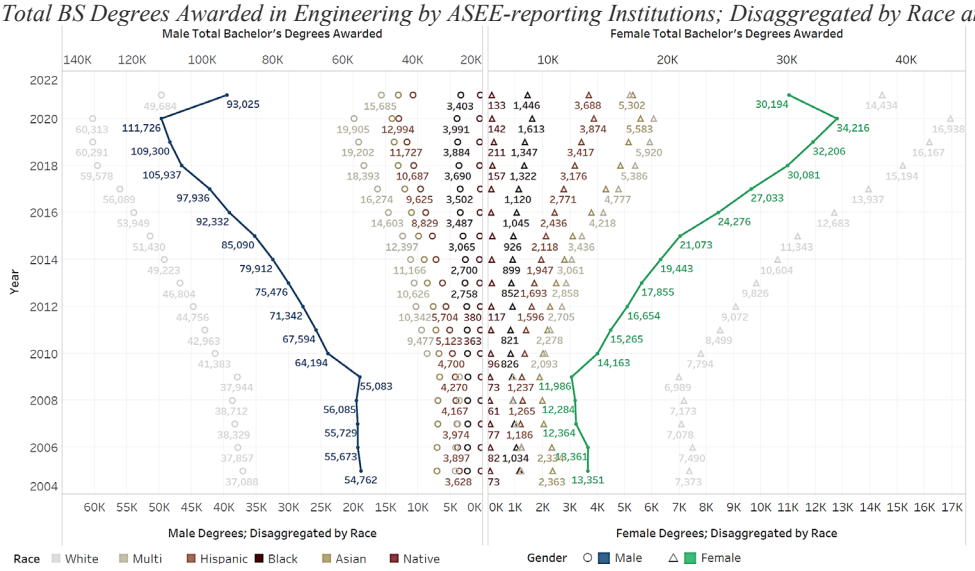
The prevailing story of diversity for women in engineering is derived from the gender percentage of total BS degrees awarded as represented by Figure 1(a). This is the origin of the one-fifth lament, but the data does show movement around 20%. When additionally disaggregating by race, Figure 1(b) shows a slow but steady increase in White, Multi, Hispanic and Asian women. The percentages for Black and Native women do indeed appear to remain the same over the 16-year period.

Figure 1: Percentage BS Degrees Awarded in Engineering by ASEE-reporting Institutions
(a) Disaggregated by Gender; (b) Disaggregated by Race and Gender



While the stagnant percentages for Black and Native women initially look disheartening, looking at the actual number of degrees awarded over time in Figure 2 does show a steady increase from 2005 to 2016. Note the dual axis for the total lines by gender is located to the top, while the axis for the disaggregated shapes by gender and race is located at the bottom. We chose to not let the detail numbers overlap in Tableau; however, they are color-coded to the respective gender or race for ease of interpreting the axis locations. This visualization highlights that the racial categories experiencing the percentage change are also driving the overall growth in the total degrees awarded.

Figure 2: Total BS Degrees Awarded in Engineering by ASEE-reporting Institutions; Disaggregated by Race and Gender



This representation points out that percentages do not tell the full story. A focus on the percentages alone could be disheartening, while the numbers of degrees awarded shine hope into the story. More degrees are being awarded in 2021 than were in 2005 for engineering across both

genders and all races. Still, it has not yet answered what disciplines experience this growth. For that, an additional disaggregation by the 22 ASEE-reported disciplines was created. The full chart for the 2005 and 2020 years is in Appendix A, and the full set of infographics in the styles of Figures 1 and 2 are in the Appendix B supplementary materials. For this paper, we focus on the top five and bottom five ranked disciplines for female representation percentage at the BS level. Table 2 also shows the actual percentage for the total engineering (e.g., the aggregated disciplines), showing that there has actually been a shift in the overall representation, despite the often heard one-fifth lament. Note that the bottom five percent female disciplines belong to the hard-applied-nonlife categorization of academic subjects, while the top five are hard-applied-life or soft-applied-life [17]. Since the mining engineering discipline accounts for such a small number of degrees awarded, its infographics are given in the supplementary materials and not discussed in this paper.

Table 2: Five Top and Bottom Disciplines by Female Representation in 2005 and 2020

Discipline Name For 2005	**Female # BS**	**Male # BS**	**% Female BS**	**Discipline Name For 2020**	**Female # BS**	**Male # BS**	**% Female BS**
Computer Engineering	555	4394	**11.2%**	Mining Engineering	24	181	**11.7%**
Mechanical Engineering	1807	12031	**13.1%**	Computer Engineering	1132	6616	**14.6%**
Electrical Engineering	1634	9944	**14.1%**	Aerospace Engineering	724	4092	**15.0%**
Electrical/Computer Engineering	400	2263	**15.0%**	Electrical Engineering	2064	11318	**15.4%**
Computer Science (inside engineering)	1209	6633	**15.4%**	Mechanical Engineering	5756	28935	**16.6%**
Overall Total Degrees	***13351***	***54762***	***19.6%***	***Overall Total Degrees***	***34216***	***111726***	***23.4%***
Industrial/Manufacturing/ Systems Engineering	1206	2333	**34.1%**	Industrial/Manufacturing/ Systems Engineering	2299	4615	**33.3%**
Biological Engr. and Agricultural Engr.	207	400	**34.1%**	Chemical Engineering	3904	6458	**37.7%**
Chemical Engineering	1585	2617	**37.7%**	Biological Engr. and Agricultural Engr.	594	892	**40.0%**
Environmental Engineering	203	284	**41.7%**	Biomedical Engineering	3800	3818	**49.9%**
Biomedical Engineering	946	1213	**43.8%**	Environmental Engineering	643	563	**53.3%**

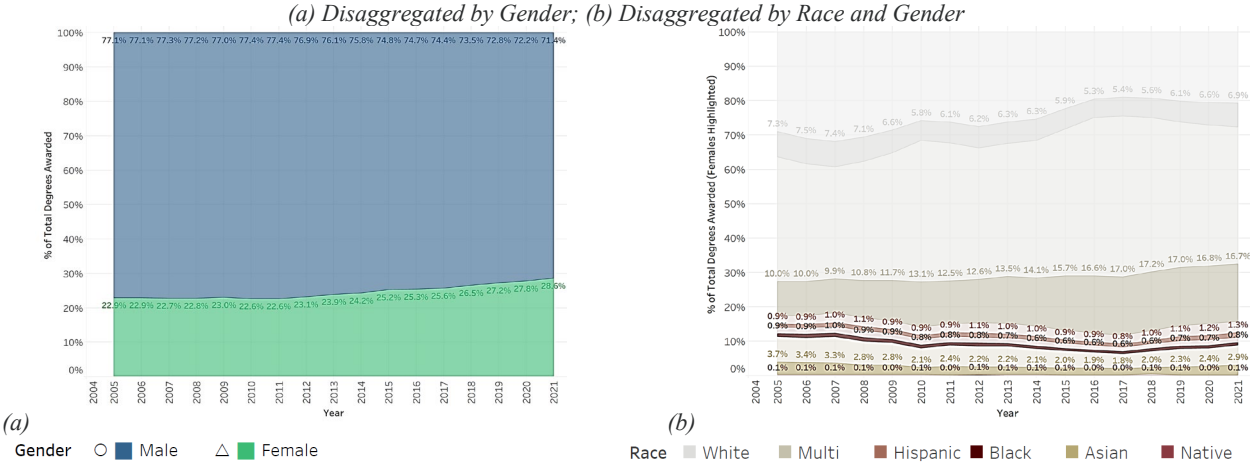
3.2 Graduate degrees

Before moving to the top and bottom performing disaggregated BS level disciplines, it is useful to note the total trends for graduate level degrees (e.g., master's degrees (MS) and doctoral (PhD) degrees). While they are not typically required for entry-level engineering careers, advanced degrees are required for academic and research positions. Looking at the

trends over time, the graduate levels also indicate a slow but general increase in the percentage representation of women in engineering similar to that represented in the total BS degrees.

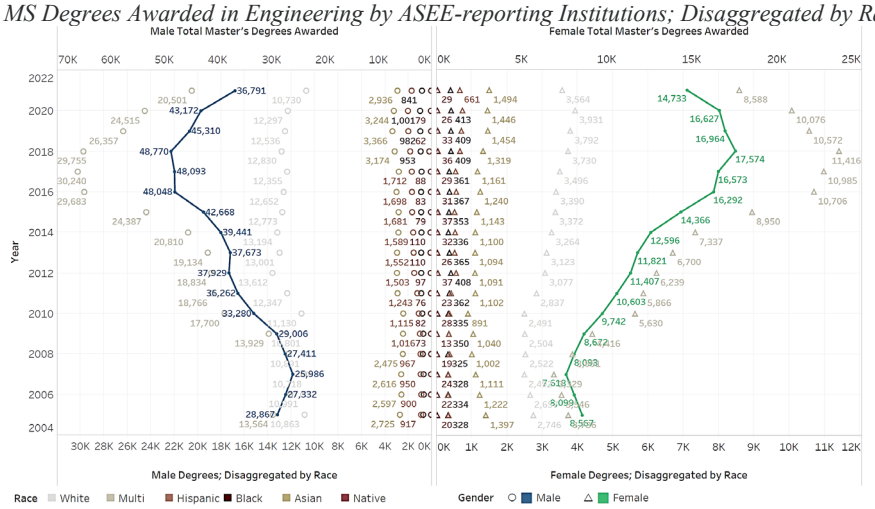
The MS level percentages displayed in Figure 3 depict both an overall increase in female percentages (a), and that the change in percentage representation is concentrated within those represented by the Multi category (b). The percentages of women in additional racial categories appears to be steady.

Figure 3: Percentage MS Degrees Awarded in Engineering by ASEE-reporting Institutions
(a) Disaggregated by Gender; (b) Disaggregated by Race and Gender



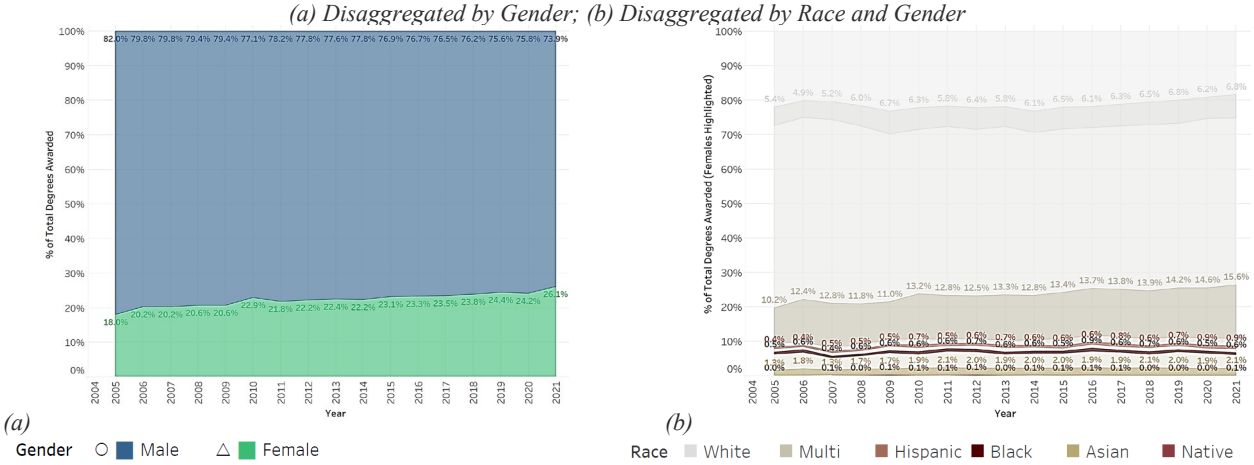
While the numbers of MS degrees awarded in Figure 4 display a slow but general upward trend for most races from the recession of 2008 onward, the drastic decline in numbers from the Multi category for both genders is likely representative of the "Foreign" portion of the ASEE-ascribed label that was affected by immigration policy changes in 2018 [25]. It is notable that even with this decrease and the impact of the COVID-19 lockdowns, twice as many MS degrees were awarded to women in 2021 than were in 2007.

Figure 4: Total MS Degrees Awarded in Engineering by ASEE-reporting Institutions; Disaggregated by Race and Gender



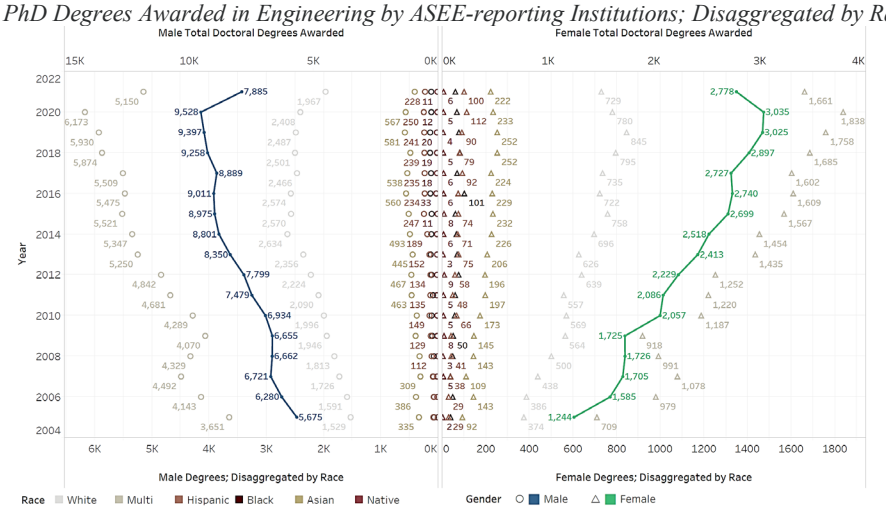
The PhD level percentages revealed in Figure 5 represent the most growth by level in not only women as a whole, but also among women of all races. This could serve as a springboard for discussions into which graduate programs are appealing to women and engendering the feelings of belonging necessary for persistence.

Figure 5: Percentage PhD Degrees Awarded in Engineering by ASEE-reporting Institutions
(a) Disaggregated by Gender; (b) Disaggregated by Race and Gender



Terminal degree level representation, like with the MS level, is likely impacted by the U.S. immigration policies, as the Multi racial category also represents the largest portion of degrees awarded [25]. Yet, Figure 6 reveals that immigration policy may impact PhD degrees to a lesser extent than MS degrees for ASEE-reporting institutions. Although the general upward trend shows a slow but steady increase for female representation, the PhD level also represents the fewest total degrees awarded by gender and race.

Figure 6: Total PhD Degrees Awarded in Engineering by ASEE-reporting Institutions; Disaggregated by Race and Gender



3.3 Computer Engineering

At the BS level, this discipline may indeed be only 15% female as shown in Figure 7(a), but due to the popularity of the subject, that amounts to almost a thousand degrees awarded to women in 2021. There has been an increase in coding-focused PreK-12 STEM outreach [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], which could be one reason for the numerical growth in this discipline as shown in Figure 8, as well as that of computer science (within engineering) discussed in the next section.

Figure 7: Computer Engineering Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

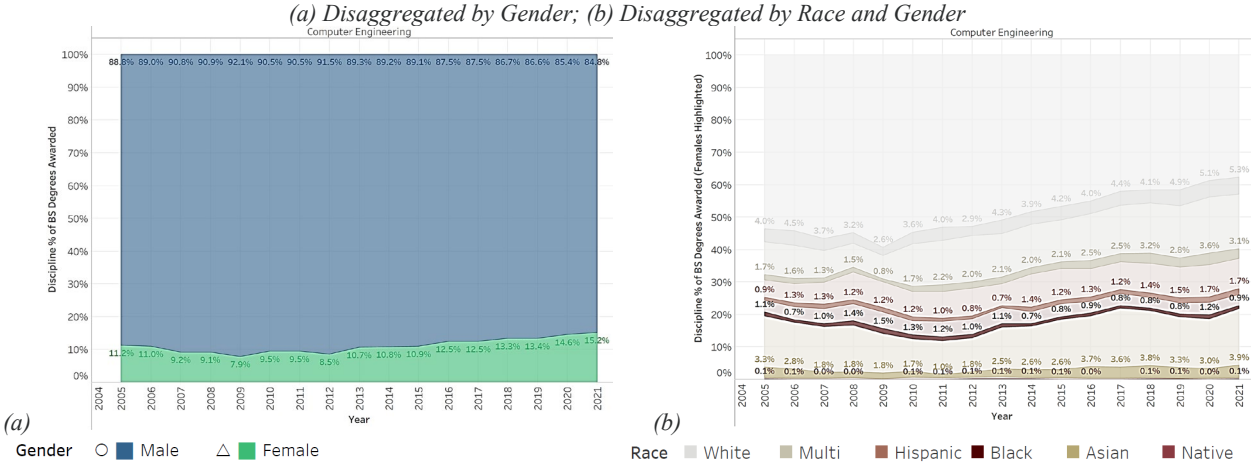
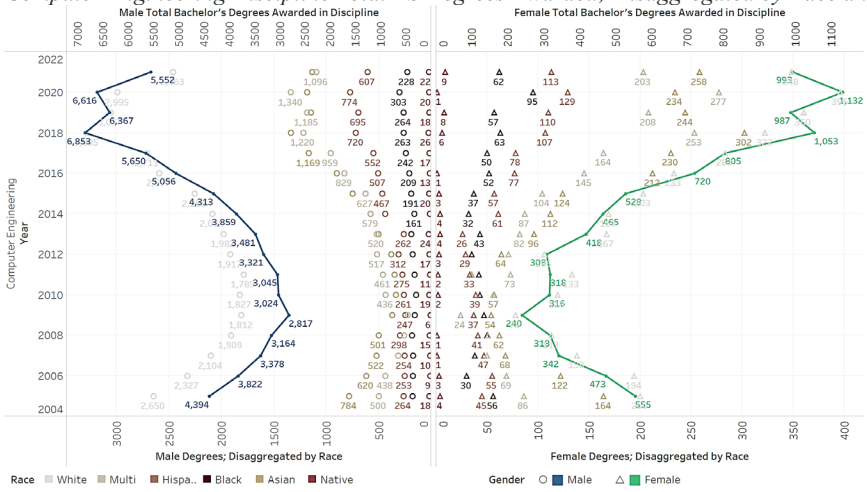


Figure 8: Computer Engineering Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.4 Computer Science (inside engineering)

At the BS level, this discipline is the second largest ASEE discipline for the number of female degrees awarded in 2021, rising from 5th in 2005. So while the almost one-fifth female representation seems disheartening, it actually represents an increase in 2021of about 3,000 degrees awarded to women over the 2005 number as displayed in Figure 9(a) and Figure 10. Given the presumption that computational skills are necessary 21st century skills, the relative lack of Native women and the shrinking of Black female percentage as displayed in Figure 9(b) merits further study.

Figure 9: Computer Science Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

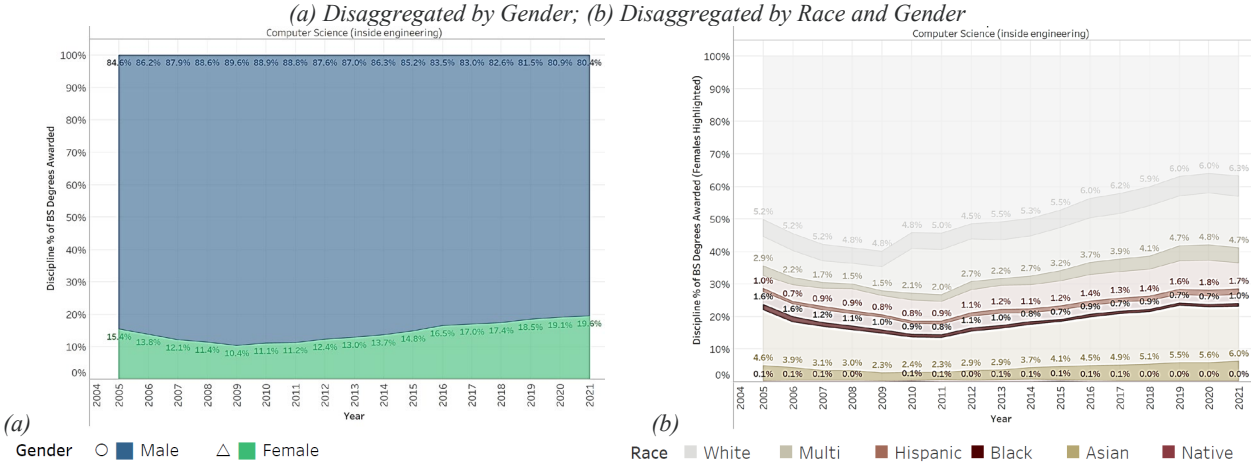
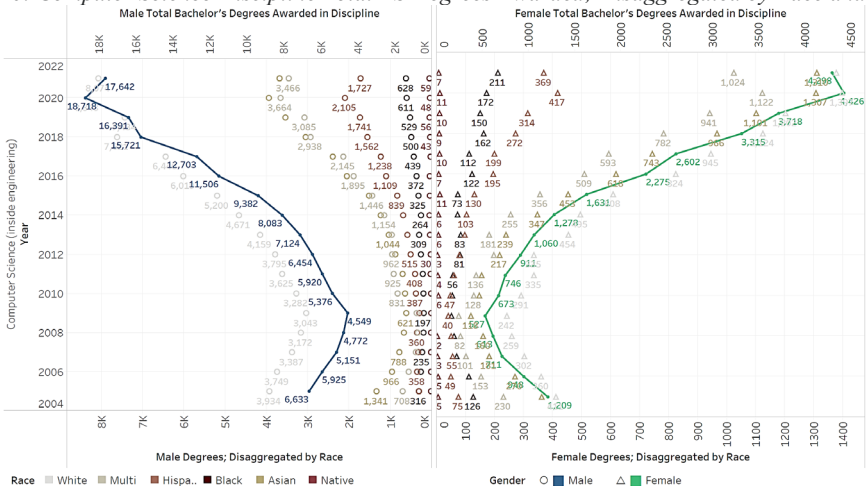


Figure 10: Computer Science Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.5 Aerospace Engineering

At the BS level, this discipline is predominantly male and White as noted by Figure 11. The percentages are increasing for Multi, Hispanic, and Asian women, but they are decreasing for White, Black, and Native women. Additionally, the racial categories of Hispanic and Multi appear to be steadily growing in number, as is the overall number of women as noted by Figure 12. However, this is one of the smaller ASEE-listed disciplines in terms of overall numbers. Even with the percentage decrease, White women still graduate more per year than the other races. Given that rocketry is one of the initial school science project crossovers to engineering, this could merit study into why underrepresented students appear to become disinterested in space and flight [40].

Figure 11: Aerospace Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

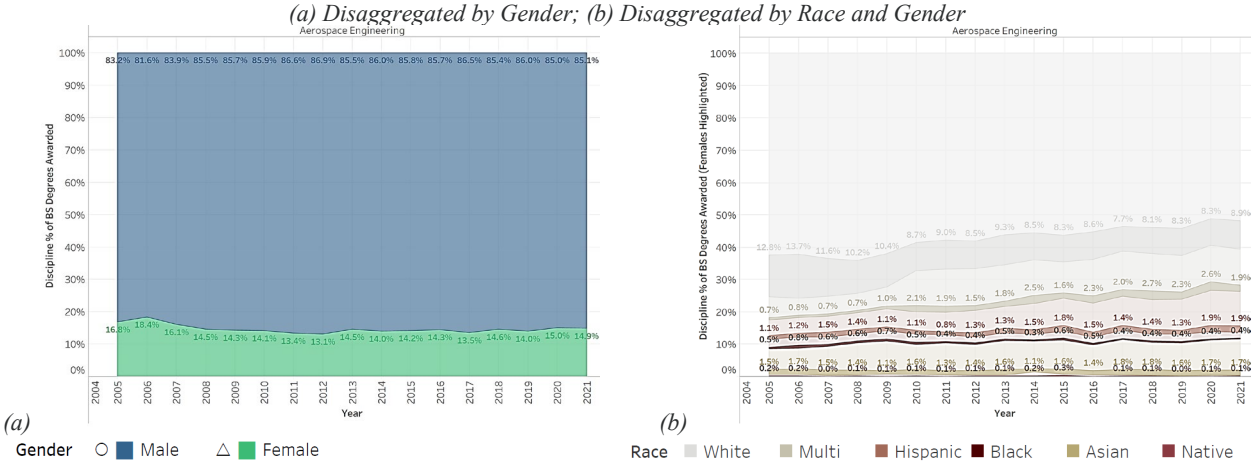
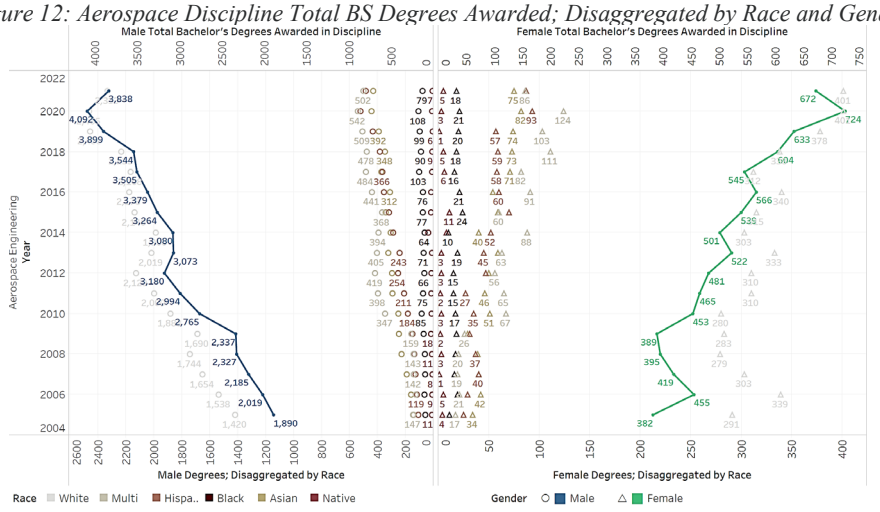


Figure 12: Aerospace Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.6 Electrical Engineering

At the BS level, this discipline is the 4th largest by total number of degrees awarded and 8th by number of female degrees awarded, so the 16% female representation in 2021 translates to 1,650 degrees, as represented by Figure 13 and Figure 14. The racial disaggregation is fairly consistent, with only slight changes to both genders. The decline in the number of White students of both genders since 2019 merits further study given the relative stability for the numbers of the other races.

Figure 13: Electrical Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions
(a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

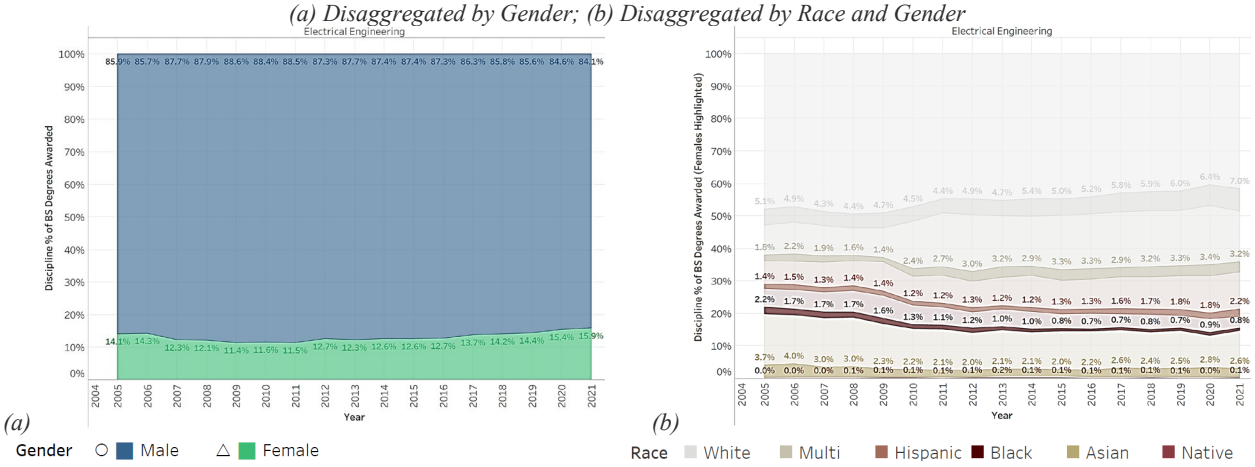
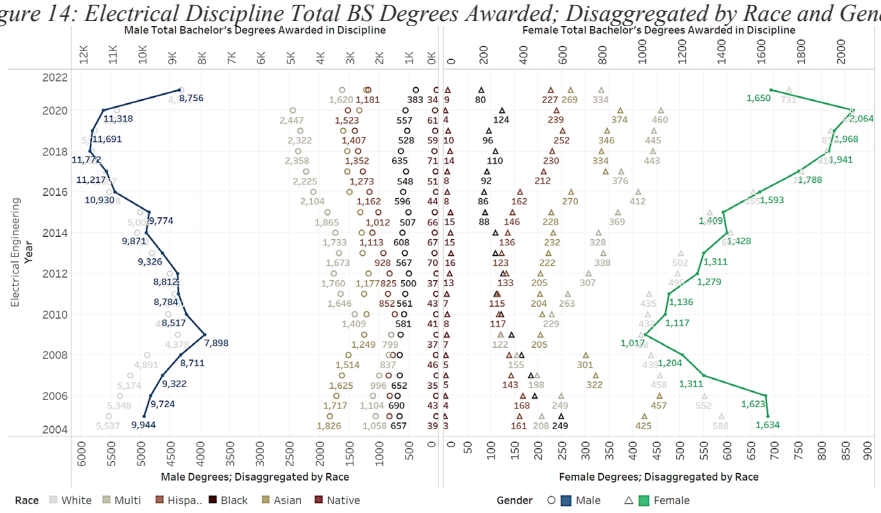


Figure 14: Electrical Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.7 Mechanical Engineering

At the BS level, this discipline has a gender percentage that rose from 13.1% in 2005 to 17.2% in 2021, with similar slow but steady increases in percentages of all racial categories except Black and Native as revealed in Figure 15. While this may not seem like much improvement, mechanical engineering actually has the largest number of female graduates for all of the ASEE-reporting institutions at this level and timeframe. It also has the most male graduates, making it the largest ASEE-listed discipline for BS degrees, as indicated by Figure 16 and revealed by the full table of disciplines in Appendix A. Further study could investigate if the "nonlife" aspect of this "hard-applied" subject is a root of the gender difference [17].

Figure 15: Mechanical Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

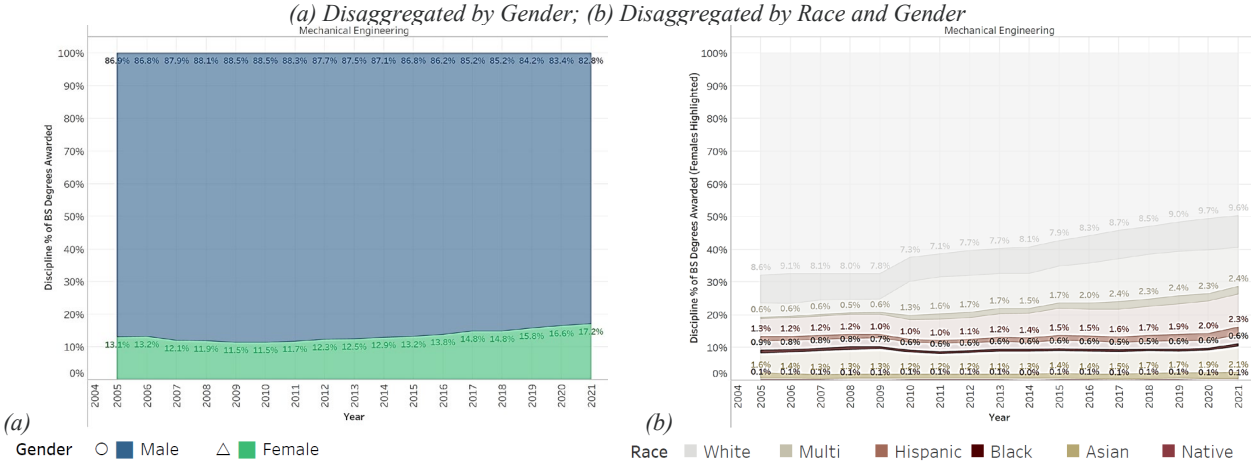
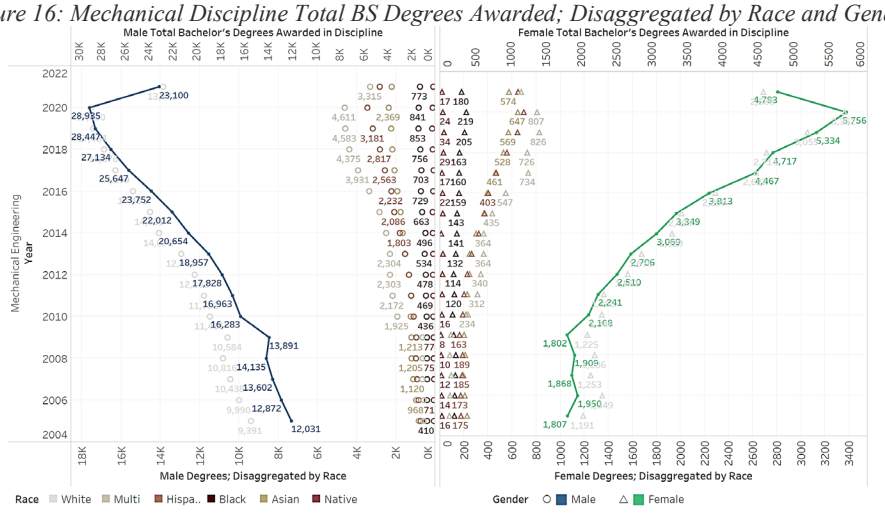


Figure 16: Mechanical Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.8 Industrial/Manufacturing/Systems Engineering

At the BS level, this discipline has hovered around a third female, between 29% to 35% representation of women, with the racial representation mostly steady for all women but decreasing for those in the Black category as depicted in Figure 17. The overall number of degrees awarded place this discipline as depicted in Figure 18 within the largest seven. In 2021, the 2,314 degrees awarded to women exceeded the number awarded to women in electrical engineering, however that discipline also attracts more men. Interestingly, this discipline is one of the few that did not see a decrease in the number of female BS degrees awarded in 2021 due to the COVID-19 lockdowns.

Figure 17: Industrial/Manufacturing/Systems Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

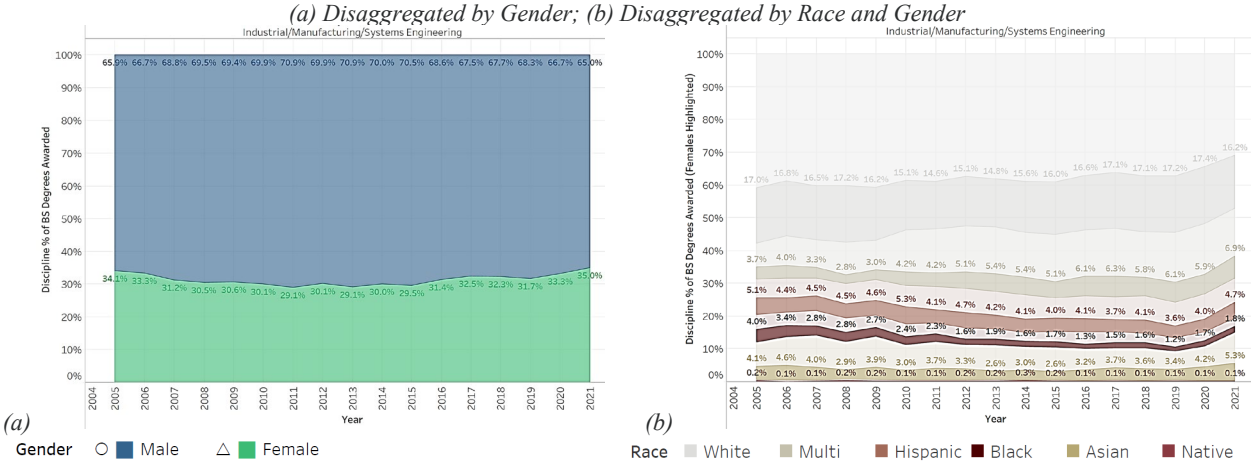
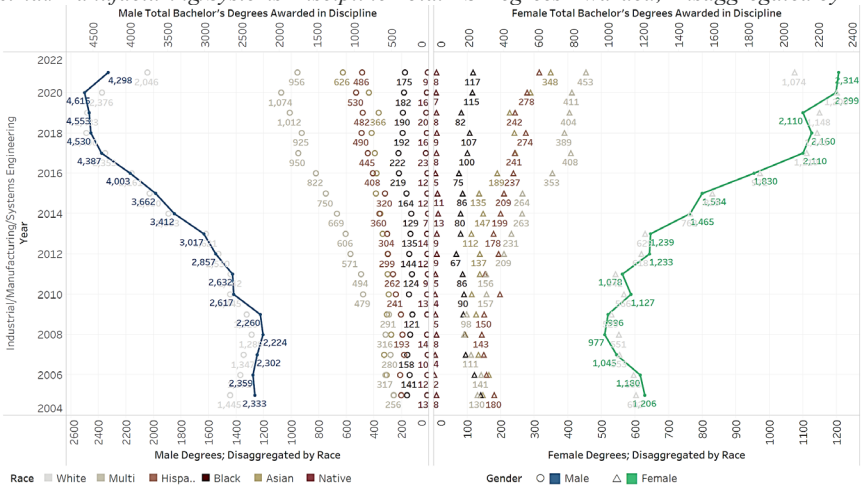


Figure 18: Industrial/Manufacturing/Systems Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.9 Chemical Engineering

At the BS level, this discipline is approaching two-fifths representation, with a fairly steady racial representation. The exception is a decrease in percent of women from the Black category, even as the total number of degrees awarded to them has steadily increased as illustrated by Figure 19 and Figure 20. This discipline is the 5th largest discipline by total degrees awarded, but it has more women overall than the ASEE-labeled civil engineering and electrical engineering, allowing it to leapfrog them to 4th most female degrees awarded in 2021. The decline in number of degrees awarded to both genders beginning in 2017 could be due to the oil and gas price volatility that began in 2014, given that the industry relies on chemical engineers for their processing plants [41].

Figure 19: Chemical Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

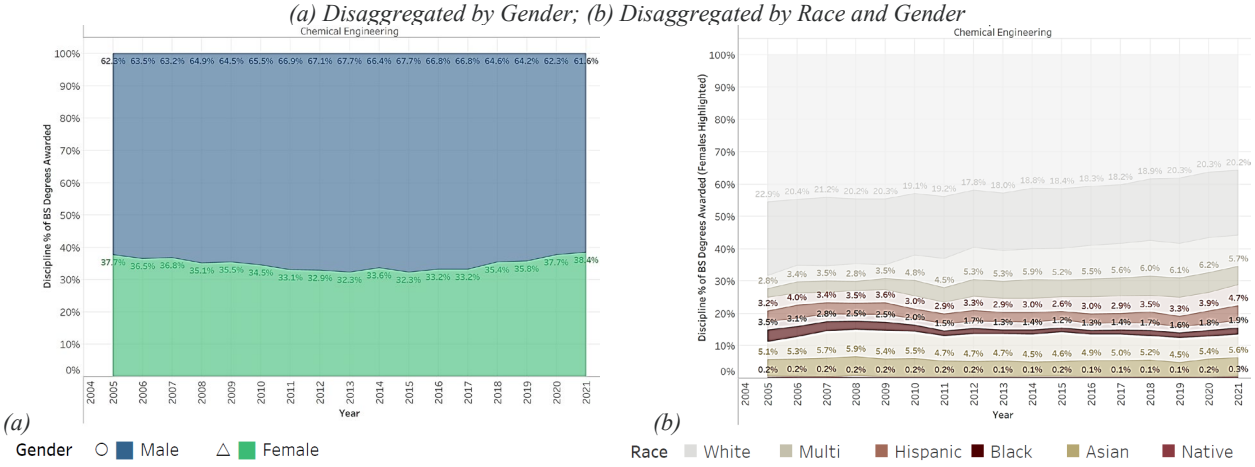
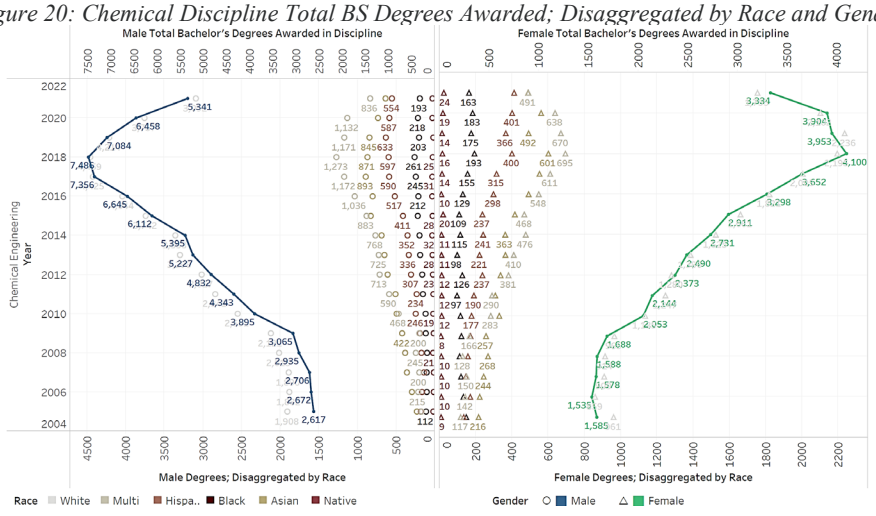


Figure 20: Chemical Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.10 Biological Engr. and Agricultural Engr.

At the BS level, this discipline is almost two-fifths female representation in 2021, with the majority of the women belonging to the White category as displayed in Figure 21. Even with consistent numerical growth as displayed in Figure 22, this discipline is one of the smaller ASEE-listed disciplines in terms of overall numbers. Still, future research could investigate how these women develop their engineering identities in a "hard-applied-life"-based field that young students would associate with farming [42].

Figure 21: Biological-Agricultural Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

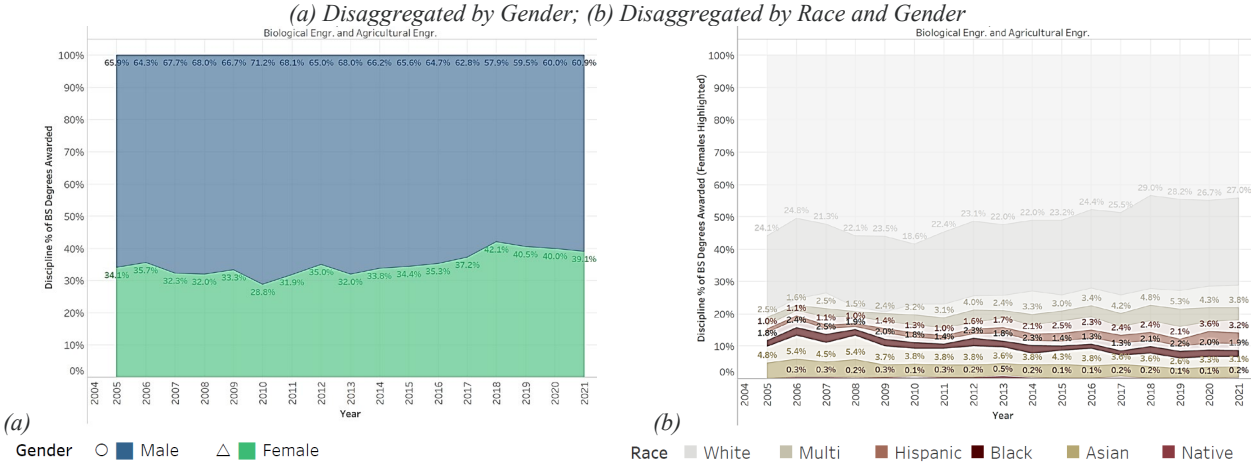
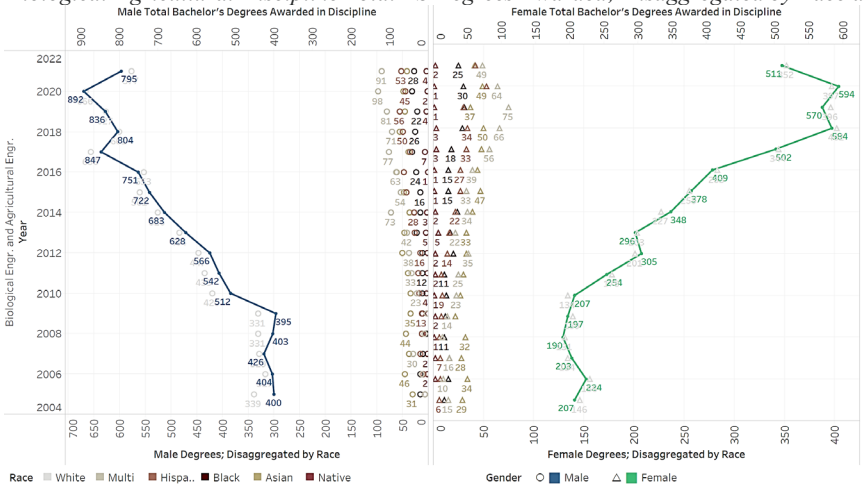


Figure 22: Biological-Agricultural Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.11 Biomedical Engineering

At the BS level, this discipline has reached gender parity as exhibited by Figure 23. This is substantial because it is the sixth largest discipline overall for ASEE as indicated by Figure 24 and revealed by the full table of disciplines in Appendix A. The racial disaggregation doesn't appear to show much shifting between racial categories, except for a small growth in all female percentages except White and Asian, as the White male percentage decreased. More study is needed to understand where these women are beginning their careers after obtaining their degrees, as leaving the engineering career pathway in order to practice medicine should be counted as a win for STEM education!

Figure 23: Biomedical Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions
(a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

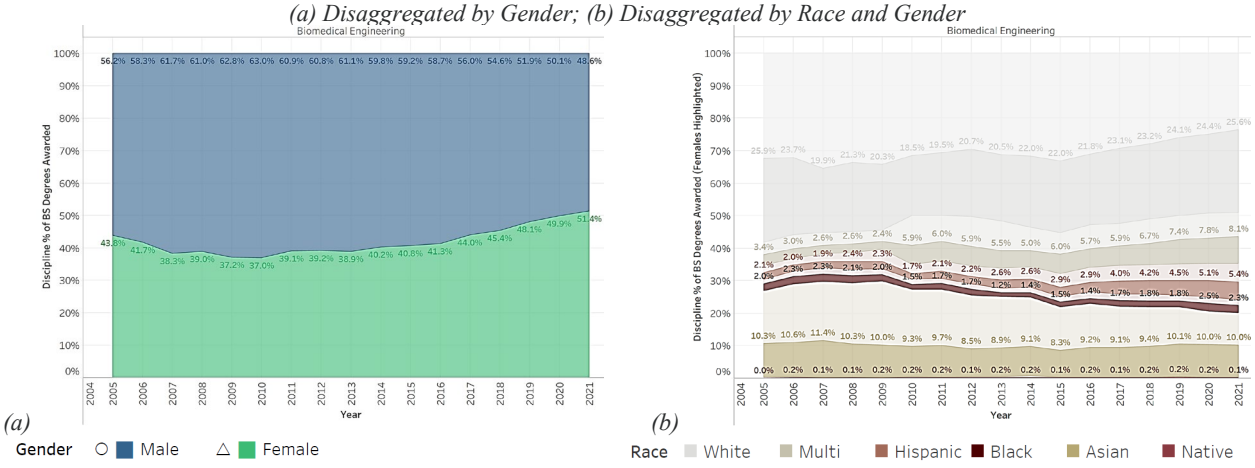
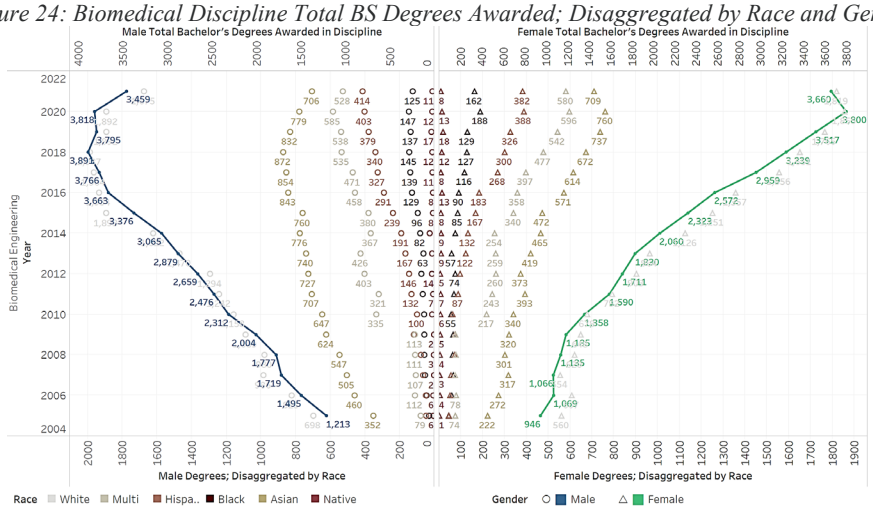


Figure 24: Biomedical Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



3.12 Environmental Engineering

At the BS level, this discipline exceeds gender parity as noted by Figure 25. While most racial categories increased, women in Black and Native categories decreased. Although this discipline is majority female, the numbers only account for 601 degrees awarded to women in 2021 as noted by Figure 26, making it 12th most female degrees awarded, and 16th largest discipline by overall size.

Figure 25: Environmental Discipline Percentage BS Degrees Awarded by ASEE-reporting Institutions (a) Disaggregated by Gender; (b) Disaggregated by Race and Gender

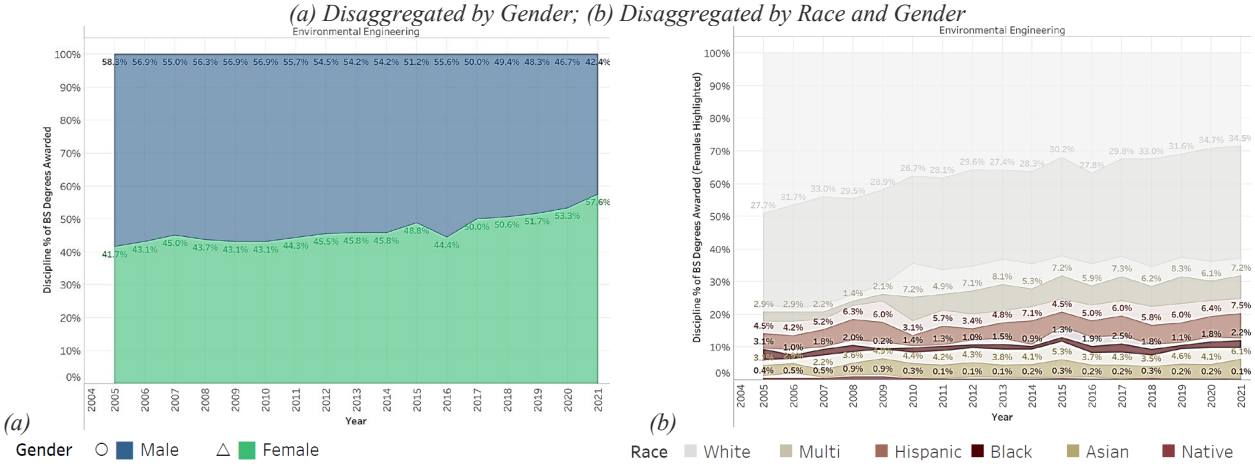
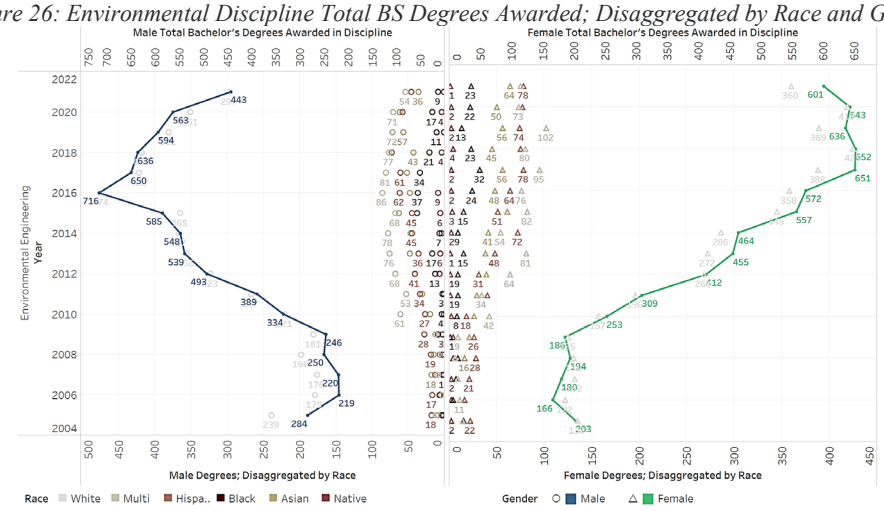


Figure 26: Environmental Discipline Total BS Degrees Awarded; Disaggregated by Race and Gender



4 Conclusions

Generally, more women and minorities are choosing to pursue engineering at all levels and in all disciplines than in the previous 16 years. At the bachelor's degree level, women appear to be congregating in environmental (53.3%), biomedical (49.9%), biological/agricultural (40.0%), chemical (37.7%), and industrial/manufacturing/systems (33.3%) disciplines, all 5 top percentages from 2020. However, also in 2020, the most women graduated from mechanical (4,783), computer science (4,298), biomedical (3,660), chemical (3,334) and civil (3,068) disciplines. This data counters the anecdotal notion that women categorically choose the mislabeled "soft" subjects [14]. It is notable that the top 7 ASEE disciplines by total size typically graduate about three times more students at the BS level than the other 15 disciplines, but only 2.5 times more women than men. These top 7 for 2020 included: biomedical engineering, computer engineering, chemical engineering, civil engineering, electrical engineering, computer science (inside engineering), and mechanical engineering. However, in 2021, computer engineering fell out of the top 7 and was replaced by industrial/manufacturing/ systems engineering disciplines.

While not the main focus of this paper, some conclusions about graduate degrees uncovered by the supplementary materials creation must also be noted. While it is one of the smaller disciplines, environmental engineering is the only one near gender parity for all three levels of higher education, with the doctoral level being above 41% female since 2016. The master's degree level for all disciplines appears to be the hardest hit by the immigration policy changes from 2018 [25]. The doctoral degree level has the fewest degrees awarded to women, with several years experiencing no female graduates of various racial categories in multiple disciplines. Of note, the biomedical discipline has neared gender parity at the doctoral level, and also has the greatest number of doctoral degrees awarded to women for ASEE-reporting institutions. It has moved from the lower 15 disciplines by size to the top 7 between 2010 and 2015.

Another important conclusion can be drawn from the data shift from 2020 to 2021 as the devastating impact of the COVID-19 pandemic lockdowns on college graduation rates was recorded. A vast majority of all three levels and 22 disciplines did indeed follow the overall trend of rapid drop in degrees awarded for 2021 due to the COVID-19 lockdowns [26]. Additionally, this drop in degrees awarded affected men more than it did women (e.g., a vast proportion across

levels and disciplines saw in increase in the percentage female representation in 2021 over 2020). Future research would need to gather the most recent data from the ASEE EDMS to determine if recovery efforts have brought students back to all disciplines equally.

These infographics may be used to motivate future research on this topic of female representation and broadening participation in engineering. When seeking to understand the representation of women in engineering, one should evaluate not only the ***percentage*** of degrees awarded, but also the ***number*** of degrees awarded to women in engineering. More nuanced understanding is derived as this data is disaggregated by race, sex, and discipline as well as placed into historical context. This manuscript provides approachable figures emphasizing how the degrees awarded in engineering have changed over time for ASEE-reporting institutions.

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6 Abstract

Background: There exists a national focus on broadening the participation of women in engineering beyond the commonly reported 20% proportion of degrees awarded. Yet, we do not know the full impact of this focus, especially as the reported aggregated data does not appear to shift over time.

Purpose: The authors wanted to understand the anecdotal musings that the women are choosing "soft" engineering disciplines, like environmental engineering, while avoiding the "hard" engineering disciplines, like mechanical engineering. Additionally, we sought to disaggregate the graduation data over time by biological identities in ways previously unpublished by the American Society for Engineering Education (ASEE) annual reports.

Method: The program Tableau was used to visualize data from ASEE, per their Engineering Data Management System (EDMS). We first cleaned data with a self-generated Jupyter Notebook file and then followed ten rules for making sense of data in creating the disaggregated visualizations at all three levels of engineering academia. We sought trends by disaggregating ASEE records by gender, race, and engineering discipline bachelor's, master's, and doctoral degree levels over a 16-year period, from 2005-2021.

Results: The percentage of bachelor's, master's, and doctoral degrees is increasing for women, as the total number of all degrees awarded is increasing for all genders in all disciplines. Racial factors remain a concern for both sexes, but these are not evenly distributed across disciplines. Women congregate in biomedical, environmental, and chemical disciplines, which are actually hard-applied-life academic subjects. However, the most women earned bachelor's degrees in the hard-applied-nonlife mechanical engineering discipline over the study timeframe. Also, degrees awarded to women in the computer science within engineering discipline climbed steadily to the second most in 2021.

Conclusions: While true that the overall proportion of women in engineering hovered at ~20% for the past 20 years, the numbers and distribution of women has shifted in some disciplines. Myriad first- and second-year retention programs, as well as outreach for all levels of PreK-12 education, are likely bringing more women into engineering majors, however, more engineering identity research is needed to determine how to empower women and minority persistence to change the proportions.

Keywords: *Engineering education, Degrees awarded, Statistics, Women in engineering, Infographics*

7 Appendix A

Tables can be just as useful as infographics. This tabulates the 2005 and 2020 percent female representation data for all 22 ASEE-reported disciplines, showing where the top and bottom five disciplines were determined for BS degrees, and how those disciplines have performed at all three engineering degree levels from 2005 (e.g., the beginning of the reliable gendered ASEE data) and from 2020.

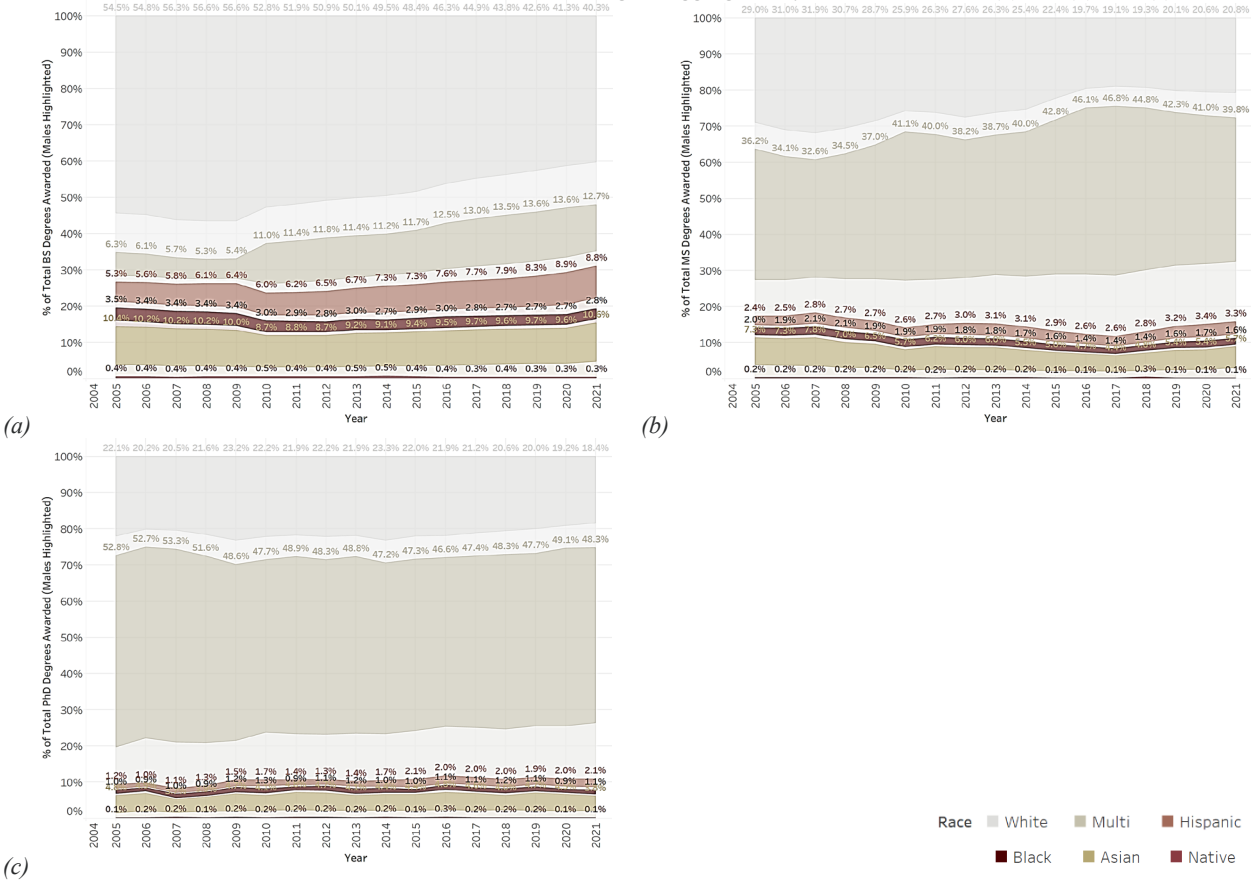
Discipline Name	Year	Female # BS	Male # BS	% F BS	Female # MS	Male # MS	% F MS	Female # PhD	Male # PhD	% F PhD
Computer Engineering	2005	555	4394	**11.2%**	428	1028	**29.4%**	428	1028	**10.1%**
Mechanical Engineering	2005	1807	12031	**13.1%**	553	3851	**12.6%**	553	3851	**12.7%**
Electrical Engineering	2005	1634	9944	**14.1%**	1070	4262	**20.1%**	1070	4262	**12.2%**
Electrical/Computer Engineering	2005	400	2263	**15.0%**	738	3183	**18.8%**	738	3183	**14.1%**
Computer Science (inside engineering)	2005	1209	6633	**15.4%**	1359	4066	**25.1%**	1359	4066	**16.7%**
Aerospace Engineering	2005	382	1890	**16.8%**	149	754	**16.5%**	149	754	**12.4%**
Petroleum Engineering	2005	52	231	**18.4%**	39	202	**16.2%**	39	202	**23.8%**
Mining Engineering	2005	14	59	**19.2%**	7	27	**20.6%**	7	27	**0.0%**
Nuclear Engineering	2005	51	212	**19.4%**	31	133	**18.9%**	31	133	**12.0%**
Overall Total Degrees	***2005***	***13351***	***54762***	***19.6%***	***8572***	***28869***	***22.9%***	***8572***	***28869***	***18.0%***
Engineering (General)	2005	186	727	**20.4%**	129	338	**27.6%**	129	338	**24.4%**
Other Engineering Disciplines	2005	555	1981	**21.9%**	683	2190	**23.8%**	683	2190	**25.1%**
Civil/Environmental Engineering	2005	41	146	**21.9%**	21	53	**28.4%**	21	53	**10.0%**
Civil Engineering	2005	1758	5984	**22.7%**	939	2629	**26.3%**	939	2629	**21.5%**
Engr. Science and Engr. Physics	2005	82	247	**24.9%**	56	206	**21.4%**	56	206	**18.7%**
Engineering Management	2005	69	198	**25.8%**	360	1168	**23.6%**	360	1168	**19.4%**
Architectural Engineering	2005	163	447	**26.7%**	43	67	**39.1%**	43	67	**16.7%**
Metallurgical and Matrls. Engineering	2005	246	528	**31.8%**	186	499	**27.2%**	186	499	**23.0%**
Industrial/Manufacturing/ Systems Engineering	2005	1206	2333	**34.1%**	686	2333	**22.7%**	686	2333	**21.3%**
Biological Engr. and Agricultural Engr.	2005	207	400	**34.1%**	57	111	**33.9%**	57	111	**16.4%**
Chemical Engineering	2005	1585	2617	**37.7%**	410	903	**31.2%**	410	903	**22.7%**
Environmental Engineering	2005	203	284	**41.7%**	230	348	**39.8%**	230	348	**28.0%**
Biomedical Engineering	2005	946	1213	**43.8%**	398	518	**43.4%**	398	518	**27.6%**

Discipline Name	Year	Female # BS	Male # BS	% F BS	Female # MS	Male # MS	% F MS	Female # PhD	Male # PhD	% F PhD
Mining Engineering	2020	24	181	**11.7%**	6	25	**19.4%**	6	25	**8.3%**
Computer Engineering	2020	1132	6616	**14.6%**	524	1363	**27.8%**	524	1363	**24.3%**
Aerospace Engineering	2020	724	4092	**15.0%**	270	1220	**18.1%**	270	1220	**15.8%**
Electrical Engineering	2020	2064	11318	**15.4%**	1192	3993	**23.0%**	1192	3993	**18.4%**
Mechanical Engineering	2020	5756	28935	**16.6%**	1305	6360	**17.0%**	1305	6360	**15.5%**
Petroleum Engineering	2020	162	800	**16.8%**	38	178	**17.6%**	38	178	**10.4%**
Nuclear Engineering	2020	76	353	**17.7%**	39	190	**17.0%**	39	190	**21.8%**
Electrical/Computer Engineering	2020	775	3360	**18.7%**	1172	3685	**24.1%**	1172	3685	**16.9%**
Computer Science (inside engineering)	2020	4426	18718	**19.1%**	3484	8423	**29.3%**	3484	8423	**19.7%**
Engr. Science and Engr. Physics	2020	173	580	**23.0%**	34	177	**16.1%**	34	177	**28.3%**
Overall Total Degrees	***2020***	***34216***	***111726***	***23.4%***	***16628***	***43177***	***27.8%***	***16628***	***43177***	***24.2%***
Other Engineering Disciplines	2020	1808	5548	**24.6%**	2512	5181	**32.7%**	2512	5181	**28.7%**
Engineering (General)	2020	659	1742	**27.4%**	156	631	**19.8%**	156	631	**30.1%**
Civil Engineering	2020	3638	9597	**27.5%**	1381	3156	**30.4%**	1381	3156	**26.9%**
Engineering Management	2020	184	484	**27.5%**	655	1491	**30.5%**	655	1491	**29.8%**
Civil/Environmental Engineering	2020	439	1113	**28.3%**	368	474	**43.7%**	368	474	**32.2%**
Architectural Engineering	2020	222	486	**31.4%**	49	78	**38.6%**	49	78	**18.8%**
Metallurgical and Matrls. Engineering	2020	714	1457	**32.9%**	366	913	**28.6%**	366	913	**28.7%**
Industrial/Manufacturing/ Systems Engineering	2020	2299	4615	**33.3%**	1106	2736	**28.8%**	1106	2736	**31.1%**
Chemical Engineering	2020	3904	6458	**37.7%**	553	1168	**32.1%**	553	1168	**29.5%**
Biological Engr. and Agricultural Engr.	2020	594	892	**40.0%**	81	120	**40.3%**	81	120	**38.8%**
Biomedical Engineering	2020	3800	3818	**49.9%**	1112	1332	**45.5%**	1112	1332	**39.1%**
Environmental Engineering	2020	643	563	**53.3%**	225	283	**44.3%**	225	283	**43.6%**

8 Appendix B

In light of the recent challenges that men appear to be having in higher education [43], we also include alternate versions of the racial percentage infographics from the "b" side of the Figures 1, 3, and 5 from the paper, but shown in Figure 27 with males highlighted. This might assist justification of scholarship for underrepresented men at a particular degree level.

Figure 27: Percentage Male Degrees Awarded in Engineering Disaggregated by Race and Gender; (a) BS; (b) MS; (c) PhD



While this discussion has focused on the top and bottom five disciplines for the BS level, for this study infographics were generated for all twenty-two of the ASEE-reported disciplines at all three engineering degree levels, including discipline-specific versions of all three levels of percentages with each gender highlighted. These infographics are available for future attributed use as supplementary materials: https://asee2024-public.drkristinlyn.com/