Intersectionality at minority-serving institutions (MSIs): A longitudinal analysis of female student participation within engineering and computing

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Abstract*—This full research paper presents a study of longitudinal data on female students at a research-intensive (R1) public minority-serving institution (MSI). Despite increased focus by state and federal governments and other business entities in the United States, most higher education institutions have yet to reach parity with women's participation in engineering and computing. Of note, the American Society of Engineering Education (ASEE) stated that women earned 22% of bachelor's degrees, 27% of master's degrees, and 24% of doctoral degrees in engineering as of 2018 meaning that there is a continuation of the decade long upward trend in the proportion of women earning engineering degrees across the educational spectrum. For instance, regarding engineering bachelor's degrees, women have seen a 53% increase in degrees awarded between 2010 and 2018. For the purpose of this study, the target institution's College of Engineering and Computing (CEC) has partnered with industry organizations to enhance their understanding of experiences among female students within engineering and computing programs. The overarching goal of those partnerships is to improve graduation and retention rates of female students and faculty. Using intersectionality as the conceptual framework, the goal of this research study is to deeply examine longitudinal data centered on outcome metrics linked to female students within engineering and computing over an 11 to 12-year span. Results will be used to answer research questions on how metrics have changed over time for female students in areas such as enrollment by department and ethnicity. Results showed an overall upward trend for enrollment and graduation rates across departments and by ethnic groups. On the other hand, some areas showed slight dips that will require additional research. Additionally, the results highlighted the need for future research including collecting qualitative data to help explain the findings from this study. Results will be shared with institutional leadership to promote the recruitment, retention, and graduation of more female students within engineering and computing academic programs.

I. Introduction

Reports from the National Science Foundation (NSF) indicated that there was a "troubling decline in the number of US citizens who are training to become scientists and engineers, whereas the number of jobs requiring science and engineering training continues to grow" [1]. The lack of women in STEM transcends traditional narratives on the importance of broadening participation and increasing STEM diversity because of the nuanced issues women face in a male-dominated field. Researchers have determined that the factors related to the persistence or lack thereof, for women in STEM, include social, cultural, and family influences to better understand the experiences of this population. Overall, common topics discussed include [2]:

- A sense of belonging within the community of students in engineering and computer science
- Implementation of peer-mentoring programs
- Exposure to professional development and mentoring with female faculty and staff in STEM
- Access and exposure to STEM career opportunities led by women

To meet domestic and global workforce demands, college programs must reach out to marginalized populations to increase their interest in seeking STEM degrees, especially within the areas of engineering and computer science. To meet these demands, increased focus on getting more women into these fields has taken priority with many colleges, including programs and initiatives linked to the areas mentioned in the previous section. But, despite growing efforts to encourage women to pursue careers in STEM, women continue to hold a disproportionately low share of STEM undergraduate degrees, particularly in engineering and computing. For example, women comprise 46% of the available workforce [3], yet they make up less than 20% of bachelor's degrees awarded in computer science and only 22% awarded in engineering [4]. These findings highlight the need to further examine the trends linked to women in engineering and computer science.

To understand the need to increase enrollment of women in STEM programs, this study will examine quantitative data associated with female students within the college of

engineering and computing (CEC) at a research-intensive (R1) public minority-serving institution (MSI). A review of the literature revealed several studies that expressed challenges experienced by females in engineering and computing, especially for those of diverse backgrounds. Additionally, studies reviewed showed that experiences varied by different types of engineering and computing fields. Therefore, data analysis included female student enrollment and graduation rates by department with race and ethnicity as a sub-focus area.

II. Literature Review

Several studies on engineering and computing education have highlighted the experiences of women, positive and negative, within the fields. Some have compared non-women of color (WOC) to WOC to highlight how different their experiences can be. For example, researchers at the University of Illinois at Urbana Champaign studied the relationship between the intersection of identities and the "chilly climate", where women in male-dominated STEM fields felt unwelcomed [5]. The study specifically aimed to understand the binding of race and gender for women of color (WOC) in engineering education. Several scales were applied to accomplish this (Engineering Identity, Ethnic Identity, Womanist Identity, Microaggressions, and Depressive Symptoms). Additionally, the authors used the Womanist Identity Attitude scale (WIAS) to provide an efficient way to understand gender, racial, and intersecting identity development of WOC. Through a mixed-method approach, including individual interviews, results indicated that among the scales used, WOC were found to have moderately statistically significant differences when compared to non-WOC female students. They also reported higher scores on the ethnic identity measure and racial microaggressions. In conclusion, WOC were found to have unique experiences within the college of engineering that impact both retention and successful degree completion within engineering programs [5].

A top engineering program in the U.S., a study was conducted to look at engineering student retention rates by gender between 2001 to 2011. This particular institution has done well with consistently graduating more female engineers and are more successful at retaining engineering students than the national average. The primary focus of the paper was to understand why students take roughly five years to graduate and whether this above-average time to graduation led to a value-added experience or a negative one for students. Results showed that female students typically graduated in 11 continuously enrolled terms which correlated to four years [6]. This study highlights female students' ability to persist in a timely fashion, even at an extremely competitive engineering program, however, future work should examine how this institution differs from others and what best practices can be gained from their success and shared across institutions. For example, what can lower-ranked or younger engineering programs learn from this institution and how would those learnings be best implemented?

Lastly, the University of North Carolina performed a qualitative research study on the experiences of 4 women in engineering programs to understand how they were able to successfully navigate gender and racial stressors while attending a predominantly white institution (PWI). The data was collected as transcripts and then coded into larger categories which included their motivation to persist, campus environment, and relationships/social networks outside of engineering. Participants expressed that their relationship with family members and friends greatly influenced their success in engineering. Participants also noted that factors such as their resilience, their determination to graduate, and their love for math, were key factors to success in their academic programs. The study concluded that WOC faced additional challenges outside of classes including a sense of belonging. Evidence suggested that women face issues with isolation, lack of support, and negative gender stereotypes [7]. Based on those three studies, the following conceptual framework was incorporated to help understand why women, especially WOC, are more likely to have certain challenges or need unique settings in place to support their success within engineering and computing.

III. Conceptual Framework

Addressing the disproportionately low numbers of women pursuing engineering and computer science degrees required exploration beyond a general literature review. Feminist critiques within feminist theory have undoubtedly contributed to growing awareness and knowledge of women's issues within the workforce, in politics, and at home, yet many groups and sub-groups of women are not adequately represented. In one of the most highly cited works of feminist philosophy, *Second Sex*, by Simone de Beauvoir, the othering of women in a variety of contexts is extensive, yet her work noticeably omits black women. WOC, and men of color, make-up an even smaller proportion of the people of color (POC) working in engineering and computer science. Critical race theory (CRT) has been widely used to study and make recommendations for how to improve the representation of all racial minorities in STEM fields. Yet, as Michael Omi and Howard Winant noted, "despite the enormous legacy and volume of racial theory, the concept of race remains poorly understood and inadequately explained" [8]. Although they referenced race from a broader perspective, Omi and Winant's work is important because it shows that analyzing women from a perspective focused solely on critical race theory lacks the depth needed to understand the nuances of life as a woman of color. This can be especially true for WOC in the male-dominated world of engineering and computer science.

The various research and theories reviewed showed the need to incorporate the construct of intersectionality as a guiding conceptual framework for the analysis and discussion of this study. The intersectionality of race, gender, cultures, and class are variables within the context of every social interaction. In 1989, legal scholar Kimberlé Crenshaw argued that to truly

understand the experiences of Black women, one must account for the cumulative effect of being both Black and female [9]. Although coined by Crenshaw, intersectionality is based on the activism and research of Black women such as Sojourner Truth and bell hooks who were the first to discuss the duality of racial and gender and its specific impact on WOC [10][11]. This framework allowed for the examination of the complex ways in which multiple systems of oppression are entangled to influence the experiences of this group of women [10][12][13]. Intersectionality has increasingly become a topic of discussion when considering WOC in engineering and their success within the field beginning in primary educational institutions and continuing through industry [14]. Based on this and the findings from the literature, the following research questions are posed to be answered:

(1) From a longitudinal standpoint, how have enrollment metrics changed for female students within the College of Engineering and Computing overall and by department?

(2) From a longitudinal standpoint, how have graduation metrics changed for female students within the College of Engineering and Computing overall and by departments?

(3) From a longitudinal standpoint, how have graduation metrics changed for female students within the College of Engineering and Computing overall and by departments from a race and ethnicity standpoint?

The following section will cover the methodology used to answer the research questions shared above.

IV. Methodology

Before any data was analyzed, an IRB was submitted and approved for this study to be conducted. Secondary data analysis was used which consisted of de-identified data. This type of data analysis is considered a systematic method with steps that should incorporate the following: (1) begin with the development of research questions, (2) identify the dataset(s) and (3) conduct a thorough evaluation of the datasets to answer the research questions [15]. For all three research questions, data was pulled from institutional datasets provided by the data accountability office. The general steps taken included [16]:

(1) Collect/Obtain quantitative data for female students and faculty members within the college of engineering and computing participants

(2) Analyze quantitative data for female students' participants in general, by race by major for the years 2008 – 2018

(3) Interpret how the results answer the research questions

The next section focused on results for each of the research questions and include the discussion pieces related to each question.

V. Results and Discussion

To answer the research questions presented in section IV, an analysis of data for each academic year between 2007-2008 and 2018-2019 was covered. The data analysis included three different focuses for female students within the college of engineering and computing: (1) overall enrollment metrics, (2) overall graduation metrics, and (3) degrees awarded to females by race and ethnicity.

A. Overall Enrollment Metrics and by Department

Results for female enrollment across the year covered in all majors in Engineering and Computer Science showed year over year increases with most areas peaking as of 2019 with 1,441 female students enrolled as shown in Table I.

TABLE I. Total Number of Female Student Enrollment in Engineering and Computing by Year (Undergrad & Grad)

	Full-Time	Part-Time	Total
Fall 2008	519	312	831
Fall 2009	514	331	845
Fall 2010	524	328	852
Fall 2011	527	302	829
Fall 2012	578	339	917
Fall 2013	683	325	1008
Fall 2015	750	361	1111
Fall 2016	703	343	1046
Fall 2017	720	423	1143
Fall 2018	830	449	1279
Fall 2019	899	542	1441

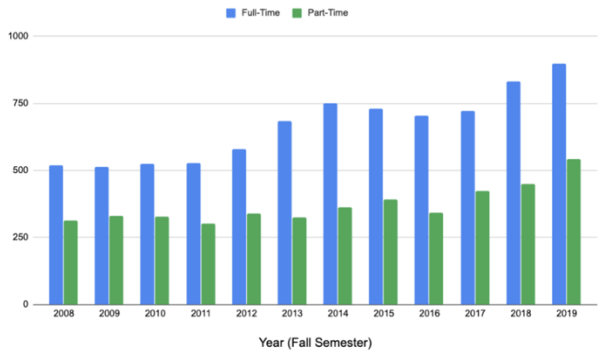

Fig. 1. Female student enrollment between 2008 and 2019

A significant drop occurred in 2015 with the original positive trend continuing in 2017 as shown in Figure 1. After conducting further analysis to further understand the drop seen in 2016, it was found that, during the summer of 2015, the institution imposed circular changes related to first-year math courses

required by engineering students. This change stated that a student could only enroll in an engineering or computer science major if they were prepared to take Calculus 1. While this change stunted growth in the male enrollment numbers, it did not negatively impact enrollment rates for female students. Following the drop in 2016, the numbers began to increase with one of the highest peaks since 2008 seen during 2018-2019.

From a departmental standpoint, Table II and Figure 2 both show that Computer Science (CS) and Civil Engineering (CE) led most years with the highest number of female students enrolled. Overall, most of the other academic areas had consistent, steady numbers across the years covered.

TABLE II. UNDERGRADUATE FEMALE ENROLLMENT BY DEPARTMENT

	BME	CE	Const	ECE	IE	ME	CS
Fall 2008	16.5%	21.4%	11.0%	13.2%	12.1%	5.5%	20.3%
Fall 2009	16.3%	23.8%	11.8%	13.1%	6.6%	6.2%	22.1%
Fall 2010	17.9%	26.5%	8.4%	15.3%	3.0%	7.0%	22.0%
Fall 2011	20.7%	26.5%	6.1%	14.1%	0.0%	9.2%	23.4%
Fall 2012	22.8%	23.2%	5.7%	12.5%	0.0%	10.5%	25.2%
Fall 2013	20.7%	22.9%	4.8%	12.8%	0.0%	11.2%	27.6%
Fall 2014	22.3%	22.3%	4.3%	13.2%	0.0%	11.4%	26.5%
Fall 2015	20.6%	22.8%	4.8%	11.1%	0.0%	12.9%	27.7%
Fall 2016	20.2%	23.3%	4.9%	11.0%	0.0%	12.8%	27.9%
Fall 2017	16.8%	25.4%	4.8%	11.0%	0.0%	12.5%	29.5%
Fall 2018	13.9%	20.9%	4.7%	12.7%	0.0%	10.3%	37.4%
Fall 2019	12.9%	20.8%	5.0%	11.9%	0.0%	9.8%	39.7%

Note: Industrial and Systems Engineering (IE) was no longer a department within the college as of Fall 2019
Note: Includes part-time and full-time students
Note: Biomedical Engineering (BME), Civil Engineering (CE), Construction Management (Const), Electrical & Computer Engineering (ECE), Industrial Engineering (IE), Mechanical Engineering (ME), Computing & Information Sciences (Computing)

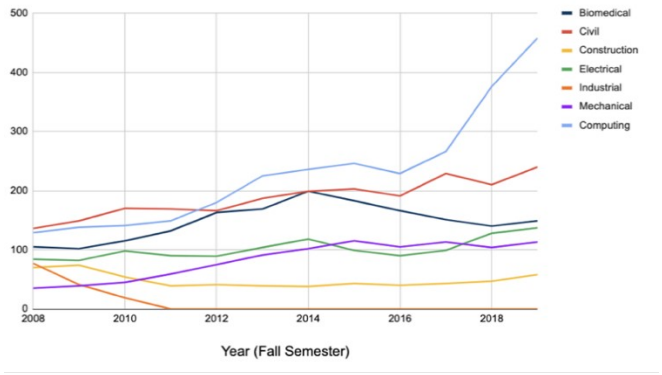

Fig. 2. Female enrollment by engineering or computing departments

After further investigation into these figures, it was found that student organizations that focused on empowering female students in engineering and computer science likely contributed to the findings [17]. Additionally, research done in other MSI universities indicates that Computer Science students believe that the addition of academic support, increased scholarship opportunities and bridge programs will increase enrollment and retention rates among underrepresented students [18]. The university researched in the current study has established all of the recommendations mentioned in [18], with the inclusion of an Academic Success Initiative (ASI) that provides students with additional peer-peer tutoring for classes that have a higher drop and lower performance rates. As well as providing scholarships for students based on their major, year, and academic merit.

Overall, researchers believed that civil engineering, along with biomedical engineering, which also saw high enrollment numbers for female students, have strong connections to helping the community and people (BME for health). The result of this connection was found to possibly contribute towards their attraction as majors for women [19].

Additionally, it was discovered that the enrollment rates for Computer Science increased significantly during the Fall of 2017 - Fall of 2019. From Fall 2017 to the Fall the following year, there was a rise of 41% number of female students enrolled. This increase could be attributed to the introduction of a new program for Computer Science students as a Bachelor of Arts. This program did not require students to take Calculus, Physics, or Senior Project courses. The Bachelor of Arts curriculum was intended for students that wanted to gain a solid background in computing fundamentals and includes a wide range of elective selections.

B. Degrees Awarded Overall and by Department

Graduation metrics also showed a steady increase from 2007-2008 and 2018-2019 with 2018 having a peak number of 308 graduating female students as shown by Table III. 2012 showed the biggest dive in female graduates coming from 204 female graduates to 159. Both 2008 and 2012 showed the least amount of female graduates with 157 and 159 female graduates

respectively. Following the decline in 2012, the trend began to grow exponentially (minor plateau between 2015-2016) and showed the biggest increase from 2012 to 2013 with a total of 43 more female graduates in 2013. Bachelor's degrees tend to see a more exponential growth while masters and doctoral degrees remain steady. Table IV shows Civil Engineering and Computer Science majors make up 54% of females that received a Bachelor's degree in 2018.

TABLE III. TOTAL NUMBER OF FEMALE DEGREES/GRADUATING CLASS IN ENGINEERING AND COMPUTING BY ACADEMIC YEAR

Semester	# of Degrees awarded to female students
Fall 2008	197
Fall 2009	157
Fall 2010	188
Fall 2011	206
Fall 2012	204
Fall 2013	159
Fall 2014	202
Fall 2015	242
Fall 2016	248
Fall 2017	247
Fall 2018	283
Fall 2019	308

Note: Includes undergrad and graduate-level students

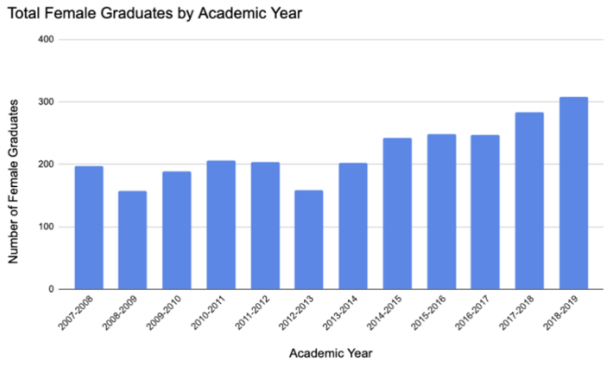

Fig. 3. Undergrad and grad-level degrees awarded to women between 2008 and 2019

Table IV shows Civil Engineering and Computer Science majors comprise 54% of females receiving a Bachelor's degree in 2018.

TABLE IV. UNDERGRADUATE DEGREES AWARDED IN ENGINEERING AND COMPUTING BY DEPARTMENT

	BME	CE	Const	ECE	IE	ME	Comp
2007-08	18.8%	12.9%	9.9%	12.9%	19.8%	5.9%	19.8%
2008-09	20.7%	14.6%	2.4%	18.3%	14.6%	7.3%	22.0%
2009-10	9.6%	13.5%	14.4%	11.5%	22.1%	8.7%	20.2%
2010-11	18.1%	26.0%	11.0%	9.4%	15.0%	3.1%	17.3%
2011-12	10.2%	30.6%	10.2%	13.0%	0.9%	6.5%	28.7%
2012-13	24.4%	21.1%	11.1%	10.0%	0.0%	4.4%	28.9%
2013-14	15.3%	25.0%	8.1%	18.5%	0.0%	7.3%	25.8%
2014-15	18.0%	22.3%	4.3%	20.9%	0.0%	8.6%	25.9%
2015-16	22.0%	16.4%	4.4%	13.2%	0.0%	11.9%	32.1%
2016-17	17.9%	23.2%	4.6%	15.9%	0.0%	7.9%	30.5%
2017-18	23.4%	23.9%	3.2%	6.9%	0.0%	14.9%	27.7%
2018-19	16.9%	28.2%	3.8%	17.4%	0.0%	7.5%	26.3%

Note: IE department closed at the end of 2012-2013 year
Note: Biomedical Engineering (BME), Civil Engineering (CE), Construction Management (Const), Electrical & Computer Engineering (ECE), Industrial Engineering (IE), Mechanical Engineering (ME), Computing & Information Sciences (Computing)

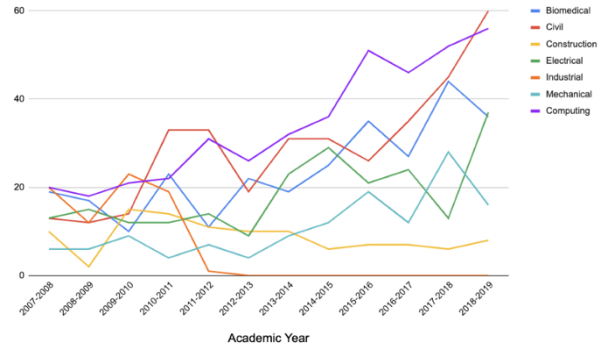

Fig. 4. Undergraduate degrees awarded by department to female students

C. *Degrees Awarded by Race/Ethnicity*

Table V and Figure 5 highlight the number of undergraduate degrees awarded for female students and is broken down by student demographics. The results from the data analysis related to degrees awarded by race and ethnicity, overall, uncovered several different findings worth noting.

First, collectively, women of diverse backgrounds, saw incremental increases year-over-year.

TABLE V. TOTAL NUMBER OF DEGREES BY ETHNICITY, FEMALES (UNDERGRAD)

	Asian	Black	Hispanic	Non-RA	White
2007-08	4.95%	8.91%	61.39%	11.88%	12.87%
2008-09	3.66%	7.32%	69.51%	8.54%	10.98%
2009-10	3.85%	12.50%	61.54%	9.62%	11.54%
2010-11	2.36%	10.24%	64.57%	13.39%	7.87%
2011-12	8.41%	9.35%	56.07%	13.08%	10.28%
2012-13	5.38%	9.68%	66.67%	7.53%	8.60%
2013-14	7.26%	5.65%	66.94%	10.48%	8.87%
2014-15	5.04%	7.91%	69.78%	6.47%	9.35%
2015-16	5.03%	11.32%	67.30%	9.43%	5.66%
2016-17	4.67%	14.00%	65.33%	7.33%	7.33%
2017-18	4.26%	9.57%	64.89%	12.23%	7.98%
2018-19	6.13%	8.49%	62.74%	14.62%	7.55%

Note: American Indian and Asian Pacific Islander and those not reporting data were less than 1% of overall numbers, therefore, were not included.
Note: Black – African American and Black; Non-RA – Non-resident alien NRA – non-resident alien

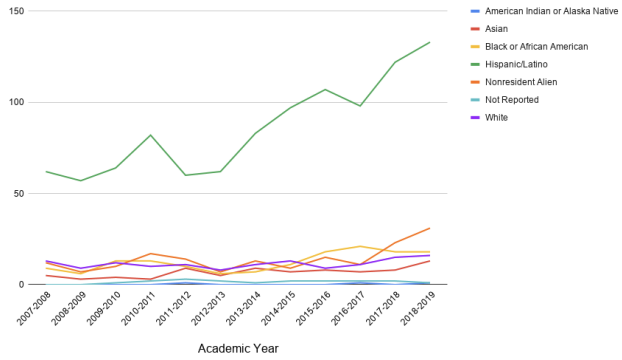

Fig. 5. Undergraduate degrees awarded to female students by race/ethnicity

Secondly, degrees awarded to Hispanic students saw large gains over the years covered within this study. Also note, between 2008 and 2019, degrees awarded to Hispanic female students increased from 62 to 133; a 53.3% increase. In 2019, the institution saw its highest numbers of undergraduate degrees awarded to Asian women, White women, and non-resident alien women to date. It is also worth noting that even though the institution is a Hispanic serving institution (HSI) and a minority-serving institution (over 80% of students enrolled are either Hispanic or African American/Black), the number of white women with degrees awarded saw their highest peak in 2019, as well. These findings suggest that HSIs and MSIs may provide a form of inclusion and cultural continuity that benefits students regardless of race. Similar results are also viewed in a study conducted at 2 Historically Black College and Universities (HBCUs) and 2 HSIs, where both Black and Hispanic students reported many benefits of attending MSIs including peers who were like family and professors who were invested in their success [20]. This is seen at this university where organizations like Society of Women Engineers, Women in Computer Science, and Society of Hispanic Engineers influence the success, feeling of belonging, and the intersectionality of identity as an "Engineer" into STEM.

At the graduate level, there was less consistent growth as evidenced by data regarding undergraduate level students. For example, Table VI and Figure 6 show that, the Hispanic population showed positive growth over the 11 years of data analysis for undergrads but that growth was limited at the graduate level. Nationally, less than 18% of engineering graduates go full-time to pursue graduate school; with women and underrepresented minorities making an even smaller fraction of this percent [21]. Many factors affect low graduate numbers such as financial burdens, low GPA, and a belief that graduate school is only for those that want to become college professors [21]. Women, however, face even more challenges as they experience the pace and workload of graduate school differently on top of having to deal with discriminatory practices in the STEM departments [21]. For each ethnic group, the numbers were primarily steady with White females seeing a fairly large drop between years 2017-18 and 2018-19.

TABLE VI. TOTAL NUMBER OF DEGREES, FEMALES BY RACE/ETHNICITY (GRAD)

	Asian	Black	Hispanic	Non-RA	White
2007-08	3.16%	4.21%	32.63%	54.74%	5.26%
2008-09	2.67%	6.67%	26.67%	56.00%	8.00%
2009-10	4.82%	9.64%	31.33%	44.58%	9.64%
2010-11	2.53%	7.59%	30.38%	54.43%	5.06%
2011-12	4.30%	4.30%	38.71%	48.39%	4.30%
2012-13	0.00%	6.06%	43.94%	42.42%	7.58%
2013-14	5.13%	7.69%	35.90%	39.74%	11.54%
2014-15	7.32%	2.44%	42.68%	42.68%	4.88%
2015-16	4.60%	4.60%	16.09%	66.67%	8.05%
2016-17	3.09%	5.15%	18.56%	56.70%	16.49%
2017-18	3.19%	8.51%	30.85%	43.62%	13.83%
2018-19	3.19%	7.45%	27.66%	58.51%	3.19%

Note: American Indian and Asian Pacific Islander and those not reporting data were less than 1% of overall numbers, therefore, were not included.
Note: Black – African American and Black; Non-RA – Non-resident alien NRA – non-resident alien

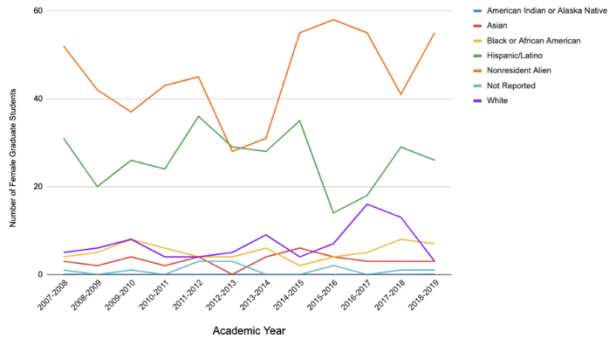

Fig. 6. Graduate degrees awarded to females by race/ethnicity

One explanation for this particular finding is that, based on the literature, Hispanic and Latino students have cultural underpinnings that lean towards pursuing careers upon

completing undergraduate degrees rather than pursuing graduate degrees [22]. If interested in graduate school, most students in this group prefer a master's degree over a Ph.D.; however, master's programs have fewer funding options than doctoral programs [22]. This is an important aspect to keep in mind when considering that within the U.S., a large number of Hispanic students at minority-serving institutions (MSIs) are first-generation or come from low-income households [23].

VI. Conclusion

The quantitative data analysis conducted within this study focused on overall enrollment numbers for female students, overall degrees awarded to female students, and degrees awarded to female students by race and ethnicity. There were several findings noted throughout the results and discussion section that can guide future quantitative and qualitative research. Most notably, the institution of focus saw their highest number of engineering and computing degrees awarded to undergraduate female students in 2019. This was attributed to year-over-year growth in the number of female students graduating with engineering and computing degrees. Additionally, as of 2019, 92.5% of their undergraduate degrees in engineering and computing were awarded to women of all racial and ethnic groups. Also, 71.23% were awarded to Hispanic and Black women who are both considered by the National Science Foundation (NSF) to underrepresented minorities (URMs) within these fields. This institution presented a unique framework for other MSIs emulate and further evaluation is needed to uncover best practices for improving the educational experiences of WOC in engineering and computer science.

When considering the conceptual framework of focus for this paper, intersectionality as well as critical race theory (CRT), the researchers recognize that while quantitative data allows one to highlight the trends of student persistence in engineering and computing (in this case, female students) from an overall and racial/ethnic perspective, understanding the cause of the changes in the data can not be found from the data alone. Additionally, this study served as a preliminary view of institutional data alongside the well-documented variables that impact WOC in engineering and computing including challenges, barriers, and persistence at the undergraduate and graduate levels. Future research may focus on the similarities and differences in URM students in engineering and computing at different institution types, noting that those within the MSI space as all institutions are not created equal. This study also showed that future research from an institution-type perspective around female students at the graduate level could help further understand the decision-making process around graduate school participation for WOC [24]. Lastly, qualitative data collection and analysis may offer further understanding of the intricacies, year-over-year, that play a role in the findings by institution type [25].

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