ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37845

Graduating in the Margins: An Analysis of Graduations Rates of Minoritized Women in Computing

Shaundra Bryant Daily (Professor of the Practice)

Shaundra B. Daily is a professor of practice in Electrical and Computer Engineering & Computer Science at Duke University. Her research involves the design, implementation, and evaluation of technologies, programs, and curricula to promote justice, equity, diversity, and inclusion in STEM fields. She is currently Co-PI of the Alliance for Identity-Inclusive Computing, Education and Workforce Director for the Athena AI Institute, and Faculty Director of the Duke Technology Scholars Program. Prior to joining Duke, she was an associate professor at the University of Florida in the Department of Computer & Information Science & Engineering. Having garnered over $40M in funding from public and private sources to support her collaborative research activities, Daily's work has been featured in USA Today, Forbes, National Public Radio, the Chicago Tribune, and recognized by Governor Roy Cooper of North Carolina. Daily earned her B.S. and M.S. in Electrical Engineering from the Florida Agricultural and Mechanical University – Florida State University College of Engineering, and a S.M. and Ph.D. from the MIT Media Lab.

Christin Shelton

Christin D. Shelton, Ph.D., received her Bachelor's degree (2004) from Talladega College and both her Masters (2007) and Ph.D. (2012) from Auburn University in Computer Science and Software Engineering. Her research falls in the areas of Human-Robot Interaction and Language Processing and involves creating a grammatical structure to enable robots to appropriately interact with and manipulate objects in the real world. She has held a number of positions in the government and has years of experience in software design, database administration, and mobile application development. Christin also makes time to coordinate various academic and extracurricular programs, led project groups, and held positions on numerous boards throughout her education to the present.

Andy He

Andy is a third-year Electrical and Computer Engineering and Computer Science double major at Duke University. My academic interests include diversity in technology, software engineering, and machine learning.

Wanda Eugene

Wanda Eugene, Ph.D. is constantly seeking out new ways to leverage technology to engage underserved communities. As a principal at DEEP Designs LLC, she specializes in cultivating technology with vulnerable populations and integrates the strategic direction of the organization. As the Executive Director of Collaboratory for Inclusive Entrepreneurship at UF Innovate, she launched Entrepreneur Diversity in Information Technology (EDIT), a free pre-incubator program that works with underserved minorities to launch tech-based businesses. Dr. Eugene holds a Ph.D. in Computer Science, a Master's in Industrial Engineering and a Master's in Interdisciplinary Studies specializing in Instructional Technology and African American Studies and a Bachelor's in Electrical Engineering.

Jakita Thomas

Graduating in the Margins: An Analysis of Graduations Rates of Minoritized Women in Computing

1. Introduction

A review of the literature in broadening participation research in computing and in STEM more broadly reveals that, while substantial research is being conducted focused on students of color and women in computing, there has been little regard for the unique intersection of gender and race experienced by minoritized women [1]–[3]. What is needed is a more complex understanding of the experiences of marginalized groups in computing who live at various intersections of racism, sexism, classism, xenophobia, heterosexism, ableism, etc., an area of research called Intersectional Computing [4]. Prior research has uncovered the many challenges that exist for women of color – including Black, Latina, Indigenous, Asian, and Native Hawaiian/Pacific Islander – when it comes to participation in the field of computing[5], [6]. For example, access to opportunities that might influence later college major decisions, toxic cultures resulting from a lack of diversity in the field [7]–[10], a desire to pursue social justice related work that is often not connected with computing [11]–[14], and other factors [15]–[18]. Although prior research suggests the nurturing environment at Minority-serving institutions support graduating rates of women of color, to begin developing a deeper understanding of the factors impacting women of color in computing, a more nuanced picture (i.e., what schools are doing well, which schools work well for specific race/ethnic identities) is necessary.

To this end, an analysis of graduation rates for students at four-year institutions between 2011 and 2018. These data were gathered from the National Center for Education Statistics Integrated Postsecondary Education Data System (IPEDS). A logistic regression analysis was conducted to understand the potential influence of various institutional factors on graduation rates. These analyses were meant to lay the groundwork for more qualitative understanding of the impact of institutional factors. The data suggest that minority-serving institutions (MSIs) outperform non-MSIs in awarding computing degrees to women of color; for women of color as a whole, all MSI designations (except Tribal Colleges and Universities), for which only two institutions have this designation) are associated with higher odds of producing a computing degree. For specific racial/ethnic breakdowns, some MSI designations may have higher odds of awarding a computing degree than others. Moreover, some MSI designations may be associated with lower odds of producing a computing degree to specific groups of women.

2. Research Approach

This research sought to answer the question: What institutions are impacting graduation rates of women of color in computing? Including sub questions: Are there characteristics of schools that impact graduation rates of women of color? Do MSIs outperform non-MSIs in awarding computing degrees to women and women of color? and Are there effects of other institutional characteristics, such as Ivy League status, Top 25 ranking (by U.S. & News World Report College Rankings), or Women's College on graduation rates? MSIs and Women's colleges were selected based on evidence in the literature that they might provide supportive environments that bolster student retention [19], [20]. Ivy League and top-ranking institutions were chosen given their often-low numbers of graduation rates of minoritized students.

Our Sample included N=1,561 institutions, with data from academic years 2010/2011-2017/2018, yielded a total of 10,808 observations. (Data were aggregated across Classification of Instructional Program codes). Below is a table summarizing the number of years providing data per university. Though some institutions provided as little as one year's worth of data, most institutions provided eight years' worth of data (1,110 institutions, or 71.1% of the sample of institutions). The final analytic sample for the analyses below had a size of N=1,561 university-level observations.

Classification of Instructional Program (CIP) codes was broadly chosen to ensure the inclusion of universities that may have multiple approaches to including computing in the curriculum. included 11.01 (Computer and Information Science), 11.02 (Computer Programming), 11.07 (Computer Science), 11.08 (Computer Software and Media Applications), 14.09 (Computer Engineering), 15.12 (Computer Engineering Technologies), 52.12 (Management Information Systems). Minority-serving institutions included, Asian American and Native American Pacific Islander-Serving (AANAPISI), Alaska Native-Serving and Native Hawaiian-Serving Institutions (ANNH), Historically Black Colleges and Universities (HBCU), Hispanic-serving Institutions (HIS), Native American-Serving Nontribal Institutions (NASNTI), Tribal Colleges and Universities (TCU), and Predominantly Black Institutions (PBI).

Table 1: Breakdown of university data collection

Count of Years Providing Data	
Years of Data Provided	**Count (%) of Universities**
1 Year	70 (4.5%)
2 Years	51 (3.3%)
3 Years	48 (3.1%)
4 Years	54 (3.6%)
5 Years	64 (4.1%)
6 Years	72 (4.6%)
7 Years	92 (5.9%)
8 Years	1,110 (71.1%)

The initial analysis utilized visualization of descriptive statistics to unearth potential institutions to look more deeply into with qualitative surveys. Then, logistic regression analysis with a binomial distribution was used to test whether MSI designation predicted the odds of computer science degrees being awarded to women. Predictors in the regression model included MSI designation, as well as additional, non-MSI institutional characteristics (women's college designation, Ivy league status, and U.S. News & World Report Top 25 ranking).

- MSI designation was broken down by specific designation type, with a binary (yes/no) indicator for each type—e.g., whether the institution was HBCU or not, whether the institution was HSI or not, and so forth.
- Women's College designation was entered as a binary predictor.
- Ivy League status was entered as a binary predictor.
- Top 25 designation was entered as a binary indicator, wherein an institution that was listed in the U.S. News & World Report's Top 25 rankings at any point during the dataset timeframe (2010/2011 – 2017/2018) was coded as "yes" for Top 25; if the institution did not appear in the top 25 during this eight academic year time frame, the institution was coded as "no" for Top 25.

Several degrees (both overall and for specific racial/ethnic groups) within institutions were summed over time. The outcome was the odds of computer science degrees awarded to the target group of interest, relative to the odds of computer science degrees being awarded to those *not* in the target group of interest. Thus, while the raw numbers of degrees were used in the calculation of the model, the results are predicted as odds/likelihood of institutions producing degrees earned by women (of color). Target groups of interest included all women, women of color, a women of color subset (women of color minus Asian women), and a breakdown of women in individual ethnic/racial groups (Asian, Black, Indigenous, Latina, Native Hawaiian/Pacific). The above specifications for the regression model were estimated ten times, for a total of ten regression analyses corresponding to outcome: computer science degrees to women overall, women of color, women of color excluding Asian women, women who identified two or more racial/ethnic categories, and women of each individual racial/ethnic category. The choice to analyze women of color without Asian women was due to an early observation that the representation was much closer to population demographics. This does not imply, however, that graduation rates for all Asian women are representative. Unfortunately, due to the way data are currently collected by IPEDs, we are unable to separate out different ethnicities (e.g., Hmong) that are not well-represented in computing. R version 4.0.2/RStudio version 1.3.1056 was used to analyze the data and perform any analysis-specific data preparations.

2.1. Definitions

The tables for the regression models present 3 numerical outputs of particular interest, for each predictor in each regression model: the odds ratio (OR), the confidence interval (CI) for the odds ratio, and the p-value. The odds ratio (OR) can be interpreted as the model-estimated odds of the target outcome in one condition, relative to the odds of the target outcome outside of that condition (e.g., the odds of an MSI producing WOC computer science degrees, relative to the odds of non-MSI producing WOC computer science degrees). ORs greater than 1 are notable because they indicate that the odds of a target outcome are associated with the predictor (e.g., the odds of producing WOC computer science degrees are higher if the institution has a particular MSI designation).

The 95% confidence interval (CI) for the odds ratio is a range of plausible values between which we are 95% certain the "true" population odds ratio resides. Note that true is placed in quotes to denote that samples, by definition, consist of only a fraction of the entire population (which is unknown here) from which they are drawn. The "true" odds ratio for HBCU vs non-HBCUs in producing degrees for Black women may be unknown but is estimated by the specified regression models. Confidence intervals whose lower bound exceeds 1 are notable because they indicate that we can be 95% certain (for a 95% CI) that the "true" population odds ratio is greater than 1; in other words, we can be 95% certain the odds of the target outcome are higher when the predictor's condition is true. The p-value for a predictor denotes its "statistical significance." It is used to test the probability of the null hypothesis that the predictor's estimated coefficient is equal to 0. If the p-value is low—.05, .01, and .001 are common pre-defined thresholds—the null hypothesis can be rejected.

Pulling these 3 pieces of information together for a specific predictor and outcome allows for a more meaningful interpretation. As an example, from these data, in the logistic regression analysis where the outcome was degrees earned by Black women, the model estimated results for HBCU as a predictor (controlling for all other predictors already in the model) was OR=4.77, 95% CI [4.46, 5.10], $p<.001$. The odds of an institution producing a computer science degree earned by a Black woman is statistically significantly higher—higher by a factor of 4.77, as estimated by our model—if the institution is HBCU vs non-HBCU. Because the HBCU predictor was entered simultaneously with the other MSI designations, as well as indicators for Ivy League status, Top 25 ranking status, and women's college designations, the effect of HBCU designation on the outcome is controlling for the effect of the other predictor variables in the model; in other words, the effect of HBCU on outcome is significant even after considering the effects of various other institutional characteristics (though it is important to note that the odds ratio is calculated such that it is specific to when all other designations are coded as 0, or not true). Thus, HBCUs significantly outperform non-HBCUs in their odds of producing computer science degrees earned by Black women.

2.2. Results

Descriptive data are presented in Figures 1 and 2. Figure 1 presents the top ten universities graduating women of color between 2011 and 2018 from MSIs. Figure 2 shows graduation rates by CIP code for women (top) compared to all graduates (middle) as well as as a percentage of total degrees awarded (bottom). Figure 3 shows CIP graduation rates broken up by race/ethnicity. Recall CIP code breakdown: 11.01 (Computer and Information Science), 11.02 (Computer Programming), 11.07 (Computer Science), 11.08 (Computer Software and Media Applications), 14.09 (Computer Engineering), 15.12 (Computer Engineering Technologies), 52.12 (Management Information Systems)

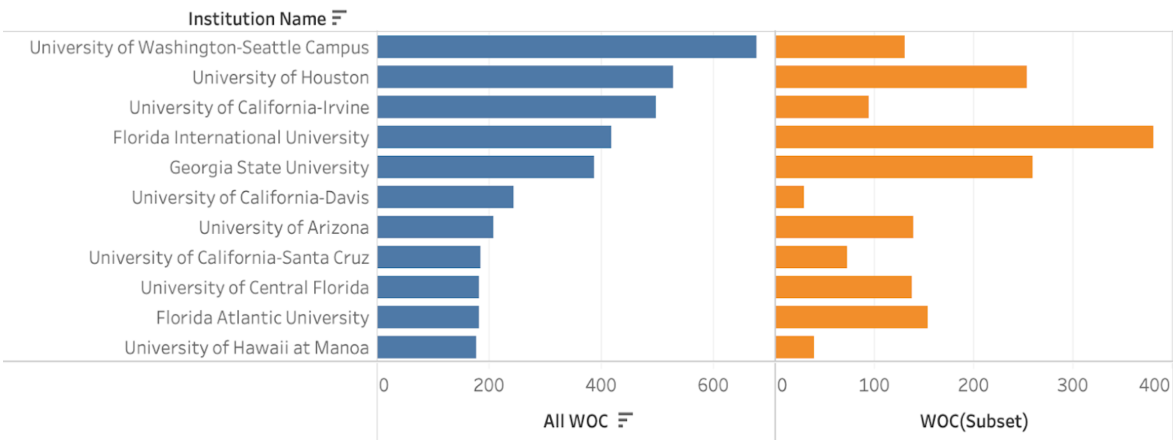

Figure 1: Top 10 Minority Serving Institutions graduating women of color between 2011 and 2018

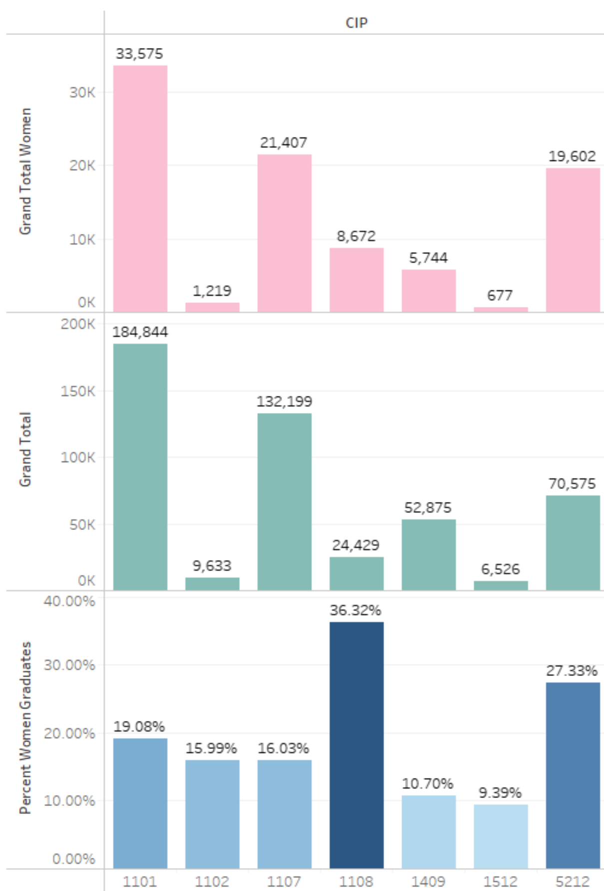

Figure 2. Graduation rates by CIP codes for all women (top), all graduates (middle), and by percentage (bottom).

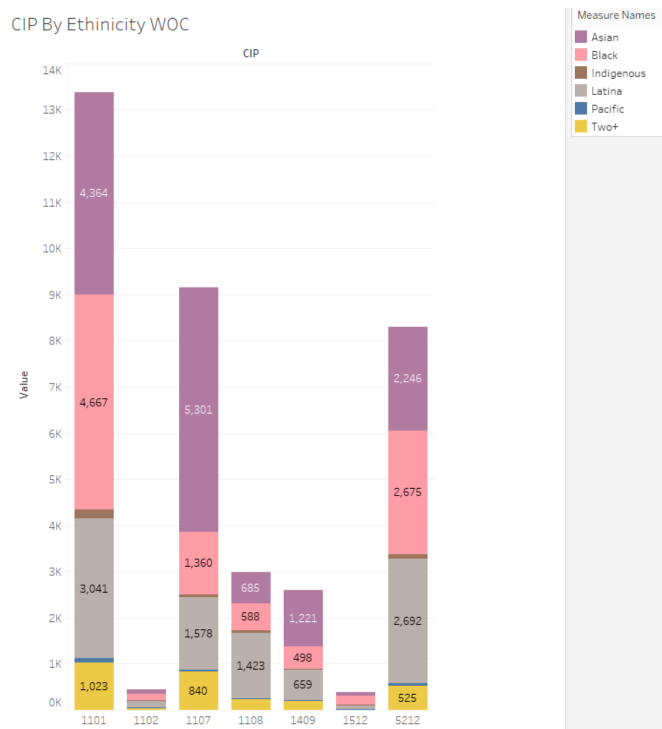

Figure 3. CIP codes broken down by race and ethnicity of graduates.

Table 2 below presents results for the first three regression models—one for each of the outcomes of degrees awarded to women overall, degrees awarded to women of color, and degrees awarded to the women of color subset—with odds ratios, confidence intervals, and p-values for each of the individual predictors in the model. Bolded p-values indicate statistically significant predictors; they indicate a significant relationship—either positive or negative—between the respective institution characteristic/designation and the likelihood of an institution awarding computer science degrees to women (of color).

Table 2: Results for first regression model

	Women			WOC			WOC Subset		
Characteristic	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
AANAPISI	1.10	[1.07, 1.14]	**<0.001**	1.40	[1.35, 1.45]	**<0.001**	0.77	[0.73, 0.82]	**<0.001**
ANNH	1.24	[1.10, 1.41]	**<0.001**	2.85	[2.48, 3.26]	**<0.001**	1.53	[1.24, 1.86]	**<0.001**
HBCU	1.30	[1.25, 1.36]	**<0.001**	2.00	[1.89, 2.11]	**<0.001**	2.52	[2.38, 2.68]	**<0.001**

	Women			WOC			WOC Subset		
Characteristic	OR [1]	95% CI[1]	p-value	OR [1]	95% CI[1]	p-value	OR [1]	95% CI[1]	p-value
HSI	0.88	[0.85, 0.90]	**<0.001**	1.34	[1.30, 1.38]	**<0.001**	1.34	[1.29, 1.40]	**<0.001**
NASNTI	1.81	[1.63, 2.01]	**<0.001**	1.77	[1.52, 2.06]	**<0.001**	2.35	[2.00, 2.75]	**<0.001**
PBI	0.85	[0.79, 0.92]	**<0.001**	1.30	[1.18, 1.43]	**<0.001**	1.60	[1.43, 1.78]	**<0.001**
TCU	0.98	[0.49, 1.82]	>0.9	0.48	[0.08, 1.52]	0.3	0.35	[0.02, 1.58]	0.3
Ivy League	1.06	[1.00, 1.13]	**0.048**	0.97	[0.89, 1.05]	0.4	1.23	[1.07, 1.43]	**0.005**
Top 25	1.52	[1.47, 1.58]	**<0.001**	2.06	[1.97, 2.16]	**<0.001**	0.67	[0.62, 0.73]	**<0.001**
Women's College	91.6	[70.6, 121]	**<0.001**	9.73	[8.65, 10.9]	**<0.001**	5.50	[4.77, 6.33]	**<0.001**

[1] OR = Odds Ratio, CI = Confidence Interval

The overall model fit chi-square tests for the following seven regression models indicate that they are significantly better at predicting their respective outcomes than a null (intercept only) model, with $c^2(10)$=5,701.74 p<.001 for the model predicting degrees to Asian women, $c^2(10)$=2,379.53, p<.001 for degrees to Black women, $c^2(9)$=28.00, p<.001 for degrees to Indigenous women, $c^2(10)$=1,334.82, p<.001 for degrees to Latina women, $c^2(7)$=57.01, p<.001 for degrees to Native Hawaiian/Pacific women, and $c^2(10)$=320.84, p<.001 for degrees to women identifying two or more racial/ethnic groups. In the tables below, bolded p-values indicate statistically significant predictors; they indicate a significant relationship—either positive or negative—between the respective institution characteristic/designation and the likelihood of an institution producing computer science degree to women (of color).

Table 3. Asian, Black and Indigenous Women

	Asian			Black		
MSI	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
AANAPISI	2.63	2.50, 2.76	**<0.001**	0.75	0.68, 0.82	**<0.001**
ANNH	5.25	4.40, 6.21	**<0.001**	1.37	0.99, 1.83	0.047

	Asian			Black		
MSI	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
HBCU	0.85	0.74, 0.97	0.021	4.77	4.46, 5.10	**<0.001**
HSI	1.32	1.26, 1.39	**<0.001**	0.63	0.58, 0.68	**<0.001**
NASNTI	0.52	0.32, 0.80	0.005	1.80	1.38, 2.30	**<0.001**
PBI	0.79	0.65, 0.96	0.018	1.21	1.01, 1.44	0.034
TCU	0.78	0.04, 3.54	0.8	0.00	0.00, 0.00	>0.9
Ivy League	0.73	0.67, 0.80	**<0.001**	1.55	1.17, 2.06	**0.002**
Top 25	5.08	4.82, 5.36	**<0.001**	0.33	0.27, 0.39	**<0.001**
Women’s	11.7	10.1, 13.5	**<0.001**	5.20	4.27, 6.27	**<0.001**

Table 4: Indigenous and Native Hawaiian/Pacific Islander

	Indigenous			**Native Hawaiian/Pacific Islander**		
MSI	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
AANAPISI	0.60	0.36, 0.95	0.041	0.68	0.62, 0.73	**<0.001**
ANNH	2.29	0.57, 5.99	0.2	0.49	0.27, 0.80	**0.010**
HBCU	0.68	0.29, 1.33	0.3	0.59	0.49, 0.70	**<0.001**
HSI	0.94	0.67, 1.28	0.7	2.37	2.25, 2.49	**<0.001**
NASNTI	3.33	1.19, 7.23	0.008	3.02	2.41, 3.72	**<0.001**
PBI	0.70	0.17, 1.83	0.5	2.39	2.07, 2.74	**<0.001**
TCU				0.00	0.00, 0.00	>0.9
Ivy League	0.34	0.02, 1.85	0.3	1.37	1.09, 1.71	**0.006**
Top 25	0.49	0.22, 0.91	0.044	0.68	0.60, 0.77	**<0.001**
Women's College	0.00	0.00, 0.00	>0.9	11.7	10.1, 13.5	**<0.001**

Table 5: More than one race

	More than one race		
MSI	**OR[1]**	**95% CI[1]**	**p-value**
AANAPISI	1.32	1.15, 1.51	**<0.001**
ANNH	4.27	2.97, 5.91	**<0.001**
HBCU	0.79	0.59, 1.03	0.10
HSI	0.89	0.78, 1.00	0.056
NASNTI	1.60	0.92, 2.57	0.070

More than one race			
MSI	**OR[1]**	**95% CI[1]**	**p-value**
PBI	0.65	0.40, 0.98	0.058
TCU	3.03	0.17, 13.7	0.3
Ivy League	0.83	0.64, 1.07	0.2
Top 25	2.15	1.87, 2.47	**<0.001**
Women's	8.90	6.69, 11.6	**<0.001**

3. Discussion

3.1. Visualizations

The rankings for MSIs graduating women of color are the following: 1. University of Washington-Seattle (ANNH), 2. University of Houston (HSI), 3. University of California-Irvine, 4. Florida International University (HSI), 5. Georgia State University (PBI), 6. University of California-Davis (ANNH), 7. University of Arizona (HSI), 8. University of-California Santa Cruz (ANNH), 9. University of Central Florida (HSI), Florida Atlantic University (HSI), 10. University of Hawaii at Manoa (ANNH). Purely based on raw graduation rates, ANNH and HSI institutions are driving the computing majors for minoritized women. Descriptive data also suggest that CIP codes 11.08 (Computer Software and Media Applications) and 52.12 (Management Information Systems) are particularly attractive to women of color. This is potentially attributable to the applied nature of these majors, which could address the equity ethic motivation (i.e., a desire to see social justice and equity implications of one's work) for minoritized women[11].

3.2. Women Overall

Women's college designation is not interpreted in the women overall outcome regression model; its presence serves the function of a) acting as a control for the other predictor variables, and b) consistency with the regression equations for more specific racial/ethnic outcomes below.

The overall model fit chi-square test for the logistic regression predicting degrees to women overall was significant, indicating that this model is significantly better at predicting the outcome than a null (intercept only) model, $c^2(10)=4{,}640.77$, $p<.001$. For degrees awarded to women, p-values for all predictors except TCU designation emerged as statistically significant. The direction of effect was not the same for all predictors; the ORs were >1 for all significant predictors except HSI and PBI, while the ORs for HSI and PBI were <1. THIS indicates that HSI and PBI designations were associated with *lower* odds of producing computer science degrees to women as a whole, while the other MSI designations (except TCU, which showed no evidence of being associated with the outcome in either direction) and other institutional characteristics were associated with *higher* odds of producing degrees to women as a whole.

Amongst the statistically significant MSI designations, the strongest positive predictor of computer science degrees to women overall was NASNTI designation, indicated by the fact that it had the largest OR that was significantly >1. Thus, the odds of an institution producing computer science degrees earned by women overall (i.e., women of any racial/ethnic category) was 1.81 times higher if the institution had a NASNTI designation. The strongest positive predictors of computing science degrees to women overall, in descending order, was NASNTI designation (OR=1.81, 95% CI [1.63, 2.01], p<.001), followed by HBCU designation (OR=1.30, 95% CI [1.25, 1.36], p<.001), ANNH (OR=1.24, 95% CI [1.10, 1.41], p<.001), and AANAPISI (OR=1.10, 95% CI [1.07, 1.14], p<.001).

Amongst the statistically significant MSI designations, the strongest negative predictor of computer science degrees to women overall was PBI, followed by HSI. While these designations were significantly associated with the outcome, they were significantly associated with lower odds, not higher odds. The odds of an institution producing computer science degrees to women overall was lower (only 85% as likely) if the institution had a PBI designation, relative to if it did not (OR=0.85, 95% CI [0.79, 0.92], p<.001). The odds of an institution producing computer science degrees to women overall was lower (only 89% as likely) if the institution had an HSI designation, relative to if it did not.

Among the statistically significant, non-MSI institutional characteristics, Top 25 ranking status was the strongest positive predictor, followed by Ivy League status. The odds of an institution producing computer science degrees to women was 1.5 times higher if the institution had made the Top 25 U.S. News & World report rankings at any point during the 2010/2011 – 2017/2018 academic year timeframe, relative to if it had not (OR=1.52, 95% CI [1.47, 1.58], p<.001). Ivy League status was significantly associated with higher odds of producing degrees to women as a whole, as indicated by its p-value; however, because the lower bound of its confidence interval contains 1, there is some uncertainty as to whether this effect is "true" in the broader population (OR=1.06, 95% CI [1.00, 1.13], p=.048).

3.3. Women of Color

The overall model fit chi-square test for the logistic regression predicting degrees to women of color was significant, indicating that this model is significantly better at predicting the outcome than a null (intercept only) model, $c^2(10)=3{,}477.26$, $p<.001$. For degrees awarded to women of color, p-values for all predictors except TCU designation and Ivy League status emerged as statistically significant. Unlike for women as a whole, the significant predictors for degrees to women of color were all in the same direction; that is to say, all of the significant predictors were associated with higher odds of an institution producing degrees to women of color. (None of the significant predictors were associated with lower odds, and TCU and Ivy League status were not significantly associated with the outcome in either direction.)

Amongst the statistically significant MSI designations, the strongest positive predictor of computer science degrees to women of color was ANNH (OR=2.85, 95% CI [2.48, 3.26], p<.001), followed by HBCU (OR=2.85, 95% CI [1.89, 2.11], p<.001), NASNTI (OR=1.77, 95% CI [1.52, 2.06], p<.001), AANAPISI (OR=1.40, 95% CI [1.35, 1.45], p<.001), HSI (OR=1.34, 95% CI [1.30, 1.38], p<.001), and PBI (OR=1.30, 95% CI [1.18, 1.43], p<.001). The odds of an institution producing degrees to women of color was 2.85 higher if the institution had an ANNH designation, relative to if it did not. Amongst the statistically significant, non-MSI institutional characteristics, Women's College was the strongest positive predictor, followed by Top 25 Ranking status. The odds of an institution producing computer science degrees to women of color was 9.73 times higher if the institution was a women's college vs if it was not (OR=9.73, 95% CI 8.65, 10.9], p<.001).

3.4. Women of Color Subset (Women of Color excluding Asian women)

The overall model fit chi-square test for the logistic regression predicting degrees to women of color subset was significant, indicating that this model is significantly better at predicting the outcome than a null (intercept only) model, $c^2(10)=1,595.927$, $p<.001$. For degrees awarded to women of color subset, p-values for all predictors except TCU designation emerged as statistically significant. The direction of the effects was not the same for all significant predictors; the ORs were >1 for most of the significant predictors, excluding AANAPISI and Top 25 Ranking status, which had ORs <1. THIS indicates that AANAPISI and Top 25 Ranking status were associated with *lower* odds of producing computer science degrees to women of color subset (women of color excluding Asian women), while the other MSI designations (except TCU, which showed no evidence of being associated with the outcome in either direction) and other institutional characteristics were associated with *higher* odds of producing degrees to women of color subset (women of color excluding Asian women).

Amongst the statistically significant MSI designations, the strongest positive predictor of computer science degrees to women of color subset was HBCU (OR=2.52, 95% CI [2.38, 2.68], p<.001), followed by NASNTI, PBI, ANNH, and HSI. The odds of an institution producing computer science degrees to women of color subset was 2.52 times higher if the institution had an HBCU designation, relative to if it did not. The only other statistically significant MSI designation was AANAPISI, with OR=0.77, 95% CI [0.73, 0.82], p<.001. However, because it had OR < 1, it was a negative predictor of outcome; in other words, the odds of an institution producing computer science degrees to the women of color subset (women of color excluding Asian women) were lower (only 77% as likely) if the institution had an AANAPISI designation, relative to if it did not.

Amongst the non-MSI institutional characteristics, Women's College was the strongest positive predictor, followed by Ivy League Status. The odds of an institution producing computer science degrees to women of color excluding Asian women was 5.30 higher if the institution was a women's college, relative to if it was not. Top 25 Ranking status was a significant negative predictor; the odds of an institution producing computer science degrees to women of color excluding Asian women was lower (only 67% as likely) if the institution had ever ranked within the U.S. News & World Report Top 25 during the 2010/2011 – 2017/2018 time frame.

3.5. Asian Women

For degrees awarded to Asian women, p-values for all predictors except TCU designation emerged as statistically significant. The direction of the effects was not the same for all significant predictors; AANAPISI, ANNH, HSI, Top 25 Ranking status, and Women's College status were significant positive predictors, while HBCU, NASNTI, PBI, and Ivy League status were significant negative predictors. The strongest positive MSI-specific predictor of degrees to Asian women was ANNH, OR=5.25, 95% CI [4.40, 6.21], p<.001; the odds of an institution producing degrees to Asian women was 5.25 times higher if the institution had an ANNH designation, relative to if it did not. AANAPISI designation was also a strong predictor of degrees to Asian women, with OR=2.63, 95% CI [2.50, 2.76], p<.001. The strongest negative MSI-specific predictor of degrees to Asian women was NASNTI designation, OR=0.52, 95% CI [0.32, 0.80], p<.001; the odds of an institution producing degrees to Asian women was lower (only 52% as likely) if the institution had an NASNTI designation, relative to if it did not.

3.6. Black Women

For computer science degrees awarded to Black women, p-values for all predictors except TCU designation emerged as statistically significant. The direction of the effects was not the same for all significant predictors; ANNH, HBCU, NASNTI, PBI, Ivy League status, and Women's Colleges were significant positive predictors, while AANAPISI, HSI, and Top 25 Ranking status were significant negative predictors. The strongest *positive* MSI-specific predictor of degrees to Black women was HBCU, OR=4.77, 95% CI [4.46, 5.10], p<.001; the odds of an institution producing degrees to Black women was 4.77 times higher if the institution had an HBCU designation, relative to if it did not. The strongest *negative* MSI-specific predictor of degrees to Black women was HSI designation, OR=0.63, 95% CI [0.58, 0.68], p<.001; the odds of an institution producing degrees to Black women was lower (only 62% as likely) if the institution had an HSI designation, relative to if it did not.

3.7. Indigenous Women

Due to the original model's failure to converge, the TCU designation indicator had to be removed from this logistic regression equation. The model's failure to converge is likely related to the combination of the fact that a) only 2 institutions had a TCU designation, and b) a relatively small number of computer science degrees overall were being awarded to Indigenous women. Indeed, 1,340 institutions produced 0 computer science degrees to Indigenous women during the 2010/2011 – 2017/2018 timeframe, while amongst the institutions who did produce computer science degrees to Indigenous women, the vast majority of them (n=153, or 69.2%) produced only one degree during these eight academic years (the max number of degrees to Indigenous women by a single institution over the course of 8 years was 12 degrees, and only one institution had a number this high).

For computer science degrees awarded to Indigenous women, the only significant p-values were for AANAPISI, NASNTI, and Top 25 Ranking status. The direction of the effects was not the same for all significant predictors; NASNTI designation was a significant positive predictor, while AANAPISI designation and Top 25 Ranking status were significant negative predictors. The odds of an institution producing computer science degrees to Indigenous women was 3.33 times higher if the institution had a NASNTI designation, relative to if it did not (OR=3.33, 95% CI [1.19, 7.23], p=.008). On the other hand, the odds of an institution producing degrees to Indigenous women were significantly lower (only 60% as likely) if the institution had an AANAPISI designation, relative to if it did not.

3.8. Latina Women

For computer science degrees awarded to Latina women, p-values for all predictors except TCU designation emerged as statistically significant. The direction of the effects was not the same for all significant predictors; HSI, NASNTI, PBI, Ivy League status, and Women's Colleges were significant positive predictors, while AANAPISI, ANNH, HBCU, and Top 25 Ranking status were significant negative predictors. The strongest *positive* MSI-specific predictor of degrees to Latina women was NASNTI, OR=3.02, 95% CI [2.41, 3.72], p<.001; the odds of an institution producing degrees to Latina women was 3.02 times higher if the institution had a NASNTI designation, relative to if it did not. HSI and PBI were also strong, positive MSI-specific predictors, with OR=2.37, 95% CI [2.25, 2.49], p<.001. and OR=2.39, 95% CI [2.07, 2.74], p<.001, respectively. The strongest *negative* MSI-specific predictor of degrees to Latina women was ANNH designation, OR=0.49, 95% CI [0.27, 0.80], p<.001; the odds of an institution producing degrees to Latina women was lower (only 49% as likely) if the institution had an ANNH designation, relative to if it did not.

3.9. Native Hawaiian/Pacific Islander Women

Due to the original model's failure to converge, the PBI designation and TCU designation indicator variables had to be removed from this logistic regression equation. The model's failure to converge is likely related to the combination of the fact that a) few institutions had a PBI or TCU designation, and b) a relatively small number of computer science degrees overall were being awarded to Native Hawaiian/Pacific women. Indeed, 1,409 institutions produced 0 computer science degrees to Native Hawaiian/Pacific women during the 2010/2011 – 2017/2018 timeframe, while amongst the institutions who did produce computer science degrees to Native Hawaiian/Pacific women, the vast majority of them (n=113, or 74.3%) produced only 1 degree during these eight academic years (the max number of degrees to Native Hawaiian/Pacific women by a single institution over the course of eight years was 7 degrees, and only 3 institutions had a number this high).

For computer science degrees awarded to Native Hawaiian/Pacific women, the only significant p-values were for AANAPISI and ANNH. Both designations were significant positive predictors. The strongest positive predictor was ANNH designation, with OR=13.8, 95% CI [6.54, 25.5], p<.001; the odds of an institution producing computer science degrees to Native Hawaiian/Pacific women was 13.8 times higher if the institution had an ANNH designation, relative to if it did not. There were no significant negative predictors of degrees to Native Hawaiian/Pacific women (although most predictors in the model overall failed to emerge as significant in either direction).

3.10. Two or More races

For computer science degrees awarded to multiracial, the only significant p-values were for AANAPISI, ANNH, Top 25 Ranking status, and Women's Colleges. All four of these predictors were positive predictors of degrees going to multiracial. The strongest *positive* MSI-specific predictor of degrees to multiracial was ANNH, with OR=4.27, 95% CI [2.97, 5.91], p<.001; the odds of an institution producing degrees to multiracial was 4.27 times higher if the institution had an ANNH designation, relative to if it did not. There were no significant negative predictors (MSI-specific or non-MSI-specific) of degrees to multiracial.

4. Summary & Future Work

Women of color in computing face a myriad of challenges for entering and remaining in computing majors and fields. This study was conducted to better understand, overall, which colleges and universities are impacting the graduation rates of women in color so that a more granular analysis can occur moving forward. In addition to descriptive data paying attention to graduations rates, logistic regression analysis was used to test whether MSI designation and other institutional characteristics, predicted the likelihood of institutions producing computer science degrees to women of color. For women as a whole, all predictors emerged as statistically significant predictors of the target outcome (computer science degrees being awarded/produced), with the exception of the Tribal College and University designation. Most (7) of these predictors were positive predictors—meaning they were associated with higher odds of computer science degrees to women; however, a few (2) were negative predictors—meaning they were associated with lower odds of computer science degrees to women.

For women of color (WOC), all predictors emerged as statistically significant, except for TCU and Ivy League status. All predictors were positive; in other words, all eight of the significant predictors were associated with higher odds of degrees being awarded to WOC. The strongest MSI-specific predictor was ANNH designation, with OR=2.85, 95% CI [2.48, 3.26], $p<.001$; the odds of an institution producing a computer science degree for WOC was 2.85 times higher if the institution had an ANNH designation, relative to if it did not. For a women of color subset—women of color minus Asian women (WOC subset)—all predictors except the TCU designation again emerged as statistically significant. Most significant predictors were positive predictors (i.e., associated with higher odds of degrees being produced to WOC subset), with only AANAPISI and Top 25 Ranking status showing as significant negative predictors (i.e., associated with lower odds of degrees being produced to WOC subset). The strongest MSI-specific predictor was HBCU, with OR=2.52, 95% CI [2.83, 2.68], $p<.001$; the odds of an institution producing a computer science degree to WOC subset was 2.52 times higher if the institution had an HBCU designation, relative to if it did not.

For Asian women specifically, the strongest positive MSI-specific predictor was ANNH designation; women's college status was the strongest non-MSI-specific positive predictor. For Black women, the strongest MSI-specific predictor was HBCU designation; women's college status was the strongest non-MSI-specific positive predictor. For Indigenous women, the strongest MSI-specific predictor was NASNTI (though ANNH also appeared to have a strong positive association); there were no significant non-MSI-specific predictors. For Latina women, the strongest MSI-specific positive predictor was NASNTI (though HSI and PBI also appeared to have strong positive associations); women's college status was the strongest non-MSI-specific positive predictor. For Native Hawaiian/Pacific Islander women, the strongest MSI-specific predictor was ANNH (though AANAPISI also appeared to have a strong positive association); there were no significant non-MSI-specific predictors. For multiracial women, the strongest

MSI-specific predictor was ANNH designation; women's college status was the strongest non-MSI-specific positive predictor.

The data suggest that yes, MSIs do outperform non-MSIs in producing computer science degrees to women of color; for women of color as a whole, all MSI designations (except TCU, for which only two institutions have this designation) are associated with higher odds of producing a computer science degree. For specific racial/ethnic breakdowns, some MSI designations may have higher odds of producing a computer science degree than others. Moreover, some MSI designations may be associated with lower (rather than higher odds) of producing a computer science degree to a specific individual WOC group.

In future work, the research team intends to combine these quantitative data with qualitative data to develop a more nuanced understanding of these institutions and the ways in which their policies and practices impact graduation rates of women of color in computing.

5. References

[1] J. Gaston Gayles and K. N. Smith, "Advancing Theoretical Frameworks for Intersectional Research on Women in STEM," *New Dir. Institutional Res.*, vol. 2018, no. 179, pp. 27–43, 2018, doi: 10.1002/ir.20274.

[2] Y. A. Rankin and J. O. Thomas, "Straighten up and fly right: rethinking intersectionality in HCI research," *Interactions*, vol. 26, no. 6, pp. 64–68, Oct. 2019, doi: 10.1145/3363033.

[3] S. L. Rodriguez and K. Lehman, "Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory," *Comput. Sci. Educ.*, vol. 27, no. 3–4, pp. 229–247, Oct. 2017, doi: 10.1080/08993408.2018.1457899.

[4] Y. A. Rankin and J. O. Thomas, "The Intersectional Experiences of Black Women in Computing," in *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, New York, NY, USA: Association for Computing Machinery, 2020, pp. 199–205. Accessed: Feb. 14, 2022. [Online]. Available: https://doi.org/10.1145/3328778.3366873

[5] M. (Mia) Ong, "The Status of Women of Color in Computer Science," *Communications of the ACM*, vol. 54, no. 7, pp. 32–34, Jul. 2011.

[6] M. Ong, C. Wright, L. L. Espinosa, and G. Orfield, "Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics," *Harv. Educ. Rev.*, vol. 81, no. 2, pp. 172–208, 2011, doi: 10.17763/haer.81.2.t022245n7x4752v2.

[7] E. O. McGee, D. M. Griffith, and S. L. Houston, "'I Know I Have to Work Twice as Hard and Hope that Makes Me Good Enough': Exploring the Stress and Strain of Black Doctoral Students in Engineering and Computing," *Teach. Coll. Rec.*, vol. 121, no. 4, pp. 1–38, Apr. 2019, doi: 10.1177/016146811912100407.

[8] A. N. Washington, "When Twice as Good Isn't Enough: The Case for Cultural Competence in Computing," in *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, New York, NY, USA, Feb. 2020, pp. 213–219. doi: 10.1145/3328778.3366792.

[9] E. E. Griffith and N. Dasgupta, "How the Demographic Composition of Academic Science and Engineering Departments Influences Workplace Culture, Faculty Experience, and Retention Risk," *Soc. Sci.*, vol. 7, no. 5, Art. no. 5, May 2018, doi: 10.3390/socsci7050071.

[10] K. A. Thomas, W. Gaskins, and K. J. Cross, "Double Standard: How Women of Color Must Navigate in the Engineering Environment," presented at the 2021 ASEE Virtual Annual Conference Content Access, Jul. 2021. Accessed: May 14, 2022. [Online]. Available: https://peer.asee.org/double-standard-how-women-of-color-must-navigate-in-the-engineering-environment

[11] E. O. McGee, "Addressing systemic racism as the cancer of Black people: equity ethic-driven research," *Nat. Rev. Cancer*, vol. 21, no. 8, Art. no. 8, Aug. 2021, doi: 10.1038/s41568-021-00368-8.

[12] E. McGee and L. Bentley, "The Equity Ethic: Black and Latinx College Students Reengineering Their STEM Careers toward Justice," *Am. J. Educ.*, vol. 124, no. 1, pp. 1–36, Nov. 2017, doi: 10.1086/693954.

[13] D. E. Naphan-Kingery, M. Miles, A. Brockman, R. McKane, P. Botchway, and E. Mcgee, "Investigation of an equity ethic in engineering and computing doctoral students - Naphan-Kingery - 2019 - Journal of Engineering Education - Wiley Online Library," vol. 108, no. 3, pp. 337–354, Aug. 2019, doi: https://doi-org.proxy.lib.duke.edu/10.1002/jee.20284.

[14] S. B. Daily *et al.*, "Alternate Pathways to Careers in Computing: Recruiting and Retaining Women Students," Jun. 2013, p. 23.144.1-23.144.11. Accessed: May 14, 2022. [Online]. Available: https://peer.asee.org/alternate-pathways-to-careers-in-computing-recruiting-and-retaining-women-students

[15] H. K. Ro and K. I. Loya, "The effect of gender and race intersectionality on student learning outcomes in engineering," *Rev. High. Educ. J. Assoc. Study High. Educ.*, vol. 38, no. 3, pp. 359–396, 2015, doi: 10.1353/rhe.2015.0014.

[16] S. B. Daily, A. E. Leonard, S. Jörg, S. Babu, and K. Gundersen, "Dancing alice: exploring embodied pedagogical strategies for learning computational thinking," in *Proceedings of the 45th ACM technical symposium on Computer science education*, New York, NY, USA, Mar. 2014, pp. 91–96. doi: 10.1145/2538862.2538917.

[17] A. N. Washington, S. B. Daily, and C. Sadler, "Identity-Inclusive Computing: Learning from the Past; Preparing for the Future," presented at the 53rd ACM Technical Symposium on Computer Science Education, Providence, RI, Mar. 2022.

[18] "Preparing the Future STEM Workforce for Diverse Environments - Shaundra Bryant Daily, Wanda Eugene, 2013." https://journals.sagepub.com/doi/abs/10.1177/0042085913490554 (accessed May 14, 2022).

[19] A. Nishio, "The Significance of the Existence of Women's Colleges and Their Entry into Science-Related Fields," *Information Technology and Economic Development*, 2008. https://www.igi-global.com/chapter/information-technology-economic-development/www.igi-global.com/chapter/information-technology-economic-development/23525 (accessed May 14, 2022).

[20] N. Veilleux, "Lessons from women's colleges: what works, what doesn't and what will work elsewhere: panel discussion," *J. Comput. Sci. Coll.*, vol. 30, no. 6, pp. 62–63, Jun. 2015.