Participation of Minority Women in Computing

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ABSTRACT

As of the Fall 2017 term, women make up 14.4% of the students enrolled in the Online Master of Science in Computer Science (OMSCS) at the Georgia Institute of Technology (Georgia Tech), with minority[1] women making up ~10% and underrepresented minority[2] women making up ~2%. The intent of this paper is to investigate the potential factors that contribute to the low numbers of minority women in STEM, more specifically the field of computer science, at the national level and within OMSCS and to begin to develop potential solutions for mitigation. Throughout the term, data was collected from both female and male students enrolled in OMSCS at Georgia Tech and national data on minority female students from the National Center for Education Statistics (NCES) was examined. OMSCS students were surveyed on topics related to gender, race/ethnicity, birthplace & current residence, higher education, employment, self-confidence in their field of study, and preferred learning styles.

Author Keywords

STEM; Women; Minorities; Gender issues; Higher education; Online education; MOOCs.

ACM Classification Keywords

K.3.2 Computer and Information Science Education: Computer science education

BACKGROUND

Minority women earned just 9% of Bachelor's degrees and 6.5% of Master's degrees awarded in the United States in computer and information sciences in the 2014-2015 academic year (U.S. Department of Education & National Center for Education Statistics, 2016a, 2016b). This number is even lower as we climb the computing education pipeline to the doctoral level. The "pipeline" is defined as "the ratio of women involved in computer science from high school to graduate school" (Gürer & Camp, 2001). According to Dr. Roli Varma, these numbers began to decline in the early to mid-1990s and based on data from the NCES, the numbers continued that trend through the remainder of the decade. We saw an uptick after the turn of the century, but the numbers peaked quickly and began declining again around 2004; there has only been an increase in women in the field in the last five years or so (U.S. Department of Education & National Center for Education Statistics, 2016a).

There are a number of factors, psychological and pedagogical, as well as some demographic inequities that contribute to this "shrinking pipeline" phenomenon. Past research that examined the attrition or absence of women and minorities from STEM fields such as computer science attributed the trend to academic deficits and the inaptitude to perform in quantitative and scientific disciplines (Beasley & Fischer, 2012). As time has passed, those theories have been debunked and further research concluded that the attrition of minorities and women from computing is partially rooted in group performance anxiety, also known as stereotype threat. Claude Steele and Joshua Aronson define stereotype threat as "being at risk of confirming, as self-characteristic, a negative stereotype about one's social group" (Steele & Aronson, 1995). Maya Beasley and Mary Fischer's research concluded that although women do not suffer from stereotype threat at a higher rate than men, it does have a significant effect on the likelihood that they will leave a STEM degree program. Additionally, minority students suffer from stereotype threat more than their white classmates, also increasing their likelihood to leave a STEM degree program (Beasley & Fischer, 2012).

While stereotype threat can affect minority groups individually, those that are members of multiple underrepresented groups face a higher risk of falling victim to stereotype threat. This higher risk is caused by what is known as the "double-minority effect" and is defined by Gonzales and colleagues as "the psychological state when two devalued identities interact to influence the individual in a way that is greater than the sum of the independent effects of those identities" (Gonzales, Blanton, & Williams, 2002). For example, we can predict, based on the work of Beasley and Fischer, that a woman of color would be at a higher risk to leave a STEM degree program than her non-minority male counterparts due to the duplication of stereotype threat effects, one being related to her gender, and the other being related to her race.

In addition to stereotype threat, women also face issues related to the "maleness" of computing and biases in gender socialization that can contribute to their

[1] For the context of this research, 'minority' refers to those identifying as non-white.

[2] For the context of this research, 'underrepresented minority' refers to the following groups: American Indian/Alaska Native, Black/African American, Hispanic/Latino, Native Hawaiian/Other Pacific Islander. Students identifying as mixed race will also be included.

underrepresentation in the field. While professions such as teaching were feminized in the 1850s and are currently highly female-dominated, a similar trend towards masculinity occurred with computer science about a century later (Boyle, 2004). According to Ellen Van Oost, masculine values were transferred to computers and computer workers in the 1950s and 60s, giving the field of computing a more male perception (Van Oost, 2000). As computing becomes more and more masculine, women and girls are being shut of the field as a result of gender stereotypes. For example, women in computing of all races are subject to subtle gender-based socialization at a young age, from both parents and educators alike. This gender-based socialization causes parents, teachers, and students to give in to the "boys only" stereotype that has plagued fields like computing for so long. This trend was investigated by Dr. Roli Varma in 2002 as she studied the low numbers of women in the information technology workforce and provided several examples as to how this socialization can occur in the classroom and at home. Some of those examples include: 1) Educators are less likely to redirect female students if they were clustered around the art in the classroom than if it were a group of male students and 2) Boys tend to receive more praise from their parents when it comes to science and math learning (Varma, 2002). Varma asserts that although parents and educators are not openly telling their female children and students that STEM is only for boys, these subtleties can have an effect on girls as they matriculate through the computer science education pipeline and potentially redirect their focus to other non-STEM fields.

Along with the potential of falling victim to stereotype threat, computer science being a predominately-male field, and biases in gender socialization, women in computing are also affected by teaching styles and their preferred learning styles. In the *Review of gender differences in learning styles*, the "transmission" model of teaching or traditional lecturing is discussed and research has shown that this model may not be suitable for female students. Most traditional teaching methods only cater to one or two preferred styles of learning and women tend to fall outside of those preferred styles, often causing a disconnect between female students and the material being taught (Kulturel-Konak, D'Allegro, & Dickinson, 2011). In addition to the fact that most teaching methods only cater to one or two learning styles, most STEM courses are competitive by nature and fail to accommodate multiple learning styles as well. Kulturel-Konak, D'Allegro, and Dickinson also indicate that the differences in learning styles between genders can also be affected by who is delivering the material. Their research shows that while women benefit more from instructors who facilitate learning, men tend to benefit more when the instructor has taken on an authoritative or expert role in the classroom (Kulturel-Konak et al., 2011). The disconnect between the material being taught, preferred learning styles, limitations on teaching methods, and the person delivering the material can all play a role in whether or not a female student grasps certain computer science concepts, can apply them correctly, and chooses to remain in the field later on in her career.

All of the afore mentioned topics were taken into consideration when developing the survey that is the foundation for this paper. Students, both male and female, were asked about their confidence levels pertaining to learning new programming languages, solving computer science problems, and their ability to complete the OMSCS program to gain a better idea of what stereotype threat looks like within this particular group of students. To paint a clearer picture of the difference in learning styles between genders, survey participants were also asked to rank their preferred learning styles (logical, visual, musical, verbal, or through movement). All of the previously discussed survey topics allowed for a high-level understanding of some of the psychological and pedagogical differences, as well as the demographic inequities that minority women face in computing that their non-minority or male counterparts do not.

DATA

OMSCS students enrolled in the Fall 2017 offering of Educational Technology (CS 6460)[3] participated in a survey between October 20, 2017 and November 29, 2017 for the purposes of this paper. Participation in the survey was strictly voluntary and students were offered participation credit in return. The survey was administered online via Qualtrics and student responses were collected anonymously. Any surveys that were left incomplete were omitted from the final count, leaving 75 complete responses (23 female students and 52 male students). In addition to the data collected from the survey, data on OMSCS demographics was also pulled to provide a breakdown all male and female students enrolled in the program by race/ethnicity.

METHODOLOGY

A two-sample t-test (assuming unequal variances) was used during survey analysis to measure any significant difference between male and female students and male and minority female students in the following categories:

- Self-Confidence in OMSCS
- Self-Confidence in Attempting and Solving Computer Science Problems
- Self-Confidence in Learning New Programming Languages
- Potential Attrition from OMSCS
- Sense of Belonging in the OMSCS Program
- Sense of Belonging in the Overall Computing Community.

[3] The OMSCS offering of CS 6460 Educational Technology is a discussion-oriented course delivered in an online environment.

Sample means from each of those categories, along with p-values are reported. A significance level of 5% or .05 is assumed throughout. Place of birth and current residence, age group, and highest degree completed were also examined across sample groups.

RESULTS

OMSCS Variables Related to Demographics

As a part of the online survey, OMSCS students registered for CS 6460 during the Fall 2017 term were asked to provide several pieces of information related to demographics.

When looking at both genders, the largest participant age group was the 30-34 year-old age group at 28% (Table 1). While this is also the largest age group for male participants in this survey (32.7%), the largest group for all female survey participants and minority female participants was the 25-29 year old group (34.8%). None of the students surveyed, regardless of race or gender, indicated that they were in the 60-64 or 65+ age groups and no female students indicated that they were in the 50-54 year old age group.

Age	Female	Male
18-24	8.7%	7.7%
25-29	34.8%	21.1%
30-34	17.4%	32.7%
35-39	21.7%	11.5%
40-44	8.7%	15.4%
45-49	4.3%	3.8%
50-54	-	3.8%
55-59	4.3%	3.8%
60-64	-	-
65+	-	-

Table 1. Age distribution of students surveyed, by gender.

Although the OMSCS students surveyed were demographically similar with regard to current country of residence, a higher percentage of female students than male students were born somewhere other than the United States (Table 2).

Place of Birth	Female	Male	Minority Female
United States	30.4%	50.0%	6.3%
Canada	4.3%	1.9%	6.3%
India	34.8%	11.5%	50.0%
China	21.7%	11.5%	31.3%
Other	8.7%	25.0%	6.3%
% Currently residing in the US	82.6%	84.6%	75.0%

Table 2. Place of birth and current residence, by gender.

While exactly half of the male survey participants were born in the United States, more than half (56.5%) of the female students surveyed were born in Asia. Of the minority women surveyed, 81.3% of them were also born in Asia.

Students were also asked about their highest degree completed and what subject that degree was in. Table 3 shows a percentage breakdown by sample group of the highest degree earned. Survey participants earned more undergraduate degrees in computer science (73.5%) across all groups than any other subject, with engineering being the second most earned (16.3%). At the Master's level, degrees in business were the most awarded degree (31.6%), followed by computer science and engineering, both at 26.3%. Although male survey participants completed degrees at a higher rate than female participants on the Bachelor's and Master's levels, female students with Ph.D.'s account for 6.7% of the total degrees earned among the group, with the minority female sample group close behind at 5.3%. This is compared to the 2.6% held by their male counterparts. While 56.3% of minority women reported that their highest degree achieved was a Bachelor's, their rates remain steady at the Master's and Ph.D. levels at 18.8% respectively.

Highest Degree Completed	Female	Male	Minority Female
Bachelors or equivalent	60.9%	67.3%	56.3%
Masters or equivalent	17.4%	28.8%	18.8%
Ph.D. or equivalent	21.7%	3.8%	18.8%

Table 3. Highest degree completed, by gender.

Self-Confidence

In the online survey, students were asked "How confident are you in your ability to successfully complete the OMSCS program" and given a response scale of 'Very unconfident' = 1, 'Unconfident' = 2, 'Neutral' = 3, 'Confident' = 4, and 'Very confident' = 5. 32 students reported that they were 'very confident' in their abilities (42.7%), while 5 reported that they were 'very unconfident' (6.7%). 18.75% of minority women reported that the they were 'very unconfident' or 'unconfident' in their abilities to be successful in the program, while no non-minority women indicated any lack of confidence. Of the male students that were surveyed, 88.5% of them reported that they were either 'confident' or 'very confident' in their abilities to successfully complete the program. Average self-confidence scores are listed below in Table 4, 1 being the lowest and 5 being the highest possible self-score.

Based on the observed difference in the two sample means for male and female students, there is no evidence to suggest that confidence level in completing the program between genders differs significantly. This also holds when looking at the two sample means between male and minority female students (Table 5).

Confidence Scores	Female	Male	*p-value*
Confidence in completing OMSCS	3.83	4.19	0.2
Confidence in learning a new programming language	3.91	4.52	0.00*
Confidence in attempting and solving computer science problems	3.74	4.19	0.08

Table 4. Average confidence scores by gender (Female and Male Samples).

Confidence Scores	Minority Female	Male	*p-value*
Confidence in completing OMSCS	3.56	4.19	0.075
Confidence in learning a new programming language	3.75	4.52	0.00*
Confidence in attempting and solving computer science problems	3.38	4.19	0.01*

Table 5. Confidence scores for male and minority female students (Minority Female and Male Samples).

In addition to self-confidence in the program, students were also asked about their level of comfort in learning a new programming language and attempting and solving computer science problems. They were asked to answer on a Likert Scale, with Strongly Disagree = 1, Disagree = 2, Neither Agree or Disagree = 3, Agree = 4, and Strongly Agree = 5 for both questions. Those scores were averaged and also shown in tables 5 and 6 above. When looking at the sample means between male and female students in table 4, the small p-value (<0.05) suggests a difference between genders with regards to confidence in learning a new programming language. The same holds true for the sample means between male and minority female students (Table 5). However, there is no evidence to suggest a significant difference between male and female students in their confidence in attempting and solving computer science problems, but when comparing the sample means of male students to minority female students, the p-value is small enough to suggest a difference between the two groups.

Potential Attrition from OMSCS

Along with confidence in their abilities to complete the OMSCS program and their abilities related to learning computer science content, students were also asked if they ever considered leaving the OMSCS program. Given the same Likert Scale that was given for the confidence questions (Strongly Disagree = 1, Disagree = 2, Neither Agree or Disagree = 3, Agree = 4, and Strongly Agree = 5), participants were asked to what extent did they agree with the following statement: "I have considered leaving the OMSCS program." Scores were averaged and can be found in tables 6 and 7.

Potential for Attrition	Female	Male	*p-value*
Considered leaving OMSCS	2.00	2.37	0.18

Table 6. Average rate for students considering leaving OMSCS (Female and Male Samples).

Potential for Attrition	Minority Female	Male	*p-value*
Considered leaving OMSCS	1.88	2.37	0.11

Table 7. Average rate for students considering leaving OMSCS (Minority Female and Male Samples).

As seen in tables 6 and 7, based on the p-values between the samples, there is no evidence to indicate that female students and minority female students have considered leaving the OMSCS program at a higher rate than their male classmates.

Sense of Belonging

Sense of belonging was measured in two different scenarios, Sense of Belonging in OMSCS and Belonging in the Overall Computing Community. Students were asked to what extent did they agree with the following statements and asked to respond using a Likert Scale (Strongly Disagree = 1, Disagree = 2, Neither Agree or Disagree = 3, Agree = 4, and Strongly Agree = 5): 1) "I feel that I belong in the OMSCS program" and 2) "I feel like a part of the overall computing community".

Ratings were averaged across genders and can be found below in tables 8 and 9. Although male students had a higher average sense of belonging within OMSCS in both comparisons, the female and minority female samples had a higher average sense of belonging in the overall computing community than the male sample of students. There is no evidence to suggest that there is any significant difference between male and female students and male and minority female students when it comes to sense of belonging, in both OMSCS and the overall computing community.

Sense of Belonging	Female	Male	*p-value*
Within OMSCS	3.83	4.00	0.43
Overall Computing Community	3.61	3.48	0.56

Table 8. Sense of belonging between female and male students (Female and Male Samples).

Sense of Belonging	Minority Female	Male	*p-value*
Within OMSCS	3.67	4.00	0.14
Overall Computing Community	3.56	3.48	0.73

Table 9. Sense of belonging between minority female and male students (Minority Female and Male Samples).

Learning Styles

Surveyed students were asked to what extent did they agree with the following statements pertaining to their preferred learning styles:

- I prefer using pictures and images to learn.
- I prefer using sound and music to learn.
- I prefer using words, in both speech and writing, to learn.
- I prefer using my body, hands, and sense of touch to learn.
- I prefer to using logic and reasoning to learn.

Participants were asked to respond on a Likert Scale, with Strongly Disagree = 1, Disagree = 2, Neither Agree or Disagree = 3, Agree = 4, and Strongly Agree = 5 as options for each question. Averages were calculated for each of the learning styles across sample groups and can be found below in tables 10 and 11.

Preferred Learning Styles	Female	Male	*p-value*
Pictures and Images	3.96	3.83	0.54
Sound and Music	2.87	2.88	0.96
Words (Speech and Writing)	3.65	3.77	0.61
Body, Hands, Sense of Touch	3.13	3.31	0.49
Logic and Reasoning	4.39	4.37	0.88

Table 10. Preferred learning styles between female and male students (Female and Male Samples).

Preferred Learning Styles	Minority Female	Male	*p-value*
Pictures and Images	4.13	3.83	0.21
Sound and Music	3.06	2.88	0.61
Words (Speech and Writing)	3.38	3.77	0.16
Body, Hands, Sense of Touch	3.19	3.31	0.69
Logic and Reasoning	4.25	4.37	0.59

Table 11. Preferred learning styles between minority female and male students (Minority Female and Male Samples).

On average, the female and minority female sample groups ranked learning with pictures and images higher as a preferred learning style than the male sample group. The least preferred learning style based on averages across sample groups was learning with sound and music. Based on the above information, there is no evidence that indicates a significant difference between the preferred learning styles of male and female students. The same can be said for the male and minority female student samples.

DISCUSSION

For the purposes of this paper, a number of factors were investigated to see if there were any differences between female sample groups (minority female and combined minority/non-minority female) and a male sample group.

Based on an analysis of the collected survey data, there was not any major differences between the sample groups demographically speaking. Although, the birthplaces between male and both female sample groups varied, about one-quarter of the students surveyed in each group currently reside in the United States. Another similarity across groups regardless of gender or minority status was that the majority of the survey participants came from a computer science or engineering background – 89.8% of the undergraduate degrees earned by participants were in computer science or engineering. Surveyed minority female students were out earning their male colleagues when it came to the number of doctorate degrees awarded (5.3% compared to 2.6%). The same can be said for the overall sample group of female students, who out earned their male colleagues, 6.7% to 2.6%. This is in line with data presented by the NCES for the 2014-15 academic year where female Ph.D. students were awarded more degrees their male counterparts, 52% to 47% (U.S. Department of Education, 2016).

Of the data collected pertaining to self-confidence, potential attrition, sense of belonging, and preferred learning styles, the only topics that suggested a significant difference between the male and female sample groups were those related to confidence. For both the female and minority female sample groups being compared to the male sample group, there appeared to be a significant difference in confidence levels when it came to learning a new programming language. There was also a significant difference in confidence levels between the male and minority female sample groups when it came to attempting and solving computer science problems. Previous research by Beasley and Fischer also indicated lower confidence levels in female students pertaining to STEM fields due to performance anxiety (Beasley & Fischer, 2012).

When it came to preferred learning styles, sense of belonging, and potential for attrition from OMSCS, there was not enough evidence to indicate a difference between any of the samples groups being compared, although Beasley and Fischer's research indicates that female students are at a higher risk of leaving a STEM degree program than male students due to performance anxiety (Beasley & Fischer, 2012). While collected survey data did not convey a difference in preferred learning styles, research by Kulturel-Konak et al. suggests that there are differences in learning styles across genders (Kulturel-Konak et al., 2011).

Recommendations

The analysis of collected survey data, review of already existing enrollment and gradation data from both OMSCS and national levels, and the review of the previously discussed background literature has led to several recommendations. The following recommendations were made with the intent to recruit and maintain women, more specifically minority women in the field of computer science:

1. **Education:** Women entering and working in STEM fields would need to be educated on the previously mentioned topics as well as anyone who considers themselves an ally of this particular community. By starting these conversations to educate women and their allies on the issues that affect women taking on STEM majors and careers, we can begin to move towards improving female participation in the field. This can be done via small workshops in schools and in the workplace.
2. **Start early:** Get young students involved early in classes and afterschool programs geared towards STEM in the K-12 space. Make sure that these programs are inclusive of female students and encourage their participation. Similar to programs that have been implemented at Georgia Tech, it would be ideal to have K-12 schools partner with STEM university programs in the area so that younger female students are able to see older female students pursuing STEM at the collegiate level. By having female students participate in these programs and take STEM courses before college, there is a higher likelihood that those same students will choose to major in STEM while in college.
3. **Teachers become learners:** Educators could be trained in better recognizing the learning styles of their students, male and female, and make attempts to tailor lesson plans to a multitude of learning styles rather than the traditional one or two we see most often. This is not to say that educators need to go so far as to provide individualized lessons for each of their students, but for them to do their part to make sure that there is some diversity in the way that they teach to reflect the diverse learning styles of their students.

CONCLUSION

Issues referred to by Dr. Roli Varma and Dr. Sadan Kulturel-Konak such as biases in gender socialization and differences in learning and teaching methods could have an effect on the number of women entering the field of computer science and the number of women that choose to stay in the field. Those issues can contribute to problems that female students face related to self-confidence, motivation to remain in the field or a related degree program, and sense of belonging. Dr. Tracy Camp posits that female participation in computer science will continue to decline if nothing is done to slow the "shrinking pipeline". The recommendations made in the previous section are just a few ways to help create a more inclusive computing community. By making the community more inclusive, there is a potential to increase the number women participating in computer science, more specifically minority women on a national scale and within OMSCS.

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REFERENCES

Beasley, M. A., & Fischer, M. J. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. *Social Psychology of Education*, *15*(4), 427–448. https://doi.org/10.1007/s11218-012-9185-3

Boyle, E. (2004). The Feminization of Teaching in America.

Gonzales, P. M., Blanton, H., & Williams, K. J. (2002). The Effects of Stereotype Threat and Double-Minority Status on the Test Performance of Latino Women. *Personality and Social Psychology Bulletin*, *28*(5), 659–670. https://doi.org/10.1177/0146167202288010

Gürer, D., & Camp, T. (2001). Investigating the Incredible Shrinking Pipeline for Women in Computer Science. *National Science Foundation*, 1–52. Retrieved from http://women.acm.org/archives/documents/finalreport.pdf

Kulturel-Konak, S., D'Allegro, M. Lou, & Dickinson, S. (2011). Review of gender differences in learning styles: Suggestions for STEM education. *Contemporary Issues in Education Research (CIER)*, *4*(3), 9–18. https://doi.org/10.19030/cier.v4i3.4116

Oost, E. van. (2000). Making the Computer Masculine. *Women, Work and Organization - Charting a Course to the Future*, 9–16.

Steele, C. M. ., & Aronson, J. (1995). Stereotype Threat and the Intellectual Test Performance of African Americans. *Journal of Personality and Social Psychology*, *69*(5), 797–811.

U.S. Department of Education, N. C. for E. S. (n.d.). *Doctor's degrees conferred by postsecondary institutions, by race/ethnicity and sex of student: Selected years, 1976-77 through 2014-15*.

U.S. Department of Education, & National Center for Education Statistics. (2016a). *Degrees in computer and information sciences conferred by postsecondary institutions, by level of degree and sex of student: 1970-71 through 2014-15*. U.S. Department of Education National Center for Education Statistics. Retrieved from https://nces.ed.gov/programs/digest/d16/tables/dt16_325.35.asp

U.S. Department of Education, & National Center for Education Statistics. (2016b). *Master's degrees conferred to females by postsecondary institutions, by race/ethnicity and field of study: 2013-14 and 2014-15No Title*.

Varma, R. (2002). Women in Information Technology: A Case Study of Undergraduate Students in a Minority-Serving Institution. *Bulletin of Science, Technology & Society*, *22*(4), 274–282. https://doi.org/10.1177/0270467602022004003