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The Effect of Robotics on Test Scores and Involvement in STEM Fields

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Problem Statement

This research study was conducted with the intention to raising awareness about the dearth of women in STEM fields and to diminishing implicit bias against women who want to pursue these areas. In grade school, girls are taking mathematics and science courses at similar rates as their male peers and are performing well overall; they are also expressing similar interest in these areas at this level. However, there is a drop-off as girls advance academically. The disparity begins to appear in high school, and worsens in college and beyond.

In high school, this disparity appears the strongest in physics and engineering, which are the fields that robotics mainly involves. Males take physics 42% of the time while females take it 36% of the time. Additionally, females are six times less likely to have taken engineering in high school.[1]

In college, gender disparities are still apparent; for instance, women receive a smaller percentage of degrees than men do. In terms of college degrees within the STEM sectors, women are awarded 43.1% of those in Mathematics and Statistics, 19.2% of those in Engineering, 19.1% of those in Physics, and 18.2% of those in Computer Sciences.[2] As women go through college, the culture and climate of STEM departments can be an important barrier to their recruitment and persistence in these fields. It is a weighty determinant in women's

[1] "State of Girls and Women in STEM" *Statistics*. National Girls Collaborative Project, 2016. Web. <https://ngcproject.org/statistics>.
[2] Ibid.

decisions to remain in a STEM major, where women are often outnumbered and can feel like they do not fit in.[3]

Although women make up 47% of the total U.S. workforce, they are less represented in science and engineering careers. Instead of seeing 47% of women across the board, women are underrepresented in the following categories:

- Chemists and Material Scientists (39%)
- Environmental Scientists and Geoscientists (27.9%)
- Industrial Engineers (17.2%)
- Chemical Engineers (15.6%)
- Civil Engineers (12.1%)
- Electrical Engineers (8.3%)
- Mechanical Engineers (7.2%)[4]

The STEM employment gap is further compounded by diversity challenges. Although they comprise 70% of college students, women and minorities make up less than 45% of STEM degree recipients. This signifies a largely available talent pool that should be a resource for many STEM fields.[5]

One year after graduation, college-educated women working fulltime in any career earn 20% less than their male counterparts. Women in computing and engineering are not immune to this disparity: they are paid 13% less and 18% less, respectively, than their male counterparts.[6] After ten years, they earn about 31% less.[7]

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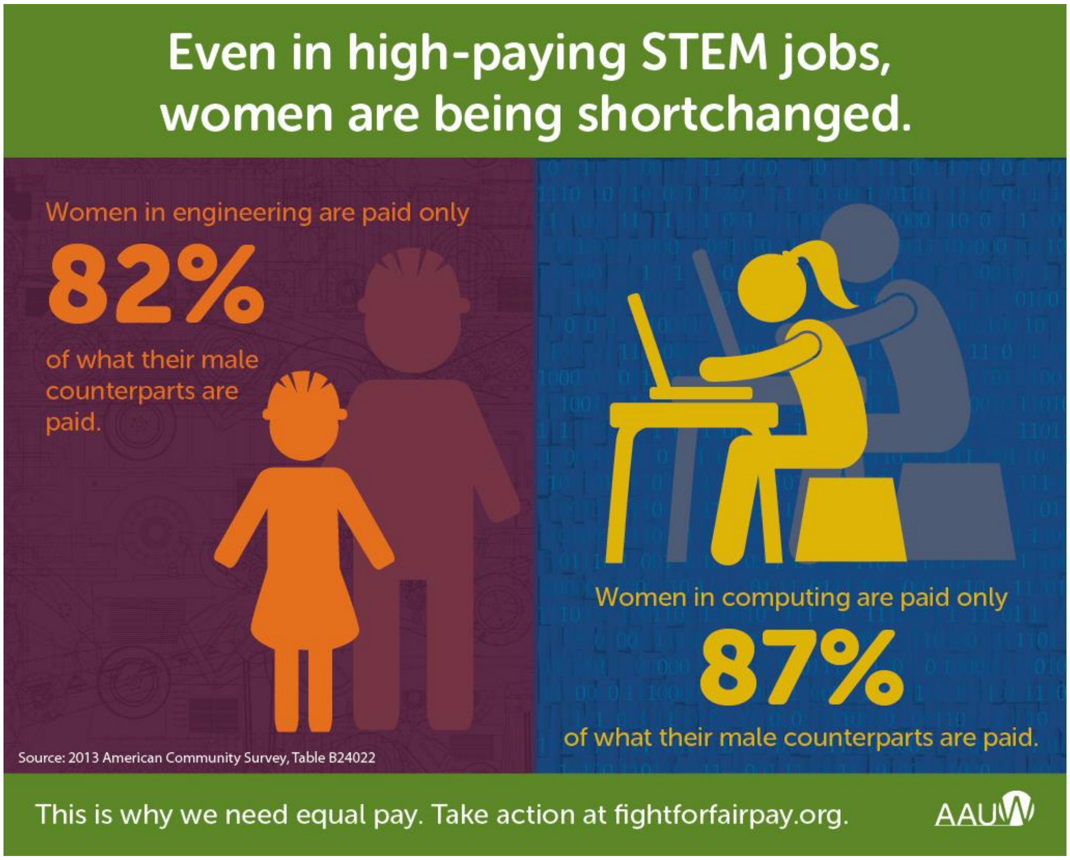
[3] St. Rose, Andresse. "STEM Major Choice and the Gender Pay Gap." *On Campus with Women*. AACU, 2010. Web.<http://archive.aacu.org/ocww/volume39_1/feature.cfm?section=1>.
[4] "State of Girls and Women in STEM" *Statistics*. National Girls Collaborative Project, 2016. Web. <https://ngcproject.org/statistics>.
[5] "STEM Depiction Opportunities." *Women in STEM* (n.d.): n. pag. The White House Council on Women and Girls, 1 Feb. 2016. Web.
[6] "Even in High-Paying STEM Fields, Women Are Shortchanged." *Empowering Women Since 1881*. AAUW, 14 Apr. 2015. Web. 17 Apr. 2016. <http://www.aauw.org/2015/04/14/women-shortchanged-in-stem/>.
[7] St. Rose, Andresse. "STEM Major Choice and the Gender Pay Gap." *On Campus with Women*. AACU, 2010. Web. <http://archive.aacu.org/ocww/volume39_1/feature.cfm?section=1>.



When talking about women in STEM, some argue that an innate difference accounts for the disparity between men and women. A couple studies support this, but most research refutes this stance. Studies generally conclude that there are no significant differences between men and women in terms of raw IQ. On the mathematics section of the SAT, women score an average of 32 points lower. Additionally, on average, men show a five-point advantage over women on the quantitative section of the Graduate Record Examination, and they score one point lower than women on the analytic section.[8]

Therefore, this research suggests that there is something else that is hindering women from contending in STEM fields—implicit bias. Much of society has notions that women and

[8] Cummins, Denies. "Why the STEM Gender Gap Is Overblown." *PBS Newshour*. PBS, 17 Apr. 2015. Web. 18 Apr. 2016. <http://www.pbs.org/newshour/making-sense/truth-women-stem-careers/>.

men should perform specific functions. When parents rate the math abilities of children with identical math performance, they rate their daughters lower than their sons, showing implicit bias. Also, if female and male students send identical emails inquiring about research opportunities, college faculty are less likely to respond to those from females. Furthermore, science faculty are less likely to hire or mentor a student if they believe the student is a woman rather than a man.[9]

Even women exhibit this implicit bias against other females. For example, when students were provided with the information that men were better than women at a certain skill, the men outperformed the women on the test of that skill. When test takers were told that men and women performed equally well in that same skill, the test results evened out. In some cases, the women outperformed the men.[10]

Promoting women in STEM, the program For Inspiration and Recognition of Science and Technology (FIRST) Robotics implemented in many schools aids the progression of gender equality in those areas. From my experience and conversations with students in robotics, the team fosters growth and development of knowledge about engineering, programming, and designing as well as interpersonal skills and the breakdown of implicit bias. This study focuses on how robotics affects the bias and academic success of girls who participate on the team.

Methodology

Data Collection

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[9] Handelsman, Jo, and Natasha Sakraney. "Implicit Bias." *Women in STEM* (n.d.): n. pag. White House Office of Science and Technology Policy, 15 Sept. 2015. Web.

[10] "Why Stereotypes Are Bad and What You Can Do about Them." *AAUW Empowering Women Since 1881 Why Stereotypes Are Bad and What You Can Do about Them Comments*. AAUW, 13 Aug. 2014. Web. 09 May 2016. <http://www.aauw.org/2014/08/13/why-stereotypes-are-bad/>.

The data that was analyzed is from my previous research titled "Influences of Robotics on Women in STEM." Instead of performing a qualitative analysis, I took the same data and completed a statistical analysis. I surveyed alumni of Mount Saint Joseph Academy, many of whom were former members of the school's Firebirds Robotics Team. The alumni answered questions about their GPA, SAT scores, and college majors. Those who were involved in robotics also answered questions about their perceptions of women in STEM before and after joining the team.

Data Analysis

Consistent with last year's study, this study will focus on SAT, GPA, and chosen or intended college majors in STEM. I believe there is a relationship between robotics and these aforementioned pieces. Hence, I hypothesize that there will be a positive correlation between involvement on the robotics team and both high scores and STEM-based college concentrations.

For the statistical analysis, we investigated four questions. (This analysis was performed in Wolfram Mathematica, a computer algebra program.) The questions are described both in common terms and mathematical terms as follows:

1. Do girls on a robotics team score higher on the SAT than those not on robotics? (Are the means of the SAT scores for Robotics and Non-robotics equal?)
2. Do girls on a robotics team attain higher GPAs than those not on robotics? (Are the means of the GPAs for Robotics and Non-robotics equal?)
3. Is there a higher percentage of STEM college majors for girls on a robotics team than for those not on robotics?
4. Does participation in robotics change girls' perceptions about certain topics? (Are the means of the "before robotics" and "after robotics" answers equal?)

Several statistical tools were employed to address the questions above: correlation, t-tests for both independent and paired samples, and signed-rank tests. The correlation distinguished whether there was a relationship between robotics and either SAT scores, GPAs, or majors. For the t-tests, the means of both Robotics and Non-robotics participants were tested. The null hypothesis was given as $\mu_1 = \mu_2$, where μ_1 was the mean for the Robotics and μ_2 was the mean for Non-robotics individuals. The *p*-value determines whether to accept or reject the null hypothesis, with a *p*-value smaller than $\propto$ indicating evidence to reject the null hypothesis. We tested at a 95% confidence level, i.e., with $\propto$ at a .05. The null hypothesis was rejected if the *p*-value was less than the .05 significance level.

For question 1, the data for each section of the SAT had to be made into two lists, one for the former robotics team members and one for the non-robotics alumni. For example, the Math section was determined by rMathSAT={} and nrMathSAT={} with the data of each Math SAT score included in the appropriate list for Robotics and Non-robotics, respectively. Then, a t-test for independent samples was performed in Mathematica by the line of code: TTest[{rMathSAT,nrMathSAT},Automatic,"TestDataTable"]. A mini table appeared as the output giving the test statistic and the *p*-value.

Additionally, a correlation test was performed to determine whether there was a relationship between involvement in robotics and SAT scores. First, the length of each list had to be determined to make an array of 1's for Robotics and 0's for Non-robotics: r=ConstantArray[1,23]; nr=ConstantArray[0,65]. Another list then needed to be made to combine Robotics and Non-robotics. This was formed from allROrNR=Join[r,nr]. A list of all of the Math SAT scores also needed to be joined in allSATM=Join[rMathSAT,nrMathSAT]. To test the correlation, the built-in function Correlation function was used: Correlation[allSATM,allROrNR]//N. The last portion forced the output to be a decimal number instead of a fraction. Similar codes was used for the other sections of the SAT including the total SAT scores.

For question 2, we planned to test the means of the GPAs. However, since the survey asked for the GPA in ranges, and most respondents' GPAs fell within the 3.6 to 4.0 range. (25 out of 28, or approximately 89%, of the robotics students were included, while 65 out of 76, or approximately 85%, of the non-robotics students were in this range.) Since there would not be enough significant variation to be meaningful, this question was not analyzed further.

Question 3 uses the same procedure as question 1. First, two lists—rMajor and nrMajor—were made to distinguish the college majors for both groups. Since majors are not quantitative in nature, 1's were used for alumni who pursued STEM majors in college while 0's were used for non-STEM majors. The lengths of each list was found in order to make both arrays. For example, since Length[rMajor] was 28, then a list of 1's was formed for Robotics participants: r=ConstantArray[1,28]. After the array for Non-robotics was formed, the lists needed to be joined by allROrNR=Join[r,nr]. After the Robotics and Non-robotics piece was finished, a list had to be made for the majors: allMajor=Join[rMajor,nrMajor]. Finally testing the correlation between robotics and STEM college majors, the command Correlation[allMajor,allROrNR]//N was used.

Question 4 required more work, but its answer was just as attainable as the others. Lists for each "before" and "after" question needed to be distinguished with the numbers 1 through 5. The values ranged from 1 ("Completely Disagree") to 5 ("Completely Agree"). An example of a list for two questions is before1={1,1,2,2,2,2,2,2,3,3,4,4,4,4,4,4,4,4,4,4,5,5,5,5,5} and after1={3,3,4,4,4,4,4,4,4,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5}. As before, the mean of each question was calculated by Mean[before1]//N. For the statistical analysis, a t-test for independent samples would not have been appropriate the "before" and "after" lists reflected responses from the same individuals. Therefore, a signed-rank test was used because there were two nominal variables (which individual was being considered and whether a given response was recorded before or after involvement in robotics) and one measurement variable (the score from 1 to 5 reflecting a stance between “Completely Disagree” and “Completely Agree”). Similar to the t-test for independent samples, this was performed as SignedRankTest[{after1,before1},Automatic,“TestDataTable”].

Data Charts

Table 1. T-Test for SAT Sections

SAT Sections	**Statistic**	***P*-Value**
Math	0.927327	0.356352
Reading	2.0252	0.045948
Writing	0.736894	0.463216
Total	1.35697	0.178382

Table 2. Correlation Test between Involvement in Robotics and SAT Sections

SAT Sections	**Correlation Coefficient**
Math	0.0995
Reading	0.213355
Writing	0.0796733
Total	0.145616

Table 3. Means of SAT Sections from Robotics and Non-robotics

SAT Sections	**Robotics**	**Non-robotics**
Math	662.609	644.308
Reading	706.957	668.615
Writing	699.565	685.469
Total	2069.13	2000.78

Table 4. Correlation Test between Involvement in Robotics and STEM College Majors

	Correlation Coefficient
STEM Majors	0.078502

Table 5. Signed Rank Test for Before and After Robotics Questions

	Statistic	***P*-Value**
Question 1	210	0.0000576554
Question 2	28	0.0147088
Question 3	45	0.00600848
Question 6	66	0.0015856
Question 7	15	0.0368884

Table 6. Means of Before and After Robotics Questions

	Before	**After**
Question 1	3.4	4.56
Question 2	4.36	4.68
Question 3	4.24	4.68
Question 6	3.72	4.2
Question 7	3.29167	3.5

Findings

Number 1: Do girls on a robotics team score higher on the SAT than those not on robotics? (Are the means of the SAT scores for Robotics and Non-robotics equal?)

For the Math SAT portion, the means for Robotics and Non-robotics were 662.609 and 644.308, respectively, as shown in Table 3. Although this appears to be an important difference, Table 1 shows that there is no statistical significance because the *p*-value was 0.356. Therefore, the null hypothesis is accepted stating both means are equal. This indicates that girls on the robotics team do not score higher on the Math SAT than those not on robotics. Additionally, there is no correlation between Math SAT scores and involvement in Robotics. This was found through the correlation test, which gave a correlation coefficient very close to 0 (0.0995) that is seen in Table 2.

For the Reading SAT portion, Table 3 displays that the mean of 706.957 for Robotics was much higher than the mean of 668.615 for Non-robotics. Here, the assumption of higher scores is valid given that *p*-value was 0.046, which may be seen in Table 1. Since this is less than the significance level of .05, the null hypothesis is rejected. This signifies that the girls in robotics score higher than others not in robotics for the Reading SAT. However, the correlation test between Reading SAT scores and participants in Robotics gave a correlation coefficient of 0.213 (as in Table 2). This denotes that there is no positive correlation between them.

For the Writing SAT portion, Table 3 shows that the means for Robotics and Non-robotics were fairly close at 699.565 and 685.469, respectively. The *p*-value in Table 1 of 0.463 is not less than the .05 significance level. Thus, the null hypothesis that states the mean values are equal is accepted. In other words, those on the robotics team do not score higher than those who were not on it. Additionally, the rounded correlation coefficient of Table 3 was 0.080, which distinguishes no correlation between Writing SAT scores and being on the robotics team.

For the Total SAT, the mean for Robotics and Non-robotics were 2069.13 and 2000.78, respectively, as shown in Table 3. Table 1 displays the *p*-value of 0.178. Since it was less than .05, the null hypothesis is accepted. This indicates that girls on the robotics team do not have higher overall scores than girls who were not on the robotics team. Also, there was no correlation between Total SAT scores and involvement in Robotics since the correlation coefficient was 0.146 as seen in Table 2.

Number 2: Do girls on a robotics team attain higher GPAs than those not on robotics?
(Are the means of the GPAs for Robotics and Non-robotics equal?)

As noted above, 25 out of 28 (89%) of the robotics students were in the 3.6 to 4.0 GPA range, and 65 out of 76 (85%) of the non-robotics students were in this range. Since there would not be enough significant variation to be meaningful, this question was not analyzed further.

Number 3: Is there a higher percentage of STEM college majors for girls on a robotic team than for those not on robotics?

Of the students surveyed, 53.6% of the Robotics students went into STEM majors while 44.7% of Non-robotics students chose those areas. Although the percentage is higher for Robotics, there is no correlation between being in robotics and going into college majors in areas of STEM given the 0.0785 correlation coefficient given in Table 4.

Number 4: Does participation in robotics change girls' perceptions about certain topics? (Are the means of the "before robotics" and "after robotics" answers equal?)

Seven statements were presented to those who were involved on the robotics team. Participants were instructed to consider how strongly they agreed or disagreed with each statement before and after joining the team. The statements are as follows:

1) I often heard about women in STEM.
2) I felt negatively towards women in STEM.
3) I felt positively towards women in STEM.
4) I always did well in math and science courses.
5) I never did well in math and science courses.
6) I often thought men had more math ability than women.
7) I would join a co-ed robotics team.

The statements were the same for "before" and "after" except for numbers 4 and 5, which were combined to form a statement of "I did better in math and science courses" for "after."

Since there was no feasible method for making a direct "before" and "after" comparison, these statements were not included in the statistical analysis.

"Before" and "After" responses to the other five statements were analyzed, and a statistically significant difference was observed in the means in all five cases. In Table 6, it may be seen that the means all went up at least 0.2 points from "before" to "after." Table 5 shows the *p*-values from the signed rank test. For Statement 1, the *p*-value was 5.777×10^5, which was the smallest one out of all. This denotes that girls on the robotics team heard about women in STEM much more during their time on robotics than before. Statements 2, 3, 6, and 7 show a similar occurrence. Although the null hypothesis was still rejected, the largest *p*-value of 0.0369 was for Statement 7.

Conclusion

From this data, I cannot conclude that girls on the Mount Saint Joseph Academy robotics teams had an overall higher average of SAT scores than those who were not on the robotics team. This was determined through the hypothesis tests implemented in Mathematica. The null hypothesis of both means being equal was tested at a 95% significance level. Overall, the *p*-values were larger than $\propto=0.05$ except for on the Reading portion of the SAT. Therefore, girls on the robotics team score higher only for the Reading portion of the SAT. This is logical since conceived since girls on the robotics team had to read tool-kit manuals and had to send letters to companies, which helped their reading skills.

Since there was not enough variation in GPA for both groups, we did not test the means for any relationship. The potential for analysis was limited because of the answers being in ranges instead of exact numbers. Also, the data collected was from a group of girls who are all academically successful. Therefore, it is not surprising that the majority of their GPAs would be in the highest range.

Both groups, Robotics and Non-robotics, have a percentage of people who have pursued STEM college majors and careers. Since many survey respondents did not provide career information, we only tested the correlation between robotics and college majors. It may not have been representative of the whole population since a small portion of the sample provided this information. This showed no correlation between girls in Robotics and having STEM college majors.

The perceptions of those on the robotics team were tested based on how they felt before and after joining robotics. A statistically significant difference was exhibited in the responses to all five statements tested. This indicates that involvement on the robotics team had a strong influence in changing the students' perceptions. Many more girls felt more positively towards women in STEM. Furthermore, being on the robotics team related to not agreeing with the statement that "Men had more math and science ability than women." This is extremely important, especially when looking at people's notion of implicit bias.

The variations between Non-robotics and Robotics groups show that women in robotics do not vary much from those who are not in robotics. However, there is a slight advantage in SAT Reading. These results do not necessarily represent the true situation for the general population since the sample was not diverse, meaning all of the people in the study came from a highly academic school where one had to have high scores to continue. Although there was no conclusive data regarding higher scores or percentages, girls in robotics could still benefit in areas such as testing scores and future STEM paths.

Although the results showed few relationships between women in robotics and advancing into fields of STEM, this is not true of women in general. This study consisted of a small sample size of women from a highly academic student population. In trying to contact various schools, we realized how difficult it was to attain data from them. Many schools did not follow up because they were busy, some schools could not get the study approved, and other schools did not seem to have the relevant data already on file or in a format to be easily extracted. Since collecting this data was very difficult, it could dissuade people from researching this further. However, this is an important topic that deserves attention. This study could be duplicated using more comprehensive data. It could also be enhanced with the following suggestions.

There are additional areas of study that could be analyzed on the subject of women in STEM and robotics if more data was collected. This study could be replicated almost exactly with a more diverse sample. Moreover, the part about careers could have been emphasized; furthermore, persistence in those careers would be significant in understanding the lack of women in STEM professions. Additionally, analyzing data from both men and women would be beneficial. The stigma of being a girl in robotics or being on a team with boys could also affect someone’s desire to join a team and reap the benefits.

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