Interest in STEM in Bay Area High School Students

Nicole Serrano
Stanford Online High School, Redwood City, CA 94063
nicole06@ohs.stanford.edu

Abstract
Previous studies show underrepresentation of minorities in STEM, but this project concentrates on comparing STEM interest between different demographic groups of high schoolers in the San Francisco Bay Area. Google Forms was used to distribute this survey, which asked participants to rate their interest in STEM from one through five and select which STEM subjects, or none, they were interested in. To analyze the results, the Kruskal-Wallis and the Mann-Whitney U tests were used to compare general and career interest in STEM due to ordinal data and a slight negative skew, and the Chi-Square Goodness of Fit test was used to assess whether or not groups were underrepresented or overrepresented in their interest in a specific field of STEM, such as science or engineering. After obtaining the results of these tests, it was discovered that the demographic category of gender differed in both interest in the overall STEM field and in specific subjects, while the demographic category of race differed only in interest in the overall STEM field.

Keywords
STEM, High School, Gender, Race, Socioeconomic Status

1. Introduction
The growth in awareness about movements such as Black Lives Matter (Michaels 2020) has resulted in increased awareness about societal inequalities. One area of inequality is the multidisciplinary field of STEM, which stands for Science, Technology, Engineering, and Mathematics. In STEM, some groups are overrepresented, such as men, Asian and White people, and other groups are underrepresented, such as women, Black, and Hispanic people (Fry, et al. 2021). In prominent technology companies, such as Facebook, Apple, and Google, women, Black, Hispanic or Latinx, and Multiracial people are underrepresented in areas of Research and Development. Because of underrepresentation in the field, studies have shown that technology discriminates against racial minorities (Bacchini and Ludovica 2019). For example, studies found that in one case, facial recognition technology works best for white men (Buolamwini and Gebru 2018), and in another case, technology used by judges to set parole was biased against black defendants (Ali, et al. 2010).

The increasing disinterest in STEM starts in primary and secondary education (Saw, et al. 2018), where societal messages often demotivate underrepresented demographic groups to steer away from STEM (Hutchinson 2015), and certain fields in STEM are considered more "masculine" or more "feminine" due to lack of representation in media and mentors (Cheryan 2016). By collecting data about high school students' interest in STEM and comparing demographic interest, schools will be able to identify and fix some of the problems of the current educational system through actions such as setting up mentoring, academic advising, curriculum reform, and opportunities to help students pursue passions in their desired fields (Tsui 2007). These actions should target specific demographic groups to help make the workforce is diverse and more representative of the actual population, making future innovations and inventions less biased and accessible to all.

Nationally, traditionally underrepresented groups in STEM and students with low socioeconomic status had significantly lower levels of career interest in STEM and were less likely to maintain or develop interest in high school (Saw et al. 2018). The San Francisco Bay Area is known as a STEM-focused area, especially because it includes Silicon Valley, a global center for technology and innovation. However, even with its reputation, are inequalities in interest and career interest in STEM and its subcategories, Science, Technology, Engineering, and Math, in the San Francisco Bay Area between race, gender, and socioeconomic status still present?

2. Methods

The objective of this study is to determine whether or not Bay Area students have differences in general and career interest among demographic groups. The null hypothesis states that there are no differences in patterns of gaps between demographics in interest in STEM. The alternative hypothesis states that there is no difference in patterns. Even though Bay Area students are near Silicon Valley, the technology center of the USA, and are known to be interested in STEM, will students have a more equalized distribution of interest? If they do have a proportional distribution of interest, high school students in the Bay Area may contribute to a more diverse workforce which will decrease bias in technology and increase accessibility.

2.1 Survey Information

For this project, Google Forms was used to create two identical forms that were sent to high school students. Both forms were opened on May 10, 2021, and closed on May 17, 2021, a one-week period of collection. To separate the data, one was sent to exclusively an organization of Bay Area independent schools, which garnered 131 responses. Another form with the same questions garnered 73 responses and was sent to various different kinds of schools with students in the Bay Area, such as Stanford Online High School, Cardinal Newman High School in Santa Rosa, CA, Maria Carillo in Santa Rosa, CA, and more high schools in Santa Rosa. This form also gathered data from social media platforms such as the subreddit r/SampleSize, Skype group chats and DMs, Instagram, and Discord servers. However, only 36 of the responses of the second form were used due to the location being strictly in the Bay Area. The purpose of separating this data into two forms was so further research focusing on Bay Area Independent Schools could be pursued if desired. There were two sections of the survey: Demographic Questions and Interest in STEM Questions.

To organize data and perform statistical tests, Google Sheets was consulted, combining both forms' data and then organizing them into formats suited for statistical tests. Two calculators: Alcula for general statistical information, such as mean, median, and mode, and VassarStats for more specific statistical tests, such as Kruskal-Wallis, Mann-Whitney U, Chi-Square Test of Goodness of Fit, and Chi-Square Test of Association, were also consulted.

2.2 Demographic Questions

In this section of the survey, some more sensitive questions, such as race, level of economic stress, and location were open-ended, and gender was optionally open-ended to make the survey more accessible and culturally competent to encourage responses from a diverse area.

For race, the prompt for participants to answer was: "Please describe your race, or the identity most often used to generalize your cultural/ethnic origin. (Merriam-Webster: 'race: any one of the groups that humans are often divided into based on physical traits regarded as common among people of shared ancestry')." After participants responded to this open-ended question, responses were categorized into the racial categories mentioned above, plus one extra category: American Indian or Alaska Native, Asian, Black or African American, Hispanic or Latino, Multiracial, Native Hawaiian or Other Pacific Islander, and White, according to the NIH definitions (NIH). However, only five racial groups were involved in statistical analysis in this study due to not having enough responses from two categories - American Indian or Alaska Native and Native Hawaiian or Other Pacific Islander. This also meant that one response had to be discarded when performing statistical analysis.

Participants answered a multiple-choice question for the category of gender with the options: “Female”, “Male”, “Nonbinary”, and “None of the Above.” However, participants had the option to elaborate if they answered, “None of the Above.” To categorize gender, the definition of gender identity by Merriam-Webster, “a person's internal sense of being male, female, some combination of male and female, or neither male nor female” was used to separate participants into three categories: male, female, and gender non-conforming. Answers from “Nonbinary” and “None of the Above” were combined into the umbrella category of “Gender Non-Conforming”.

For the level of economic stress, participants answered this prompt: “Based on your experience, what is the level of economic comfort or distress experienced in your household? (For example: Do you have extra money to spend? Are you aware of what you purchase? Do you think about money or discuss it often?) Please elaborate here:”. After collecting data, responses were categorized into one of three categories: Distressed, where the participant’s family needs financial aid and worries about finances; Comfortable, where the participant’s family is aware of money but is not too worried; and U-Stress, or “good stress”, where the participant is not worried about financial state at all and reports having excess wealth.

2.3 Interest in STEM Questions

In the Interest in STEM section, participants answered prompts and questions about their ranking for interest in STEM, and what fields (STEM and non-STEM) that they desired to pursue.

STEM is the acronym for the multidisciplinary field of Science, Technology, Engineering, and Mathematics. Science is defined as the treatment or application of natural sciences, including physics, chemistry, and biology, and social and behavioral sciences – psychology, economics, sociology, and political science. Some examples of careers in science would include: neurosurgeon, psychologist, and astrophysicist. Technology includes computer and information sciences that involve the creation and operation of devices by a system of people and organizations and knowledge, and some careers in technology would include computer programmer and database management. The field of engineering involves designing and creating products and processes for problem-solving. Some careers in engineering are mechanical engineers, electrical engineers, and chemical engineers. Lastly, mathematics involves the theoretical and applied study of patterns and relationships among quantities, numbers, and shapes. Fields of study that are under the umbrella of mathematics are Applied Mathematics, computational mathematics, and statistics.

Participants were asked to rank their agreement with statements pertaining to Interest in STEM: “I am interested in STEM.” and “I want to go into a STEM career.” on the Likert scale. A five-point scale was chosen so that participants could indicate the degree of agreement or disagreement while not being overly detailed. For both statements, the options were:

a) Strongly Disagree (1)
b) Disagree (2)
c) Neither Agree Nor Disagree (3)
d) Agree (4)
e) Strongly Agree (5)

Then, participants were asked to select the STEM field(s) they were interested in overall and then as a career with the options: “Science”, “Technology”, “Engineering”, “Mathematics”, and “None” with the prompts: “Which main STEM field are you interested in?” and “Which STEM field are you interested in as a career?”

Each of these questions was followed up by a short answer prompt asking them to elaborate on what fields they were interested in:

- Following overall interest: “What other fields and subfields are you interested in? For example: Medicine (Cardiology) or Performing Arts (Ballet).”
- Following career interest: “What field and subfield do you plan to go into? (If you are not sure, please input: "Undecided.")”

This information could be used in future studies to determine whether or not one demographic group is focused on a specific field compared to other fields, or whether or not there is a wide variety of interests.

3. Data and Statistical Analysis

To analyze the data, three different statistical tests were used. VassarStats was used to perform the statistical tests, and Google Sheets was used to store and organize data and create charts and graphs.

To determine whether or not there was statistically significant evidence of a difference between demographic groups in the categories of race, gender, and socioeconomic status in career and general interest, the nonparametric Kruskal-Wallis test was initially used. This test was used because of the comparison of median rankings from the Likert Scale of Strongly Disagree to Strongly Agree (1 - 5), which is ordinal data, and the data involves at least three groups per category. If there was a statistically significant result from the Kruskal-Wallis test, the nonparametric Mann-Whitney U test would be performed to go into further detail about which combination(s) of two groups have statistically significant evidence of a difference. The Mann-Whitney U Test is also nonparametric and uses ordinal data. The null hypothesis for both of these tests was that there was no statistically significant difference among or between different groups in a demographic category.

The Chi-Square Goodness of Fit Test was used to compare the distribution of respondents in groups in a category to the distribution of responses from those groups in a certain field; this test was used because the data collected (number of responses for a field) was frequency data under nominal categories. The aim of this test was to see whether or not the distribution of responses per demographic group for a certain field was the same as the distribution of the responses per demographic group in the population. The null hypothesis for this test is that the observed frequencies fit the expected pattern, while the alternative hypothesis for this test is that the observed frequencies do not fit the expected pattern.

3.1 Data Presentation

For general and career interest in STEM, the data exhibited negative skew (see Figures 1, 2). The median of the whole data set for general interest in STEM was 4, while the mode was 5. Because of this imbalance, the data set is skewed negatively. For career interest in STEM, the median of the whole data set was 4, while the mode was once again 5. Because of this distribution of the means of central tendency, the data set is also skewed negatively. From this distribution of data, one can conclude that Bay Area students are overall interested in STEM.

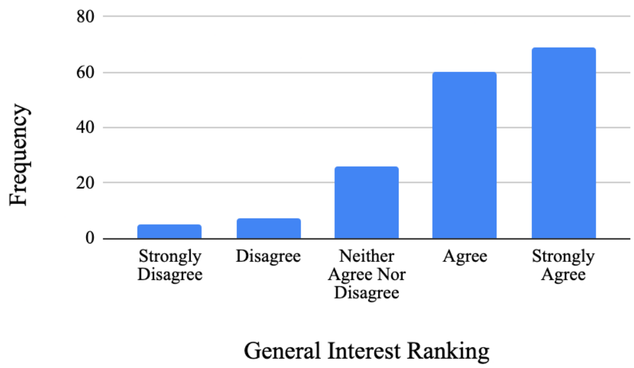


Figure 1. General Interest in STEM Ranking Frequency

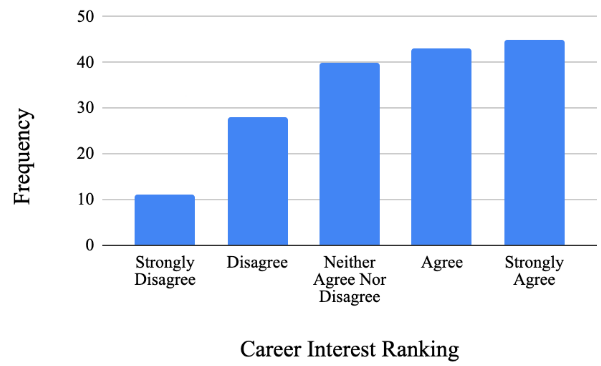


Figure 2. General Interest in STEM Ranking Frequency

For specific subject interest, Science was the subject that had the highest frequency of responses, while Math, on the other hand, received the least number of responses (see Figures 3, 4).

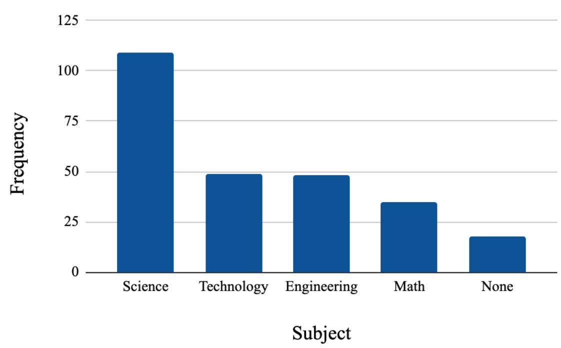


Figure 3. General Subject Interest in STEM

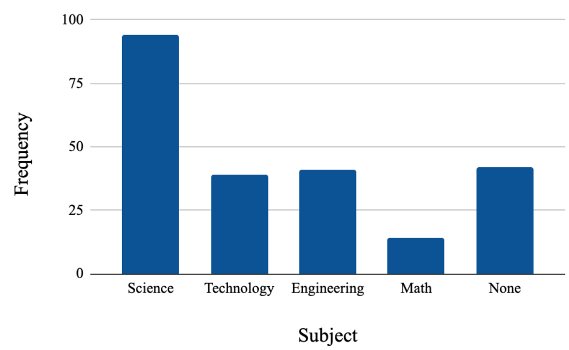


Figure 4. Career Subject Interest in STEM

3.2 Kruskal-Wallis

If the P-value is less than 0.05, the null hypothesis is rejected, and there is statistically significant evidence of a difference among at least one category's median rankings from another. If the P-value is less than 0.01, the null hypothesis is rejected once again and there is statistically highly significant evidence of a difference among at least one category's median rankings from another. Degrees of freedom were found by subtracting the number of samples by one. However, if the test fails to find a statistically significant result, then no conclusions can be drawn from the data.

Overall, the median for general and career interest for the whole sample is 4, and the mode is 5. These results indicate a heightened interest in STEM among Bay Area students, which aligns with the general belief that Bay Area students are interested in STEM.

Only one statistically significant result was found in General Interest. Both race ($P = 0.1157$) and socioeconomic status ($P = 0.2478$) failed to produce a statistically significant result, which means that there is a possibility that in each demographic category, demographic groups have the same median interest. However, gender's result, ($P = 0.0374$, $P < 0.05$) indicates that there is statistically significant evidence of a difference between at least one of the categories from the other categories, showing an inequality in interest. Because of this result, relationships among gender categories will be tested with the Mann-Whitney U Test to see which genders differ from each other in interest.

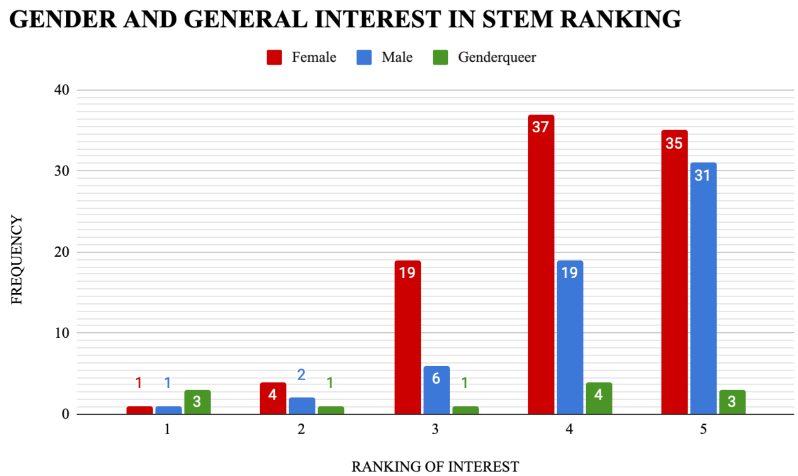


Figure 5. Bar Graph - (General) Gender Frequency (Y) of Ranking (X)

Unlike General Interest, only one statistically insignificant result and two statistically significant results were found in Career Interest. The statistically insignificant result was found in socioeconomic status once again ($P = 0.2739$, $P > 0.05$). From both general and career interest, one can infer that socioeconomic status may not have as much of an impact on STEM interest as other demographic categories. However, race ($P = 0.0135$) and gender ($P = 0.0223$) both resulted in statistically significant results, which means that there are still inequalities in interest in these respective categories. In the future, these categories may still have underrepresented and overrepresented groups. To find out which groups have greater or less interest than others, further testing into career interest between groups in their respective categories would be conducted with the Mann-Whitney U Test.

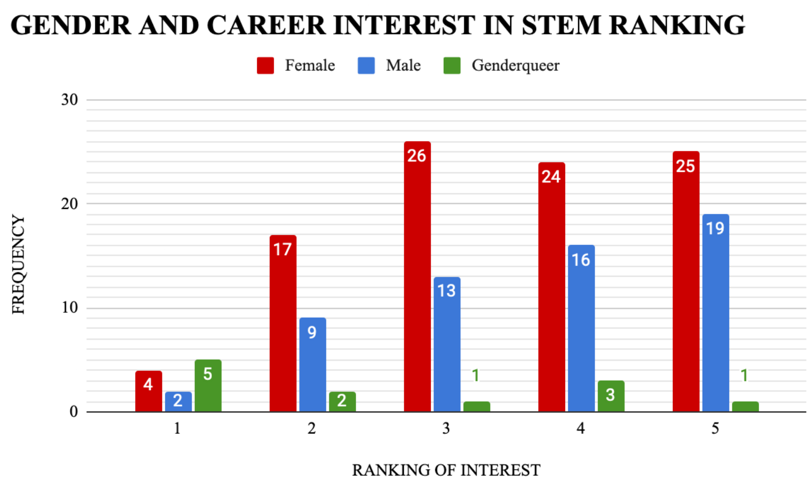


Figure 6. Bar Graph - (Career) Gender Frequency (Y) of Ranking (X)

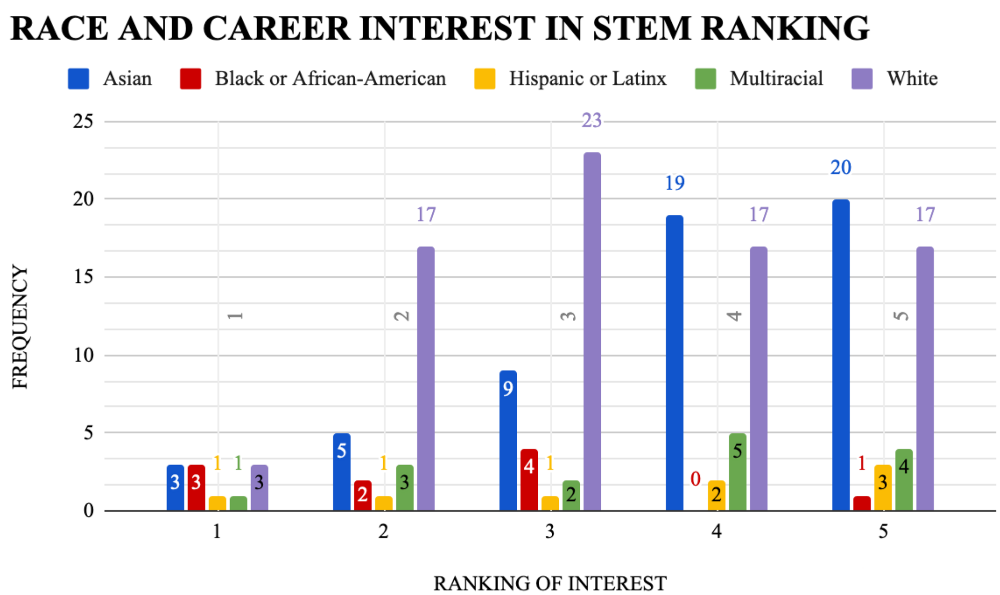


Figure 7. Bar Graph – (Career) Race Frequency (Y) of Ranking (X)

3.3 Mann-Whitney U

Similar to the Kruskal-Wallis, the P-value is less than 0.05, the null hypothesis is rejected, and there is statistically significant evidence of a difference between the median rankings of the two groups compared. If the P-value is less than 0.01, the null hypothesis is rejected once again and there is statistically highly significant evidence of a difference between the median rankings of the two groups compared.

Because the demographic category of gender was the only one that showed a statistically significant result for general interest, further testing was conducted among the different groups. Only one statistically significant result came from the comparison of the different groups - male and genderqueer ($P = 0.0324$, $P < 0.05$). Male had a median of 5 and a mode of 5, while genderqueer had a median of 4 and a mode of 4. From this statistically significant result, one can conclude that men have a higher interest in STEM than genderqueer people in general interest in STEM. The other two comparisons, female and male, and female and genderqueer, returned results that were not statistically significant, which means that there is a possibility that the groups compared in these two comparisons are more equally interested in STEM. Female and male not having a statistically significant difference could mean that the gender gap in Interest in STEM is decreasing, which would lead towards a more diverse and representative workforce to increase accessibility and decrease bias of products.

For career interest in STEM, race and gender had statistically significant results in the Kruskal-Wallis test, so further testing with the Mann-Whitney U test was conducted. For race, the comparisons that resulted in a statistically significant or statistically highly significant result were Asian & Black ($P = 0.0027$, statistically highly significant), Asian & White ($P = 0.0143$, statistically significant), and Black & White ($P = 0.0308$, statistically significant). Asian had a median interest of 4 and a mode of 5, Black had a median of 2.5 and a mode of 3, and White had a median of 3 and a mode of 3. These results suggest that Asians have higher interest than White people and Black people. In the future of the Bay Area, Asian people may be overrepresented in the STEM field, while White people may see a decline in representation, and Black people in the future may remain underrepresented. However, with other comparisons between minorities, there is no statistically significant evidence of a difference.

For career interest in gender, female & genderqueer (P = 0.0164) and male & genderqueer (P = 0.008) showed statistically significant and statistically highly significant results, respectively. Female had a median of 4 and a mode of 3, male had a median of 4 and a mode of 5, and genderqueer had a median of 2 and a mode of 1. These results suggest that genderqueer people are less interested in the STEM field than both women and men, which could be due to societal discrimination due to their gender identity. However, it was interesting to note that female and male did not have a statistically significant result, which could possibly suggest that women are more empowered to pursue STEM in the Bay Area compared to historically being underrepresented in the STEM field. This empowerment could be attributed to movements targeting girls such as Women in STEM and Girls Can Code and also the growing feminist movement. In the Bay Area, women and men may see more equal representation, while genderqueer people may still remain underrepresented.

3.4 Chi-Square Goodness of Fit

The null hypothesis for this test is that the observed frequencies fit the expected pattern, which in this case, is that the number of people from each category interested in a field is proportional to the percentage of the sample that they make up. The alternative hypothesis is that the observed frequencies do not fit the expected pattern.

If the chi-square value is less than the critical value, it is not statistically significant. On the other hand, if the chi-square value is above the critical value, it is statistically significant. The degrees of freedom are calculated by tallying the number of categories being compared and subtracting that number by one, and the number will be consistent for each demographic category throughout all of the remaining tests.

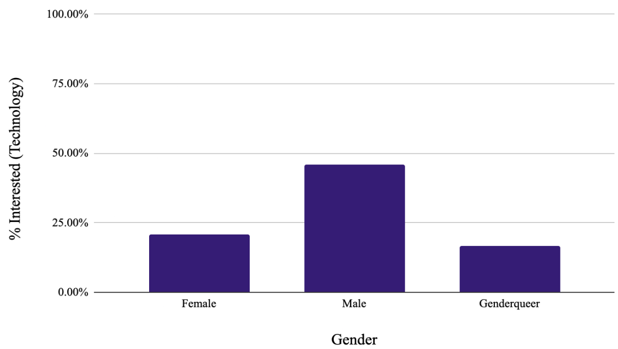
Each category - general and career interest - has four subcategories - Science, Technology, Engineering, and Math - which are tested to see whether or not the observed frequencies fit the expected pattern. If the observed frequencies do not fit the expected pattern, then one can determine whether a group is underrepresented or overrepresented in a field.

3.4.1 General Interest

For general interest in science, race (P = 0.6681), gender (P = 0.1231), and economic stress (P = 0.7945) all had statistically insignificant results, and this outcome could indicate that interest is growing among previously underrepresented minorities.

In the category of technology, only gender (P = 0.0146, P < 0.05) returned a statistically significant result, with race (P = 0.4156) and economic stress (P = 0.956) being statistically insignificant. Looking at the frequencies (see Figure 5), percentages of female and genderqueer responses that are interested in technology are much lesser than the percentage of men. This could mean that women and genderqueer people are underrepresented in their interest in

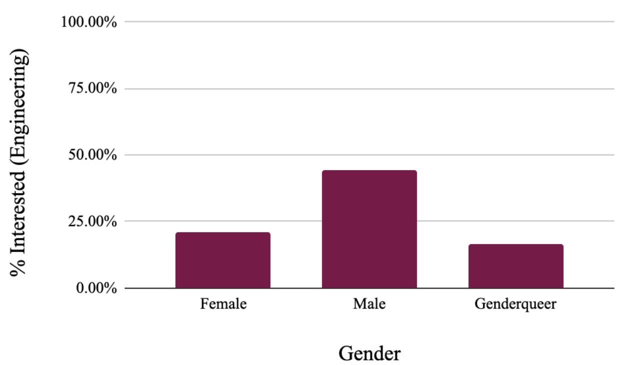
Figure 8. % of Gender Generally Interested in Technology



technology and that this specific field could still see underrepresentation of women and genderqueer people. However, other minorities in demographic categories have roughly similar interest in these fields, and this could positively influence the technological field by including more diverse perspectives from different racial and economic backgrounds to make technology fairer and more accessible.

In the field of engineering, race (P = 0.7468) and economic stress (P = 0.6667) did not return statistically significant results, while gender (P = 0.0233) was found to be statistically significant. Upon further inspection, there is a much smaller percentage of women and genderqueer people that are interested in engineering compared to men (see Figures 6, 9). Similar to technology, this could mean that women and gender non-conforming people are still underrepresented in their interest in engineering in the Bay Area.

Figure 9. % of Gender Generally Interested in Engineering

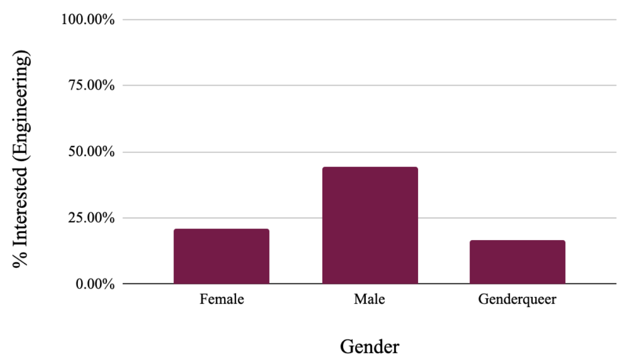


For mathematics, all demographic categories - race (P = 0.3355), gender (P = 0.1374), and economic stress (P = 0.6408) - are not statistically significant. Looking at the small percentages of interest in all demographic groups, most people are not interested in math as a subject. Overall, this area may need improvement to increase interest. However, everyone has a roughly similar level of interest in math.

3.4.2 Career Interest

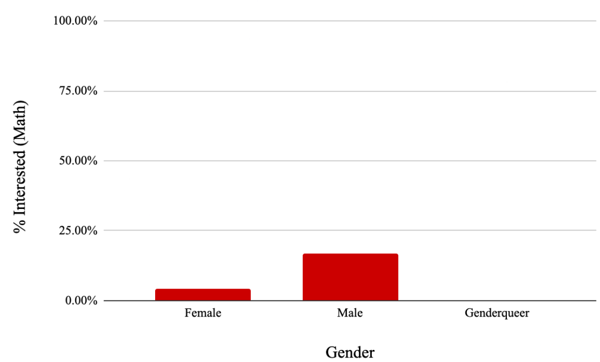
Firstly, for career interest in science, no demographic category resulted in a statistically significant result - race (P = 0.4917), gender (P = 0.2794), and economic stress (P = 0.9802). Similar to the results for general interest, this roughly similar level of interest in each demographic category could indicate the growth of career interest in minorities which are traditionally underrepresented in science. Because of this growth, the workforce of the future could see a more diverse and representative population in this field.

Figure 10. % of Gender Interested in Engineering Career



For career interest in technology, race (P = 0.1882) and economic stress (P = 0.5571) had statistically insignificant results, while gender (P = 0.0193, $P < 0.05$) was statistically significant. Similar to general interest, racial minorities and people who are stressed financially are indicating a higher interest in technology than shown in national studies. Examining gender by looking at the frequencies of each gender category, the percentage of women and genderqueer people interested in technology once again fall short of the percentage of men (see Figure 7). Because of this gap of interest in career, this could mean that women and genderqueer people will still continue to be underrepresented in the field in the Bay Area, while men will continue to dominate the technology field.

Figure 11. % of Gender Interested in Math Career



When comparing career interest in engineering, none of the demographic categories - race (P = 0.5026), gender (P = 0.1033), and economic stress (P = 0.5194) - exhibited statistically significant results due to having less differences among percentages (see Figure 10). Thus, none of the categories showed statistically significant results, which differs from general interest, where gender showed a statistically significant difference. Even though initially, there were statistically significant results for general interest in engineering, the lack of statistical significance in this result could mean that people who are interested in a subject are not necessarily interested in pursuing that subject as a career. Also, the lack of statistical significance could indicate a growth in career interest in engineering, which would lead to less inequality in the engineering field.

For the last subject category of math, race (P = 0.8731) and economic stress (P = 0.2865) were not statistically significant, but gender (P = 0.0167, $P < 0.05$) was statistically significant, with men having the highest proportion of interest (see Figure 11). This statistical significance could indicate that even though it could not be determined whether or not women, men, or genderqueer people had a disproportionate general interest in math, a smaller percentage of women and genderqueer people, compared to a larger percentage of men, are interested in pursuing mathematics as a career (see Figure 8). Because of the inconsistency between general and career interest, it is also safe to assume that what a student is interested in is not necessarily their desired career pursuit.

4. Conclusions

Even though Bay Area high school students display an interest in STEM, this project has found that there are still differences in interest in STEM between minorities. In general interest for the overall STEM field, tests found that demographic categories in gender exhibited a statistically significant difference, namely men and genderqueer students. However, when testing for career interest, race and gender were both found to have statistically significant differences among their respective categories. In race, Asian and White people had a higher interest than Black people, and Asians had a higher interest than White people.

When examining the distribution of responses for specific subjects, for both general and career interest, only gender had a statistically significant result. For general interest, the chi-square goodness of fit test returned a statistically significant result for technology and engineering. For career interest, the test resulted in statistically significant results for technology and math. Women and Gender Non-Conforming people are still falling behind in interest compared to men.

What was also interesting to note was the lack of statistical significance in other categories, such as between women and men in both general and career interest in STEM, specific subject interest for race, all types of interest for economic stress, and the lack of statistical significance for the category of science.

Therefore, even though there are still inequalities in interest in STEM present in Bay Area high school students, demographic groups that had statistically significant relationships in previous studies were not statistically significant in this study. The lack of statistical significance could indicate that previously underrepresented demographic groups did not have differences in interest from demographic groups that are overrepresented, which may lead to a more proportional distribution of workers from all demographic categories. Through this study, demographic areas that need more resources have been identified, and initiatives can be implemented in areas with high concentrations of these demographic groups to boost interest in STEM.

5. Future Research

Future investigations could include looking into a specific demographic, such as race or gender, and probing into more of the factors that result in the statistically significant differences among demographics such as race and gender, such as previous exposure to STEM or family members in STEM. Also, because two forms were used to separate the data into Bay Area independent schools and other schools outside of that organization, further research can be conducted using only the data gathered from one specific survey. Another idea for further investigation is the redistribution of this survey after a certain period of time to determine whether or not the proportion of interest according to demographic categories has changed over time. Further statistical analysis could be run comparing the two times.

If this project is performed again, more time would be allotted for data collection and analysis. The priority for data collection would be obtaining a more representative sample, especially since some categories in demographics, such as American Indian or Alaska Native and Native Hawaiian or Pacific Islander in race had to be removed due to no responses in those groups. Also, some groups received little responses compared to other groups. One notable example is the category of Economically Distressed, which received only seventeen responses, compared to Economically Comfortable, which received 113 responses. More diversity could be achieved by reaching out to people in groups who originally did not have many, or any, responses. Additionally, the data for general and career interest in STEM as a whole was negatively skewed, and a larger and more representative sample could make the distribution less skewed.

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Biography

Nicole Serrano is a current full-time student at The College Preparatory School and a single-course student at Stanford Online High School. She is currently a member of Mensa International, the high-IQ society, and Johns Hopkins' Center for Talented Youth. At her school, Nicole is a member of the Science Olympiad team. Nicole is also passionate about social justice, and she wants to work towards solving inequalities in the STEM field. She is also involved in the active improvement of her community, volunteering at shelters such as St. Vincent de Paul and food banks, as well as helping to solve problems all over the globe, from volunteering at orphanages in the Philippines to tutoring students in lower-income communities in India. In the future, Nicole plans to go into the biomedical field, as she is interested in both research and medical practice.