

Redefining the Engineer:  
An Examination on Engineering Culture and  
the Impact on Underrepresented Students at  
Cal Poly

Danica Liang

Liberal Arts & Engineering Studies

Spring 2019 Senior Project

# Introduction

Diversity and inclusion as it pertains to the field of engineering has been a popular topic of discussion and research. However, despite the huge interest that this topic garners, a lot of the work goes into answering the question, “How do we get more women into engineering?”

There are two main things that are wrong with this question. The first concern I have with this question is its emphasis is on women. While closing the gender gap in engineering is important, there are other underrepresented groups that are often overlooked in favor of a “diversity” that only consists of women. Another prominent underrepresented group is people of color. In my research question and findings, I will be addressing both women and people of color.

Secondly, in asking this question, the end goal is to increase the number of women. However, the lack of diversity in engineering stems a lot deeper than simply numbers. Increasing the number of underrepresented groups in engineering alone will not solve this problem. For example, this question fails to account for retention. If more women enter engineering, but they are less likely to stay in engineering, then the increase in women entering engineering is not very impactful. A question - although framed to encourage diversity measures - does not end up being helpful towards cultivating diversity. Instead, we need to tackle the factors that affect the numbers, such as culture.

From personal experience, there is something that uniquely distinguishes engineering culture from other fields - one that is not written about enough and for this reason, it is a topic that I hope to tackle. I’d like to look at how engineering culture may affect the experiences of underrepresented groups in the field. Looking at this from an ethnic studies perspective, analyzing the culture of engineering is critical to understanding the diversity problem of engineering. The lack of diversity in engineering is not a new problem, and for this problem to persist over time implies that there is something systematically wrong.

Some may argue that these disparities result from the “pipeline problem,” the argument that industries are not diverse due to the lack of available talent to hire. After releasing their a dismal diversity report in 2016 - black and Hispanic people only make up 2% and 4% of their workplace, respectively) - the company’s head of diversity explained these numbers with the following statement, “Appropriate representation in technology or any other industry will depend upon more people having the opportunity to gain necessary skills through the public education system.” In other words, she blames the pipeline problem. However, there is evidence otherwise.

According to USA Today in an article published in 2014, tech companies report a 2-3% make-up of black and Hispanic employees, yet graduation numbers show that there are twice that percentage of black and Hispanic students graduating from computer science programs. The problem is not that there isn't enough talent.

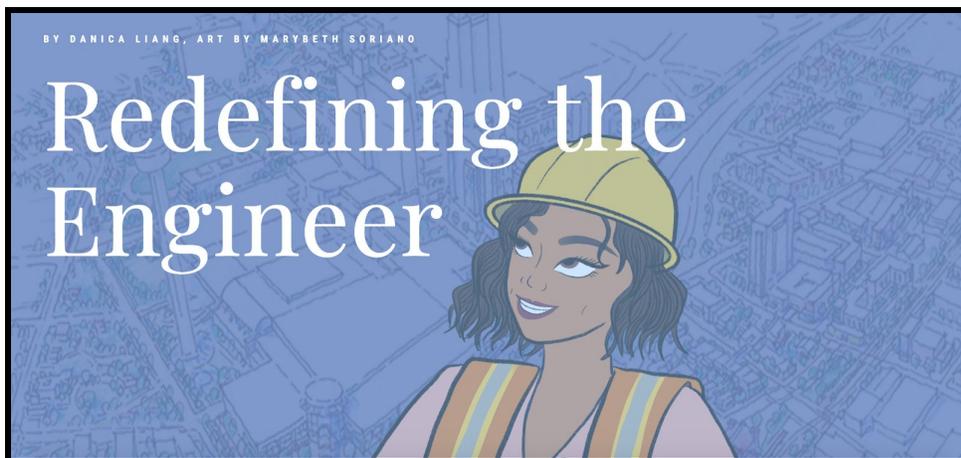
And yet, the numbers do not reflect this. I suggest that there is something wrong with the system, a culture of rigor and objectivity, that inhibits certain groups, such as women and people of color, from achieving the same levels of success that we see of other groups. This is the topic I have chosen to examine.

## Application/Product

I have written various stories that ultimately reflect the personal narratives of several individuals who identify as engineering students from underrepresented backgrounds. Interweaved with these stories are some interesting findings from a survey I conducted. In this initial survey, I gathered information on the existing culture that makes up Cal Poly's College of Engineering, as told by the students. Combining both storytelling and data, both serve to complement one another in showcasing the underrepresented student experience, as well as rewriting the narrative of who an engineering student is.

This content is displayed on a [website](#) and ultimately serve the purpose of informing the CENG community of stories that have not been publicly told before. By reading through my article and looking at the different data visualizations, users can use my work to inform themselves on a topic related to diversity and inclusion in higher education engineering, and to reconsider the different experiences that higher education engineering culture may produce.

Shown below, I have included a screenshot of my website:



Source: [danicaliangu.com/senior-project](https://danicaliangu.com/senior-project)

# Background

My senior project focused on exploring the impact of higher education engineering culture on underrepresented students. I wanted to answer the following question: Does Cal Poly's engineering culture result in contrasting academic experiences for underrepresented engineering students, in comparison to overrepresented engineering students? In looking at this question, I wanted to challenge the "objective" nature of engineering and see if the culture offers any insight into the lack of women and people of color in engineering. I also hoped to offer different narratives about the students who make up engineering and to defy engineering stereotypes and defy any preconceived notions of what makes up the "average engineering student."

First, I created a survey open to all engineering students, built to analyze Cal Poly's engineering environment and get a general sense of Cal Poly's engineering culture, as told by the student population. Although I know it would be unrealistic to garner responses that truly reflected the engineering student body, I made efforts to diversify the demographics that made up the people who responded to my survey. I scheduled classroom visits with professors all across different engineering majors, emailed department newsletters, and advertised my survey to various engineering groups on campus.

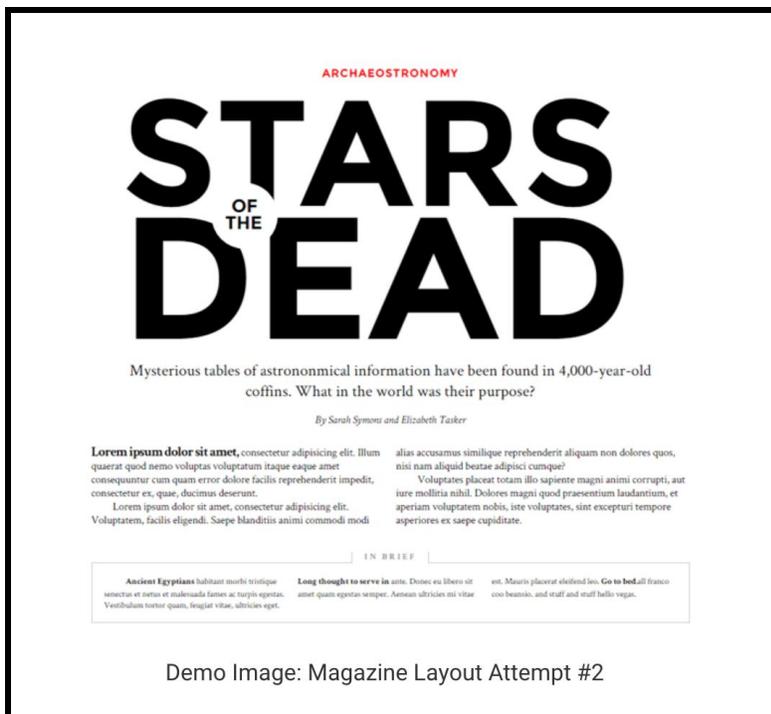
Next, I needed to find a handful of individuals who would be interested in sharing their story with me. To target underrepresented students, I reached out to groups that served these communities such as Multicultural Engineering Program (MEP) and TRIO Services. I successfully completed six interviews in which I asked questions such as how they got into engineering, their classroom experiences, and their sense of belonging.

Once I had my survey results and had finished interviewing and transcribing, I looked at both data sources to find overlap in themes. Focusing on these themes and choosing only a few individuals from the six I interviewed, I constructed a story centering these individuals. I put these stories on a website I developed primarily using basic web development (HTML, CSS, JavaScript) and chose a few data visualizations that touched on the themes discussed in the stories, as well as ones that had compelling results.

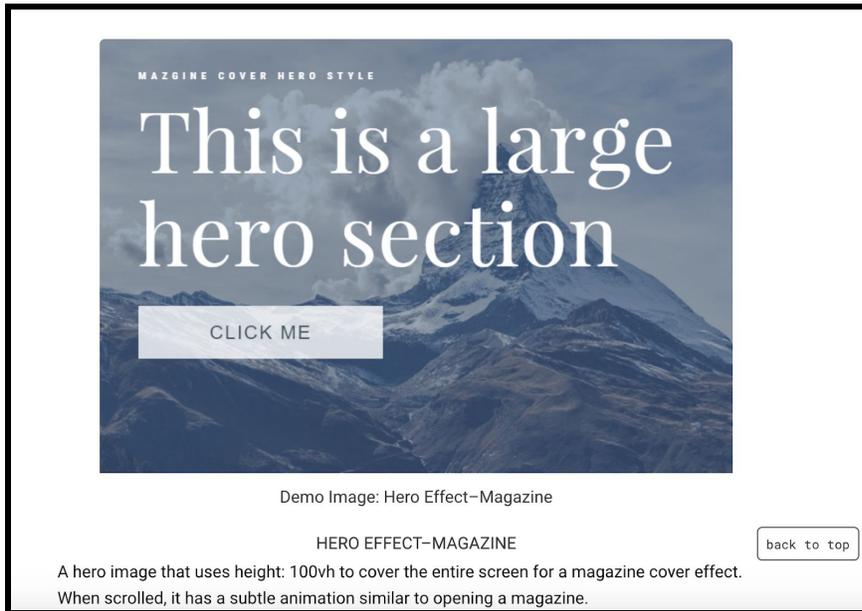
# Design

## Organization

The website in which I published my story navigates like most other websites set up for writing, such as Medium. However, by creating my own website, I was able to customize it to fit my senior project and generally have more ownership over the user experience. Below, I have included some website templates I found online that I considered using. I ended up choosing the second one.



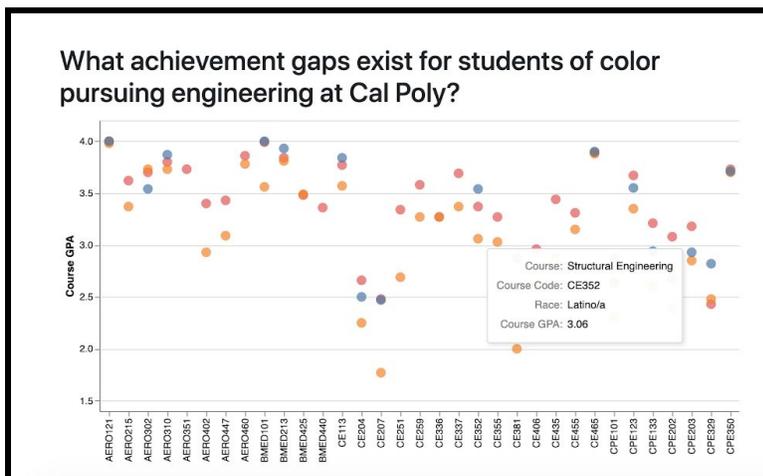
Source: <https://freefrontend.com/css-magazine-layouts/>



Source: <https://freefrontend.com/css-magazine-layouts/>

## User Requirements

On my website, users are able to navigate by scrolling down a layout of text intertwined with data visualization pieces and other photos and graphics that the user can also choose to look at. Some of these data visualizations are interactive, allowing the user to hover over elements of the graph and dive deeper into the data. Below, I have included an example of an interactive data visualization on my website:



When the user hovers their cursor over one of the dots on this graph related to achievement gaps between students of color and other students, they are able to see all of the related data (specific course, course code, race, and course GPA) pertaining to that data point.

## Implementation

### Data Gathering and Analysis

In the data gathering and analysis process, I came up with a survey and interview questions. I submitted paperwork to the Cal Poly Institutional Research Board (IRB) for approval. When the paperwork was approved, I released my survey to the engineering student body by advertising it to various clubs, groups, and professors/classes. During this time, I also submitted additional IRB paperwork to get my interview questions approved. Once they were approved, I sought out individuals who were interested in sharing their story. I reached out to groups on campus that supported underrepresented students to advertise about this opportunity. I conducted interviews and then I transcribed them. When I had finished getting results for my survey and transcribing my interview content, I compared the two sources of data and looked for observations and parallels between the two. Based on these observations, I created data visualizations using Python.

### Journalism

As for the storytelling aspect, I used an online template to create a layout for the article. I then used the data collected and the interview results to write a story. I completed an initial rough draft and had peers proofread my draft. After several drafts and revisions, I made final edits to the draft and put up the content on the website.

### Analysis/Verification

In evaluating the success and value of my project, I got direct feedback from peers and faculty advisors on the data gathering and analysis process. I met up regularly with my advisors and referred to classmates and professors in the Statistics Department to ensure that I was creating effective and accurate data visualizations.

Furthermore, before finalizing the content on my website, I conducted usability tests on the functionality of my data visualizations, storytelling, as well as the user experience in navigating the website. I received valuable feedback that helped guide the direction of my website content and layout. For example, one of the responses I got was that the stories felt disjointed when I

included artwork and quotes related to a different interviewee than the one that the story focused on. With this, I was trying to draw parallels between things said amongst my interviewees. However, I did not recognize that this interfered with the storytelling. To fix this, I switched the ordering of the content which significantly improved the flow of the story.

## Interdisciplinary Connections

In tackling the diversity problems that make up engineering education through a creative and technical lens, my interdisciplinary project combines areas in both liberal arts and engineering.

### Liberal Arts Connection

Through my project, I am able to utilize my ethnic studies concentration to critically analyze the experience of minority students in engineering and how systemic inequalities may produce contrasting experiences for these students, in comparison to other students. Furthermore, I use storytelling to showcase these narratives and notable observations I find from my data. In employing the art of storytelling, I have drawn from my writing-intensive coursework to create something that is compelling for the reader. I have also used storytelling as a mode to deconstruct the ways in which we absorb data. In an ethnic studies lens, this is my way of questioning how we normally see charts, graphs, data, numbers and offering a different approach to challenge our associations with these features and to highlight a nontraditional way of looking at data. This further alludes to the content of the project. In learning more about the different experiences of women and students of color in engineering, the work of my senior project defies existing stereotypes or preconceived ideas about engineering and attempts to rewrite these narratives.

### Engineering Connection

My project employs a lot of what I've learned in my engineering coursework. In developing a website to display my project, I had to ensure that the user interface and user experience of the website is friendly, accessible, and easy to use. I also used the technical skills I learned in my data science class to analyze data and create meaningful data visualizations using the survey results. In doing so, I gained experience using different data visualization frameworks in Python such as Pandas, Matplotlib, Pygal, and eventually settled on using a combination of Seaborn and Altair. I also spent time on cleaning data through various approaches such as identifying invalid data and removing it, standardizing certain data responses, and changing values to make the data look more neat, and easily processed and analyzed. When I finally started creating graphs and charts, I went through a phase of data exploration to gather initial observations by creating

subsets of the original data frame I had. I created subsets based on gender, creating a data frame for all of the female responses, a separate data frame for all of the male responses, and did the same process for looking at ethnicity. I created subsets for white students, Asian students, black students, hispanic students, Indigenous students, and mixed students. This made it easier to compare and contrast the results.

## Related Works

“Discovering Factors Affecting Student Retention in Computer Science at Cal Poly” - Diane Eykholt

A related work that focuses on a topic that is similar to mine is LAES alumna Diane Ekyholt’s senior project. When starting literature review for my senior project, I first looked for completed senior projects with similar topics about diversity in engineering, and especially engineering education. Diane Ekyholt’s senior project about the factors for student retention in the Computer Science Department at Cal Poly fit the bill perfectly. Many of the factors that she finds to be impactful for students and their retention in the department have to do with the social behavior, norms, and expectations related to the students’ academic experiences. From this, the idea of analyzing engineering culture piqued my interest. Eykholt’s use of gathering qualitative data through her survey also encouraged me to consider this data collection method as well. In spite of how similar Eykholt’s senior project is to mine, my senior project focuses specifically on culture and also focuses on all of engineering, not just computer science. Additionally, I am most interested in analyzing the effects and impact on students who are underrepresented such as women and people of color in engineering.

“How Our Engineering Environments are Killing Diversity” - Kate Heddleston

Software Engineer Kate Heddleston’s blog post about the negative impact of the engineering workplace environment on diversity measures was incredibly fascinating for me to read. I had not once considered the impact of the culture and environment before reading this post.

Heddleston asserts the importance of considering environment, and concludes that tech’s environment of unconscious biases and problematic behaviors perpetuate and create systemic inequalities that ultimately harm efforts to diversify the field. The following quote encapsulates this in an analogy to canaries in a coal mine:

“Women in tech are the canary in the coal mine. Normally when the canary in the coal mine starts dying you know the environment is toxic and you should get the hell out. Instead, the tech industry is looking at the canary, wondering why it can’t breathe, saying ‘Lean in, canary. Lean in!’ When one canary dies they get a new one because getting more canaries is how you fix the

lack of canaries, right? Except the problem is that there isn't enough oxygen in the coal mine, not that there are too few canaries.”

Heddleston puts in simpler terms that the tech industry's diversity efforts have been focused on increasing the number of women in tech, but these efforts are irrelevant when women continue to leave the field at high rates. Instead, we must look at why women leave the field - and the answer becomes more clear: there is something wrong with the environment.

I adopt this same idea into my senior project which is why I focus on analyzing engineering culture at Cal Poly. Whereas Heddleston's blog post is about diversity efforts in tech and more specifically on gender diversity, my senior project looks at all engineering at Cal Poly and looks at diversity through both gender and race. Also, my senior project is much more data-driven with my conclusions made through the results of my survey and personal interviews. Heddleston's post differs in that it draws mainly from her own personal experiences or the experiences of colleagues and friends.

## Future Work

There are many topics that can be explored in this senior project. For example, in looking at engineering culture and how it affects underrepresented groups, I focus primarily on looking at women and people of color. However, there are other underrepresented groups that are just as important to look at, such as LGBTQ+, students with disabilities, older students, and/or students from nontraditional backgrounds. In considering which underrepresented groups I would look at for my project, I chose to focus on women and people of color because due to my personal experiences at Cal Poly, my extracurricular involvement in diversity initiatives across campus, and my ethnics studies coursework, I felt that I was most knowledgeable in this domain. Given more time, research, and resources, I would have liked to also examine these other minority groups within engineering to see if there are any notable observations or conclusions I can find to ultimately offer additional meaningful ways to diversify engineering.

Another limitation is that my survey and interviews are not representative of the CENG student body and I can also see how my personal biases affected my survey and interviews. Although my survey garnered a lot of responses (200+), this is still a pretty small number compared to the number of students who are in the college, which is approximately 6000. I also noticed some tell-tale signs that further lead me to believe that my project does not represent CENG. I observed 60% of my survey responses are from students who identify as women, but in looking at Cal Poly institutional research, only approximately 25.8% of CENG is made up of women. As for my interviews, due to limitations in time and resources, I only advertised the interviews to a small subset of student clubs and groups on campus and also reached out to students in my

personal network. In future work, I would like to reach out to more students and groups on campus in the hopes of getting results that more accurately reflect the CENG study body.

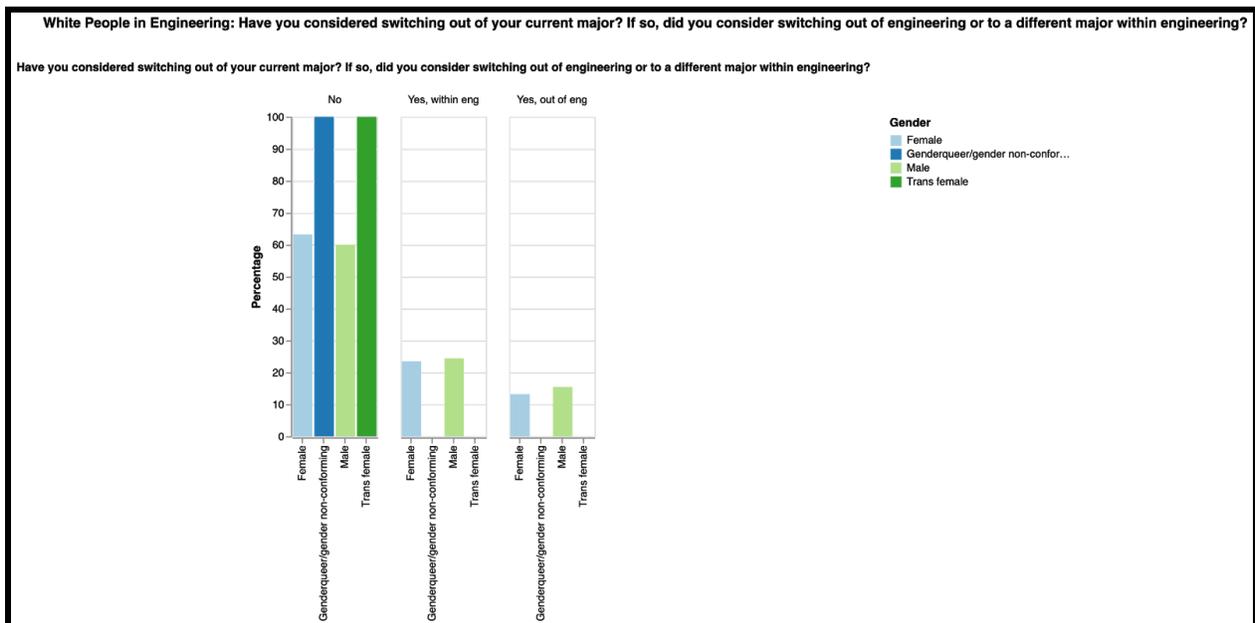
## Conclusion

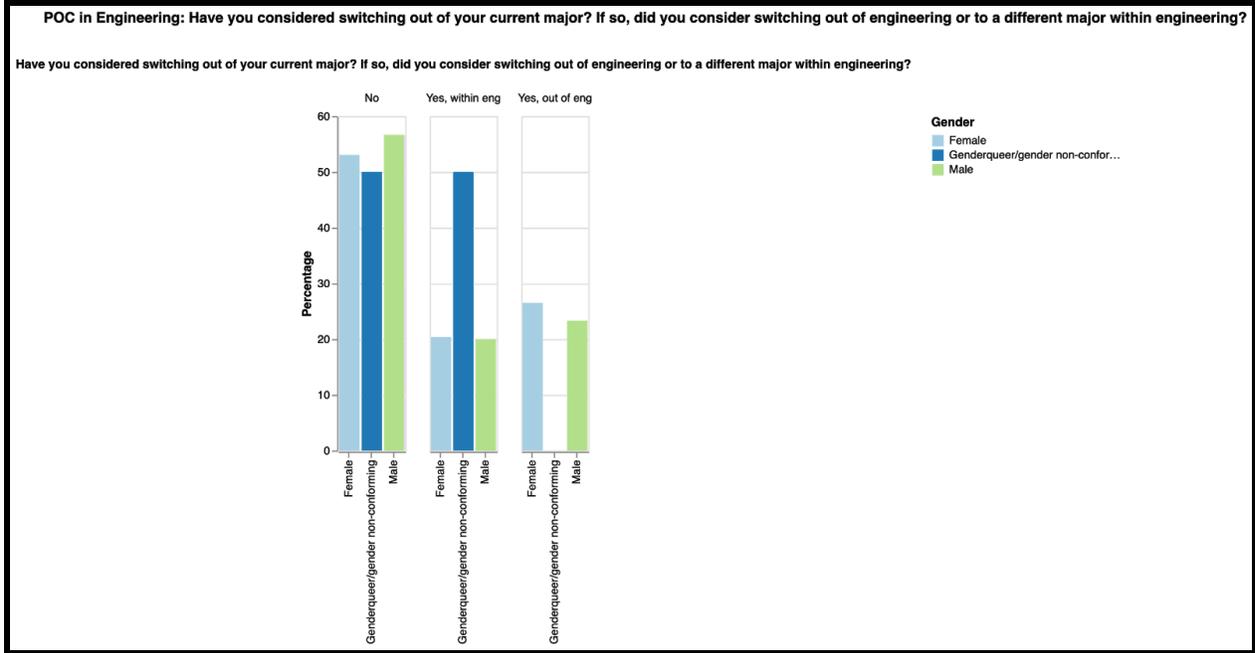
### Findings

From my interviews with the six underrepresented students in engineering, I was able to find these common themes:

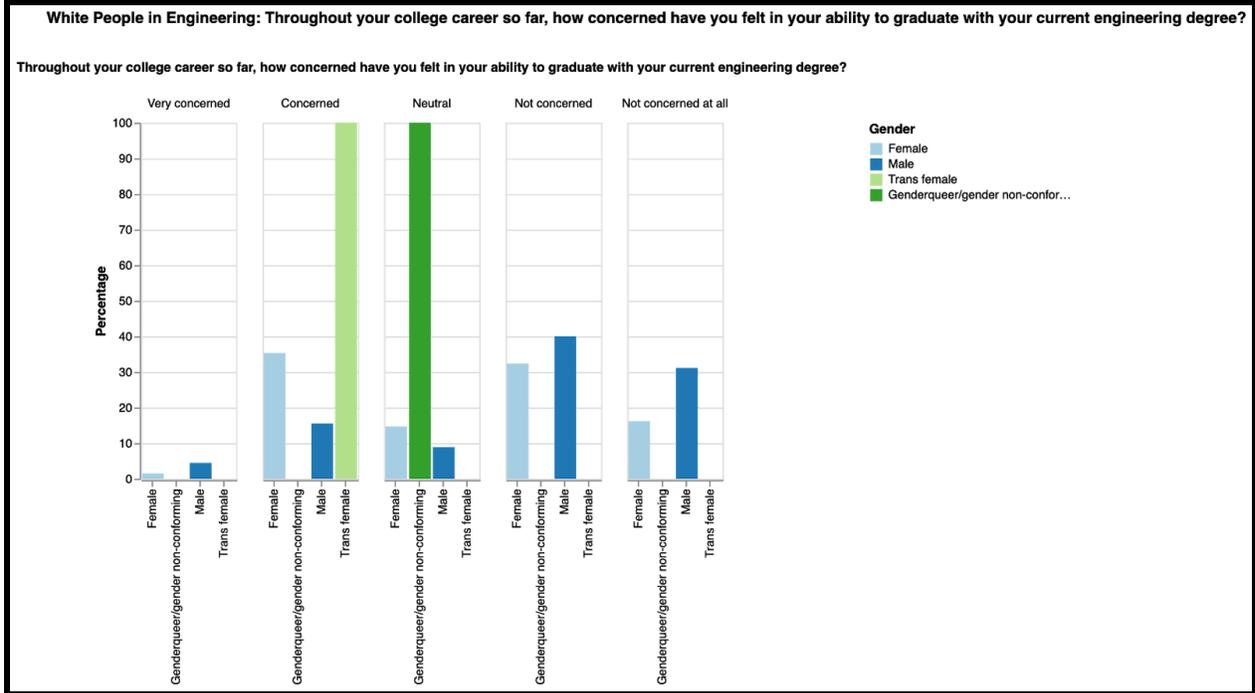
- Introduction to engineering through family members (direct visibility)
- Consistent feelings of academic incompetence
- Negative mindset is common when feeling discouraged, but this makes it harder to improve one’s academic performance
- Collaboration with peers is key to succeeding academically
- It is difficult to find relatable peers
- Academic performance and relationship with peers affect one’s sense of belonging
- Engineering education does not feel student-focused
- Heavy workload affects personal life and mental health

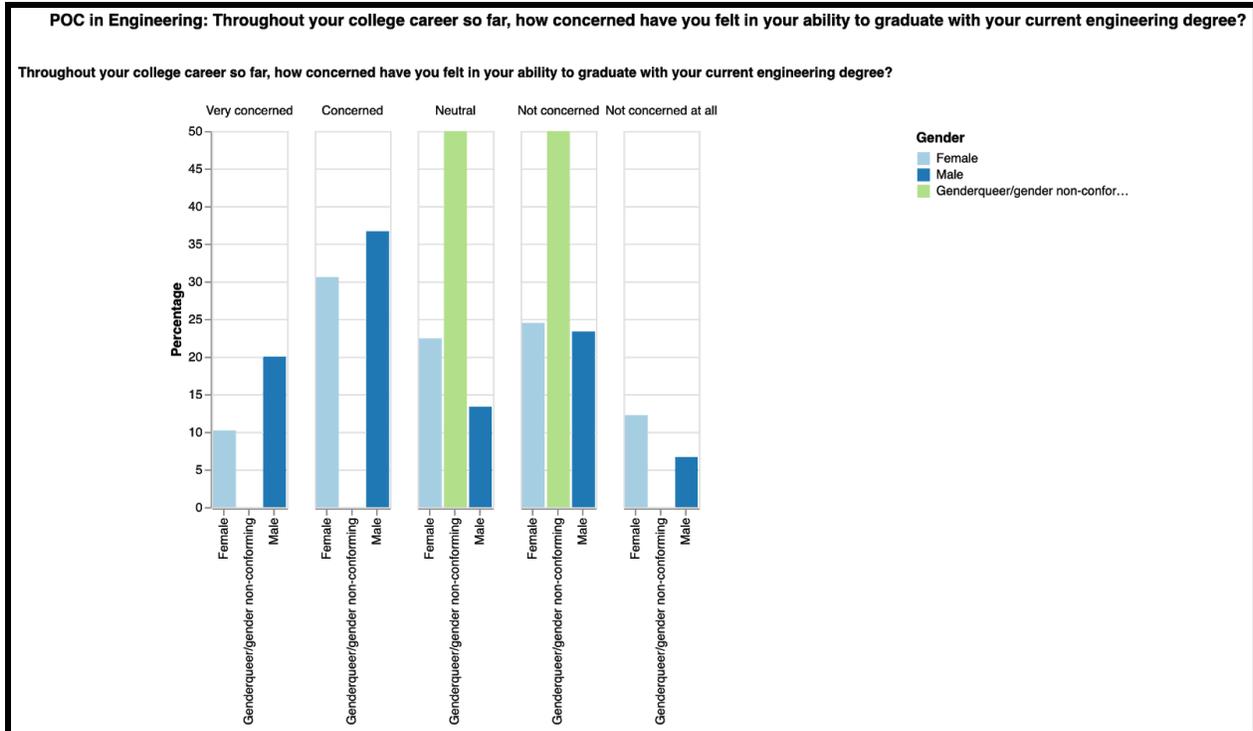
In terms of meaningful data visualizations, I found the following to be insightful observations:





Comparing white students with students of color, we can see that the rates in which students of color have considered switching majors are much higher.





The rate at which white men have felt concerned about graduating in their major is significantly less than if we look at people of color in engineering.

Surprisingly, I felt like I found a lot more notable observations when filtering through race and gender, as simply opposed to gender - which I understand to be the more common kind of research when looking at gaps in diversity within engineering. From my findings, I am able to conclude that underrepresented students in engineering have different experiences, as compared to students who identify as the majority (primarily white and Asian men). Something that is interesting to note is that depending on the question asked, it seemed that Asian men would skew more in similarity towards white men or people of color and it's important to recognize that while Asian men are overrepresented in engineering, they are still in some ways - a minority - especially on the Cal Poly campus.

I believe I have contributed sufficiently to my senior project, in meeting my initial development goals. My initial development goals were a bit ambitious - a research project, a data visualization project, and a journalism project, all encompassed in one. Although I had hoped to do more background research on the history of engineering education, I was successful in creating a research project that was approved by the Cal Poly Institutional Research Board (IRB), and gathered valuable research through survey collection and conducting interviews. As for data visualization, I had aspired to integrate machine learning into my data visualizations by creating prediction models or implement clustering to group similar observations. While I did not get to this point due to restraints in time, I was able to create simpler but very useful data visualizations

that make meaning out of data. In terms of the journalism and storytelling aspect of my project, I successfully crafted a story that I believe to be engaging and creative. Given my time constraint, I did not have as many people to look over my writing as I initially wanted, so I could have spent more time on it perfecting it, but what I have meets my initial development goals.

I believe that my work is an effective solution for my problem which is to answer this question: Does Cal Poly's engineering culture result in contrasting academic experiences for underrepresented engineering students, in comparison to overrepresented engineering students? In looking at the data from my survey alongside with the stories that my interviewees shared with me, we can compare and contrast the overrepresented student experience with the underrepresented student experience, and see if there are any normalized practices within engineering culture that result in these consequences. Furthermore, my senior project has been able to amplify the voices of minority students in engineering to offer different narratives and ultimately defies the said experience of the "average engineering student."

## Cited Sources

O'Connor, Clare. "Facebook's 'Pipeline' Excuse: Black Women In Tech Speak Out On

Diversity Failure." *Forbes*, Forbes Magazine, 20 July 2016,

[www.forbes.com/sites/clareoconnor/2016/07/18/facebooks-pipeline-excuse-black-women-in-tech-speak-out-on-diversity-failure/#1c9dfb2b21d4](http://www.forbes.com/sites/clareoconnor/2016/07/18/facebooks-pipeline-excuse-black-women-in-tech-speak-out-on-diversity-failure/#1c9dfb2b21d4).

Weise, Elizabeth, and Jessica Guynn. "Tech Jobs: Minorities Have Degrees, but Don't Get

Hired." *USA Today*, Gannett Satellite Information Network, 13 Oct. 2014,

[www.usatoday.com/story/tech/2014/10/12/silicon-valley-diversity-tech-hiring-computer-science-graduates-african-american-hispanic/14684211/](http://www.usatoday.com/story/tech/2014/10/12/silicon-valley-diversity-tech-hiring-computer-science-graduates-african-american-hispanic/14684211/).