Statistical Analysis of the CAR (Confront, Address, Replace) Strategy and Its Efficacy when Applied to Master-slave Terminology

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Abstract

Paper category: Evidence-Based Practice. "Master-slave" terminology is still commonplace in engineering education and industry, however, questions have been raised about negative impacts of such language. Usage of iniquitous terminology such as"master-slave" in academia can make students—especially those who identify as women and/or Black/African-American—feel uncomfortable, potentially evoking Stereotype Threat and/or Curriculum Trauma [1], [2]. Indeed, prior research shows that students from a number of backgrounds find non-inclusive terminologies such as "master-slave" to be a major problem [1]. Currently, women-identifying and gender nonbinary students are underrepresented in the engineering industry while Black/African-American students are underrepresented in the entire higher education system, including engineering fields [3], [4].

The CAR Strategy, introduced here, stands for: 1) confront; 2) address; 3) replace and aims to provide a framework for *driving out* exclusionary terminologies in engineering education such as "master-slave." The first step is to confront the historical significance of "master-slave" terminology. The second step is to address the technical inaccuracies of "master-slave". Lastly, replace "master-slave" with an optional but recommended replacement terminology.

This study reports specifically on student perceptions and the effectiveness of The CAR Strategy piloted as a teaching framework in the computer engineering department of a Predominantly White Institution (PWI) in California. Of 64 students surveyed: 70% either agree or strongly agree that The CAR Strategy is an effective framework for driving out iniquitous terminologies such as "master-slave" in engineering education; and 67% either agree or strongly agree they would like to see all professors use The CAR Strategy when applicable in their classes.

Combining the statistical analysis with qualitative data points, we find The CAR Strategy to be an overall effective framework for *driving out* non-inclusive terminologies in engineering education. Further research is warranted on The CAR Strategy's efficacy on other potentially problematic terminologies in engineering education such as "female-male" (connectors), "blacklist-whitelist" (element selection), and "blackhat-whitehat" (hackers).

Introduction

This paper is a follow-up to our April 2020 study which confirmed "master slave" terminology may create classroom conditions to evoke Stereotype Threat [1].

Engineering enrollment rates in Bachelor's, Master's, and Doctoral programs for Black/African-American and Hispanic students are much lower than their respective demographics in the United States [3], [5]. These race and ethnicity terms were chosen for this study because they align with the categorizations on the United States census. Likewise, women-identifying engineering students account for about 25% of students in Bachelor's, Master's, and Doctoral engineering programs in the U.S. but women-identifying individuals make up 50.8% of the U.S. population [3], [5].

Although these disparity gaps have shrunk in the last 40 years, the current underrepresentation of women-identifying students as well as Black/African-American and Hispanic-identifying engineering students is still a compelling national interest in the U.S. [6]. Decreasing disparity gaps among students from underrepresented and minoritized groups who matriculate through engineering programs can lead to more economic opportunities for these students and help eradicate national concerns such as the racial wealth gap [7]. Stereotype Threat also explains why this retention gap is so large and how institutions are continuing to enable unwelcoming climates for members of historically excluded backgrounds [1].Thus, policies, programs, and pedagogy focused on intentionally eradicating underrepresentation of women and racial/ethnic minorities in American engineering education are necessary.

One key concern for increasing the number of underrepresented engineering students is the lack of a sense of belonging those students may feel while enrolled as a student. Previous research shows that a lack of strong sense of belonging in higher education is a common reason for the early withdrawal of ethnic minority students [8]. In fact, students who find few peers in their class—often underrepresented ethnic groups and women—"tend to feel much more strongly that they don't belong" [9] so a lack of community can deter underrepresented students from pursuing engineering in the first place.

The CAR Strategy is one pedagogy that intends to contribute to eradicating underrepresentation of racial/ethnic minorities in engineering. It aims to provide a framework for *driving out* non-inclusive terminologies in engineering education such as "master-slave." This paper reports specifically on student perceptions and the effectiveness of The CAR Strategy piloted as a teaching framework in the computer engineering department of a Predominantly White Institution (PWI) in California.
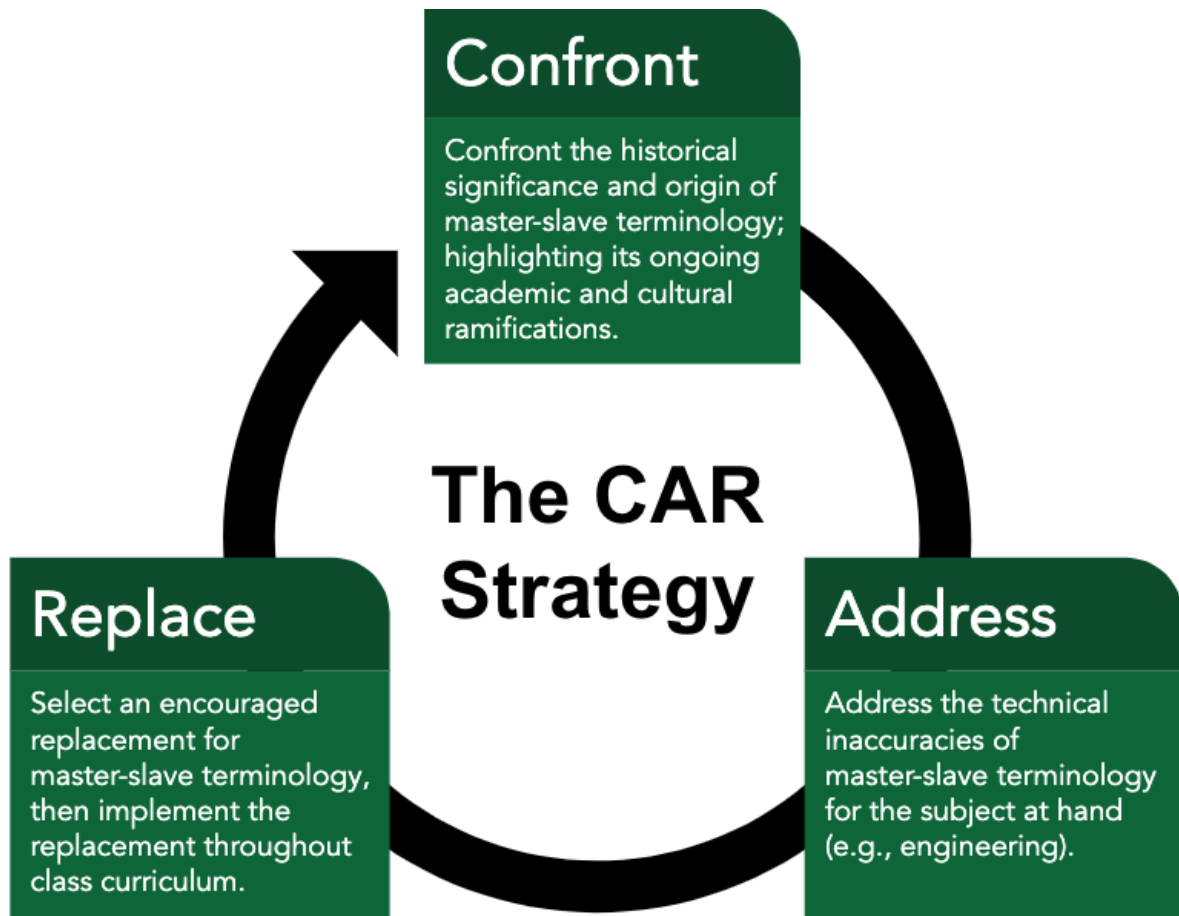
Figure 1: Visual graphic of The CAR Strategy: 1) confront; 2) address; and 3) replace.

The CAR Strategy, summarized in Fig. 1, consists of three steps and stands for: 1) confront; 2) address; 3) replace. The first step in this strategy is to confront the historical significance of "master-slave" terminology. By educating students, professors, and those in industry about the historical origins and implications of "master-slave" terminology, folks in academia and industry will better understand why the terminology may be discomforting to some [1].

The second step in The CAR Strategy is to address the technical inaccuracies of "master-slave" terminology. In most cases where this terminology is used, it does not properly describe the relationship between certain mechanics in software and hardware. For example, in a Domain Name System (DNS) the "slave" can actively refuse to execute zone transfers if they are malformed despite the original direction coming from the "master" [10]. This example is noteworthy because human slaves do not typically have the option to refuse a task assigned by their human master without severe consequences.

The final step of this strategy is to replace "master-slave" with a recommended replacement terminology. Replacing "master-slave" not only prevents students from feeling uncomfortable [1], but the replacement terms can also be made to more accurately describe the process happening within software or hardware. Another way to conceptualize The CAR Strategy is to confront the past, address the present consequences, and replace problematic terminologies for the future. More importantly, we hypothesize that the replacement of "master-slave" will help to cancel the normalization of terminologies which reify racial hierarchies.

Background

The earliest appearances of "master-slave" terminology in technical settings occurred in 1904 [11]. Since then, the use of "master-slave" terminology has increased substantially in describing engineered systems. Today, "master-slave" can be found in engineering topics such as brake/clutch cylinder systems in car engines, serial peripheral interface connections in microcontrollers, online git repositories, aeronautical missile systems, computer network database architectures, architectural designs of residential homes, and more [12], [13], [14], [15], [16], [17].

"Master-slave" terminology is correlated with feelings of exclusion and Stereotype Threat for students. This creates an uncomfortable atmosphere in the classroom and can potentially prevent students from actively engaging and asking questions in class [1]. In computing systems, "master-slave" terminology is frequently used to describe how flip-flops function. According to Eglash's research, many Black engineers felt that such terminology does not conceptually make sense as a descriptor [11]. Furthermore, from this research it was revealed that in real industry settings, the "master-slave" relationship is not even apparent according to those same Black engineers [11]. Highlighting this inaccuracy with "master-slave" is important because academia should strive to use nomenclature that is accurate and comfortable for all students to use—not just white and/or male students who have the privilege to feel comfortable accepting the "master-slave" metaphor [1].

However, "master-slave" isn't the only type of problematic terminology commonly used in engineering. Terms like "whitelist/blacklist" , and even "male/female" have been labeled as problematic terminologies by many in the industry today [18]. In fact, "whitelist/blacklist" has already been labeled so problematic that many major technical organizations and companies have vowed to replace and actively stop using such engineering jargon going forward [19]. Although industry is aware of and promising to replace terminologies like "master-slave," there is still a need for The CAR Strategy because undergraduate curriculum contributes to the development of industry-ready engineers. Additionally, The CAR Strategy ensures we are not

simply erasing and replacing "master-slave," but also confronting its past and addressing its present so engineers do not make similar mistakes in the future.

While some may argue that the terminologies discussed aren't necessarily exclusionary in nature, previous research has concluded that if the language reminds someone they belong to a historically excluded group, it could lead to an overall negative academic performance for those individuals [20].

Even though it is clear that industry has realized the problem of "master-slave" and vowed for systemic changes, academia still needs The CAR Strategy because academia has fallen short in addressing these systemic changes. In the scope of this paper, we focus on "master-slave" in engineering terminologies as the starting point of confronting, addressing, and replacing non-inclusive terminologies in engineering education.

Many past studies take the approach of analyzing how learning environments lead to underrepresented groups leaving STEM fields [21]. However, our study takes the approach of specifically focussing on student perceptions and efficacy of a new teaching strategy meant to confront, address, and replace "master-slave" terminology and similar iniquitous terminologies which have previously shown to create discomfort amongst students [1]. This study embodies true engineering education reform and hopes to serve as a foundation or inspiration for future anti-racist pedagogies.

The CAR Strategy is a mechanism aiming to improve retention rates of underrepresented students by reducing the negative impacts caused by the presence of "master-slave" terminology on student retention and belonging, as well as student learning.

The CAR Strategy

The strategy is composed of three tactics: 1) Confront; 2) Address; and 3) Replace, otherwise known as The CAR Strategy—aiming to "drive out" non-inclusive terminologies such as "master-slave" in engineering education.

The first step of The CAR Strategy—confront—advises instructors or guest lecturers to confront the historical significance of "master-slave" terminology and other exclusive terminologies. For example, adequately discussing American slavery and sex trafficking is one way to accomplish this. Confronting the history of U.S. enslavement is the first step of The CAR Strategy because it establishes the historical context and present day consequences to students who may believe metaphor terminology in engineering education does not matter and/or is not worth discussing in

an engineering course. Considering 42% of students in the April 2020 study agreed the use of "master-slave" terminology makes them feel uncomfortable, it is reasonable to assume that discussing this topic will result in an uncomfortable conversation for a class to discuss [1]. Having this uncomfortable conversation is important because it will prompt students to think about how this terminology can make their fellow peers feel uncomfortable and excluded in learning environments.

The second step of The CAR Strategy—address—requires instructors to address the specific technical inaccuracies of "master-slave" terminology for the subject they are teaching. This second step is chosen because the 22% of students in the previous study who did feel comfortable with the problematic terminology [1] may need to see or hear technical reasonings to personally justify a change to the terminology.

The third and last step of The CAR Strategy—replacement—recommends instructors as well as their students select a preferred replacement for "master-slave" terminology. Since the majority of students in the 2020 study who felt uncomfortable with the "master-slave" nomenclature were also in agreeal with the idea of replacing "master-slave" terminology in the classroom, officially replacing the nomenclature seems to be an appropriate solution [1].

This study attempts to determine whether The CAR Strategy is a legitimate and effective strategy professors can use to replace iniquitous terminology such as "master-slave" within engineering education. Specifically, this study focuses on if and how The CAR Strategy may change student opinions regarding "master-slave" terminology as well as their perceptions on the CAR teaching strategy. Lastly, this study will discuss which alternative terminologies CAR participants found promising for "master-slave".

Survey Design

This section details the design of our pilot program, survey instruments, and statistical analysis. The CAR Strategy is consolidated into a three minute and forty five second video which serves as the implementation of the teaching strategy [22]. Before students are sent the video, students voluntarily fill out a Google Forms survey which is denoted as the pre-CAR survey. Then, once the video is watched, students voluntarily fill out a second Google Forms survey which is denoted as the post-CAR survey. The pre-CAR and post-CAR surveys are exactly the same except for the additional post-CAR survey questions shown in Table 5. Filling out the surveys and watching The CAR Strategy video are completed asynchronously and remotely. Thus, from start to finish this trial of The CAR Strategy requires approximately a total of 15 to 25 minutes of a students' time depending on how long they take to fill out the surveys.

In both surveys, a Likert scale [23] is used to assess the student's familiarity with the engineering terminology "master-slave", whether they have ever considered the impact the term may have on others, and whether the term makes them personally feel uncomfortable as shown in Table 1. The respondents either respond with "Strongly Disagree", "Disagree", "Neutral", "Agree", "Strongly Agree", or "Prefer not to answer". Depending on their response to the last question in this section, the survey's logic sends respondents to another set of questions about the term.

Question Identifier	Question	Type
B1	I am familiar with the engineering terminology "master-slave"	Likert agreement
B2	I have never considered the impact "master-slave" terminology may have on others.	Likert agreement
B3	The use of "master-slave" terminology makes me feel uncomfortable	Likert agreement

Table 1: Questions asked to all respondents in the beginning of the pre-CAR and post-CAR surveys.

If a respondent agrees, strongly agrees, is neutral, or prefers not to answer that "master-slave" makes them feel uncomfortable, the survey asks the questions shown in Table 2. The questions address Stereotype Threat by asking respondents if the jargon reminds them of being part of a historically marginalized group. They also attempt to determine how the use of the terms affect the sense of inclusivity and any feelings related to Curriculum Trauma [2].

Question Identifier	Question	Type
C1	Use of the term reminds me I'm part of a historically excluded group	Likert agreement
C2	Use of this term makes me feel like an outsider in the classroom	Likert agreement
C3	I'm afraid of how my classmates might feel about this term	Likert agreement

Table 2: Questions asked of respondents if they answer "Strongly agree", "Agree", "Neutral", or "Prefer not to answer" to whether "master-slave" terminology makes them feel uncomfortable.

For students who are not made uncomfortable by the use of a term, we ask the questions shown in Table 3. These questions aim to capture the viewpoints of students who do not find "master-slave" a discomforting terminology. Specifically, the questions hone in on the extent to which students feel empathetic towards their peers who feel differently. Additionally, the last question of this section assesses students willingness to a potential change in curriculum.

Question Identifier	Questions	Type
D1	I would be surprised if a fellow student mentioned discomfort with this term	Likert agreement
D2	I would feel empathetic towards a classmate who finds this term problematic	Likert agreement
D3	I would be accepting of using an alternate phrase if a classmate expressed discomfort with the use of this term	Likert agreement

Table 3: Pre-CAR and post-CAR questions asked of respondents if they answer "Strongly Disagree" or "Disagree" to whether "master-slave" terminology makes them feel uncomfortable.

The next section of the survey is asked to all respondents and solicits perceptions of The CAR Strategy. As shown in , three questions are asked, each one related to each step of The CAR Strategy. Each question also allows students to elaborate on their opinions with an open ended question.

Question Identifier	Questions	Type
E1	Professors should appropriately confront the historical significance and origins of "master-slave" terminology in courses that traditionally use the term	Likert agreement
E2	Care to elaborate?	Long answer
F1	"Master-slave" terminology is an accurate description of the engineering systems it represents	Likert agreement
F2	Care to elaborate?	Long answer
G1	Which alternative terminology would you prefer to replace "master-slave?"	Multiple choice

| G2 | Care to elaborate? | Long answer |

Table 4: Questions asked to all respondents in both the pre-CAR and post-CAR surveys.

The post-CAR survey contains additional questions which are not present in the pre-CAR survey. As shown in Table 5, these questions aim to gauge the efficacy of The CAR Strategy as a new pedagogy by asking one question for each step of the strategy and three general questions on the strategy as a whole.

Question Identifier	Questions	Type
E3	The CAR Strategy appropriately confronted the historical significance and origins of "master-slave" terminology	Likert agreement
F3	The CAR Strategy helped me realize the technical inaccuracies of "master-slave" terminology	Likert agreement
G3	I was satisfied with the replacement terminology my professor selected through The CAR Strategy	Likert agreement
H1	Overall, I believe The CAR Strategy is an effective framework for aiming to drive out iniquitous terminologies such as "master-slave" in STEM education	Likert agreement
H2	I would like to see all my professors use The CAR Strategy (when applicable) in my classes	Likert agreement
H3	What positive or negative feedback do you have on The CAR Strategy?	Long Answer

Table 5: Questions asked to all respondents in only the post-CAR survey.

Last in the survey, we ask the demographic questions shown in Table 6. We include the demographic questions at the end of the survey to avoid priming students to think about their identity before engaging with the term "master-slave". The last question in this section is optional and allows us to link pre-CAR and post-CAR responses to better analyze data.

Question Identifier	Question
J2	Are you the first person in your immediate family to attend

	college?
J3	What is your gender/gender identity?
J4	How would you describe your race or ethnic identity?
J5	What are the last 5 digits of your Library Code on the back of your student identification card?

Table 6: Pre-CAR and post-CAR demographics questions for all respondents. These questions were asked at the end of the survey to avoid introducing Stereotype Threat.

Statistical Methods

Aside from the standard descriptive statistics like pie charts and bar graphs that can be made from the pre-CAR and post-CAR datasets separately, a more sophisticated statistical analysis is implemented to examine a third dataset. This third dataset, denoted as the "linked-CAR dataset", comprises students who fill out both the pre-CAR and post-CAR surveys and twice enter the same five digit library code from their student identification card.

From the linked-CAR dataset, the statistical software, Minitab, is used to conduct paired t-hypothesis tests while the programming environment, MATLAB, is used to plot the linked-CAR dataset responses onto alluvial diagrams.

The paired t-test is a form of hypothesis test in statistics used when interested in the difference between two variables for the same subject; often the two variables are separated by time [24]. Each paired t-test specifies a null hypothesis and alternative hypothesis in terms of the survey question of interest. All null hypotheses are defined as there being no change, on average, in a student's responses to a question before and after exposure to The CAR Strategy. All alternative hypotheses are defined as there being a change towards inclusivity, on average, in a student's responses to a question before and after exposure to The CAR Strategy. For this study, The CAR Strategy's effect on a given survey question is considered statistically significant if the paired t-test produces a probability-value (p-value) that is less than or equal to the significance level (alpha) which is 5% (alpha = 0.05). If the p-value rounded to the hundredth place is less than or equal to alpha, the null hypothesis can be rejected, and thus the alternative hypothesis is accepted. Likewise, if the p-value is greater than alpha, the null hypothesis cannot be rejected, and thus the alternative hypothesis is rejected. In order to calculate the p-value the Likert scale is converted from strongly disagree, disagree, neutral, agree, and strongly agree to numerical values of 1, 2, 3, 4, and 5, respectively.

Although paired t-tests provide an objective and statistical consensus on The CAR Strategy, it does not produce very illustrative diagrams. For this reason, MATLAB is used to produce alluvial diagrams for each survey question for which The CAR Strategy is proven statistically significant. Alluvial diagrams, also known as alluvial plots, illustrate the data patterns and relationships between adjacent sample data [25]. In this study, a custom MATLAB program is utilized to produce alluvial plots which visually connect linked-CAR dataset one question at a time. The left side of an alluvial diagram designates student responses to questions in the pre-CAR survey while the right side of an alluvial diagram designates the same students' responses to the same question in the post-CAR survey. For each alluvial plot the sample size (n) varies because some survey questions had less respondents due to the two possible respondent paths in the pre-CAR and post-CAR surveys. In this study, alluvial diagrams serve to help readers better comprehend and notice the effect The CAR Strategy has on students before and after exposure to the new pedagogy.

Quantitative Results

The CAR Strategy surveys were distributed to electrical and computer engineering students at California Polytechnic (Cal Poly) State University enrolled in Microcontroller-Based Systems Design during the Spring term 2020. A total of 94 and 65 students responded to the pre-CAR and post-CAR surveys, respectively. The demographics of the respondents are shown in Fig. 2 and Fig. 3. Per Institutional Review Board requirements, we did not require a response for any question. Therefore, the number of respondents varies per item.
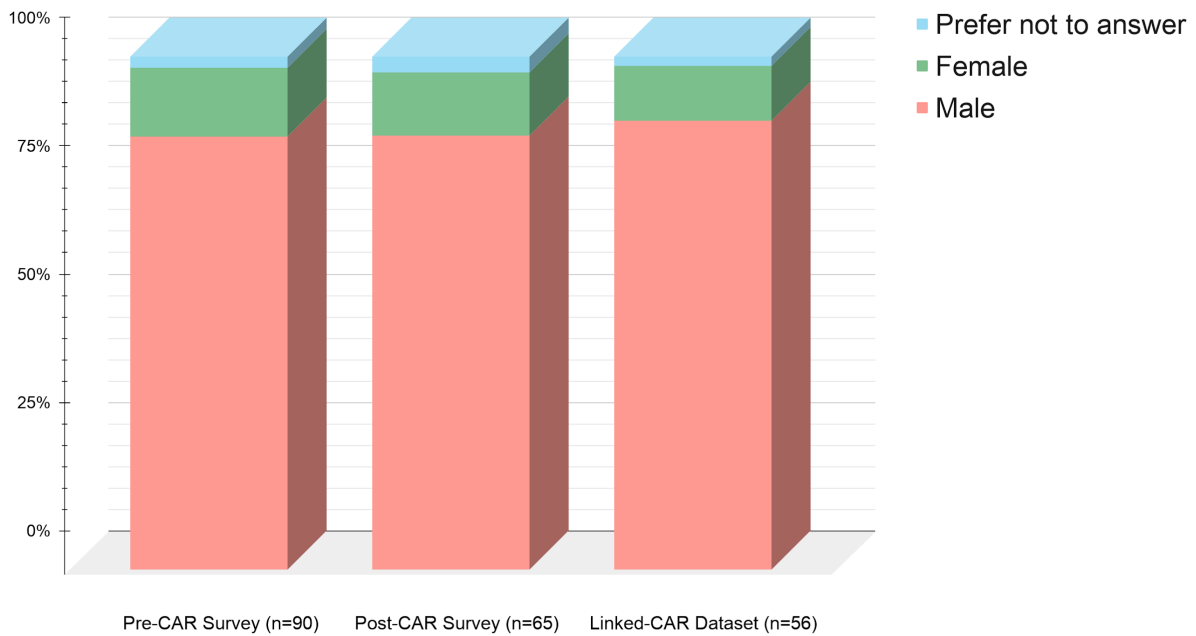
Figure 2: Demographic distribution of gender in the pre-CAR, post-CAR, and linked-CAR datasets.
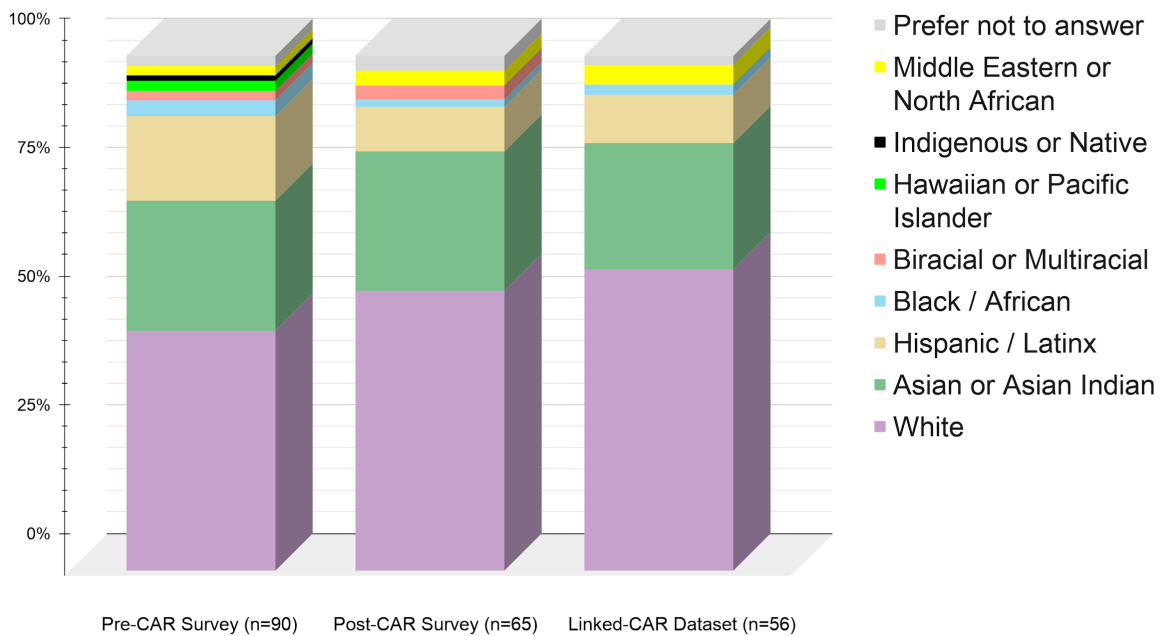

Figure 3: Demographic distribution of race in the pre-CAR, post-CAR, and linked-CAR datasets.

To no surprise, the respondent population is predominantly white and male which is representative of the student population at Cal Poly and its College of Engineering, respectively (cite CP demographic data here). Although these demographics are not ideal for representing diverse perspectives on The CAR Strategy, the numbers are also somewhat representative of the overall makeup of many electrical engineering and computer engineering programs nationwide. Besides, one of the end-goals of The CAR Strategy is to ultimately increase the diversity and improve retention within engineering programs. Thus, the results should be valuable in measuring current student sentiment as it exists overall.

The overall results for the questions in both the pre-CAR and post-CAR surveys shows promising statistics on students' perceptions of The CAR Strategy. As shown in , of all 64 post-CAR respondents, 70% either agree or strongly agree The CAR Strategy is an effective framework for driving out iniquitous terminologies such as "master-slave" in engineering education. Similarly, as shown in , 67% of post-CAR respondents either agree or strongly agree they would like to see all professors use The CAR Strategy when applicable in their classes.
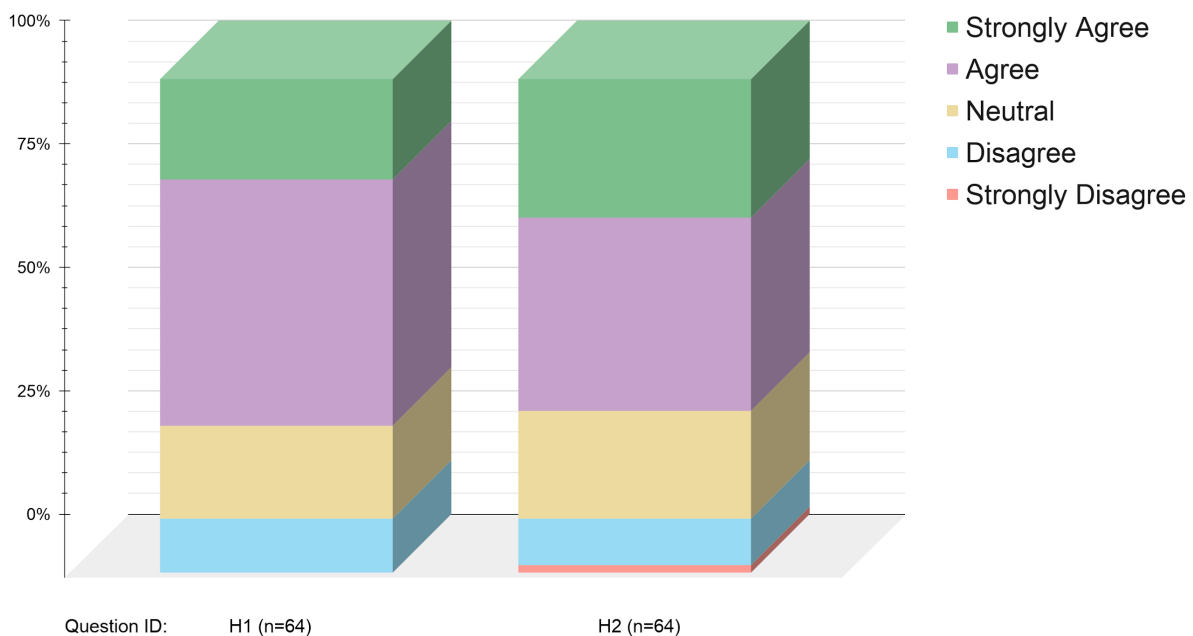

Figure 4: Distribution of responses for questions H1 and H2. H1 probed the effectiveness of the framework's mission while H2 examined if students preferred professors use The CAR Strategy in their classes, when applicable.

Moreover, after exposure to The CAR Strategy, respondents felt strongly about how well the pedagogy executed its purposes in each step. For the "confront" step, of all 64 post-CAR respondents, 85.9% either agree or strongly agree The CAR Strategy appropriately confronted

historical significance and origins of "master-slave" terminology (E3post). While for the "address" step, of all 64 post-CAR respondents, 68.2% either agree or strongly agree The CAR Strategy helped them realize technical inaccuracies of "master-slave" terminology (F3post). And lastly, for the "replace" step, of all 64 post-CAR respondents, 58.7% either agree or strongly agree they were satisfied with the replacement terminology their professor selected through The CAR Strategy (G3post).
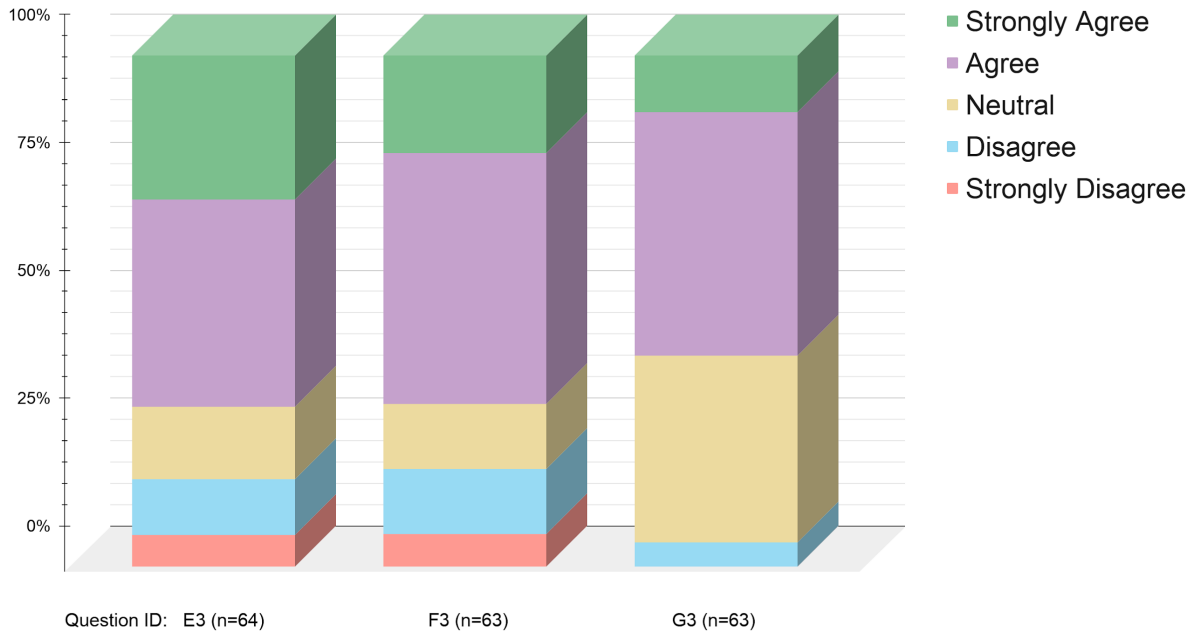

Figure 5: Distribution of responses for questions E3, F3, and G3.

The survey responses above indeed are promising, but in order to solidify and confirm the efficacy of the experimental teaching framework, additional statistical analysis is applied via Minitab and MATLAB.

After running all 56 linked-CAR survey responses through ten different paired-sample hypothesis tests, The CAR Strategy provided sufficient evidence to suggest it is statistically significant (at confidence levels < 5%) in promoting a more inclusive student experience.

Of the hypothesis tests run on the ten linked-CAR survey questions which assess The CAR Strategy, seven of the hypothesis tests achieved a rounded p-value of less than or equal to 0.05, as shown in Table 7. Each hypothesis test produced an "individual value plot of differences" to help visualize the differences in students' change in responses before and after The CAR Strategy. Each data point represents a student's numerical difference in their Likert-scaled responses to a question in the pre-CAR and post-CAR surveys where the difference is defined as

the post-CAR value minus the pre-CAR value. The data shows clear trends on how exposure to The CAR Strategy affects student responses.

Question B1 was determined not applicable to the hypothesis tests and thus omitted because the vast majority of students were already familiar with "master-slave" engineering terminology prior to exposure to The CAR Strategy.
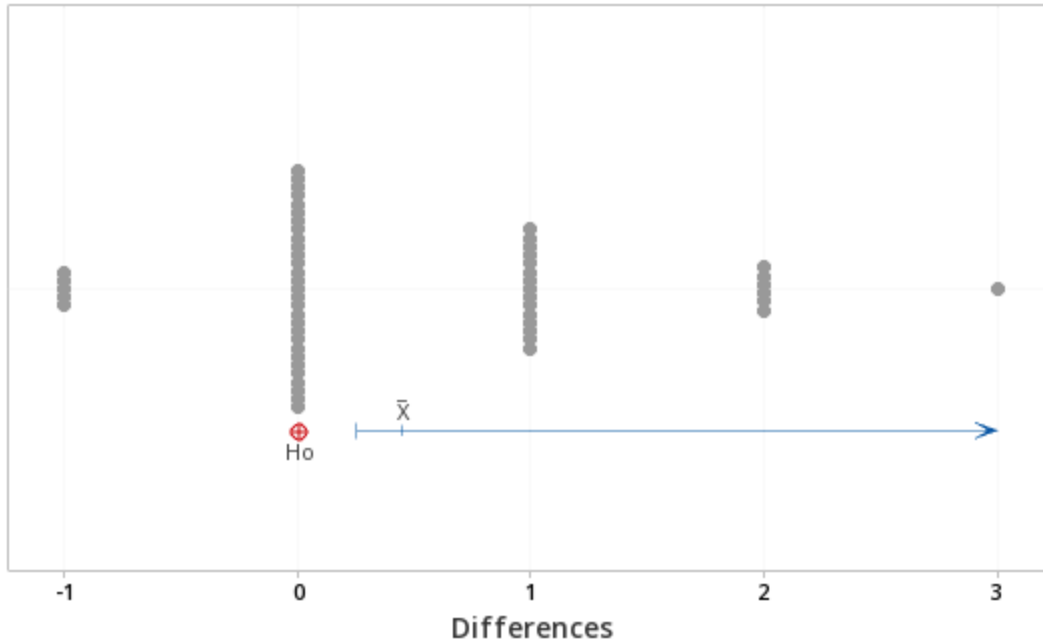

Figure 6: An example of the Minitab paired-sample hypothesis test's "Individual Value Plot of Differences" for question B3 (n = 56). Each data point represents a student's numerical difference in their Likert-scaled responses to question B3 in the pre-CAR and post-CAR surveys. The null hypothesis, H_O, claims that there is no difference in a student's responses, and the mean of all differences, X-bar, equals 0.446.
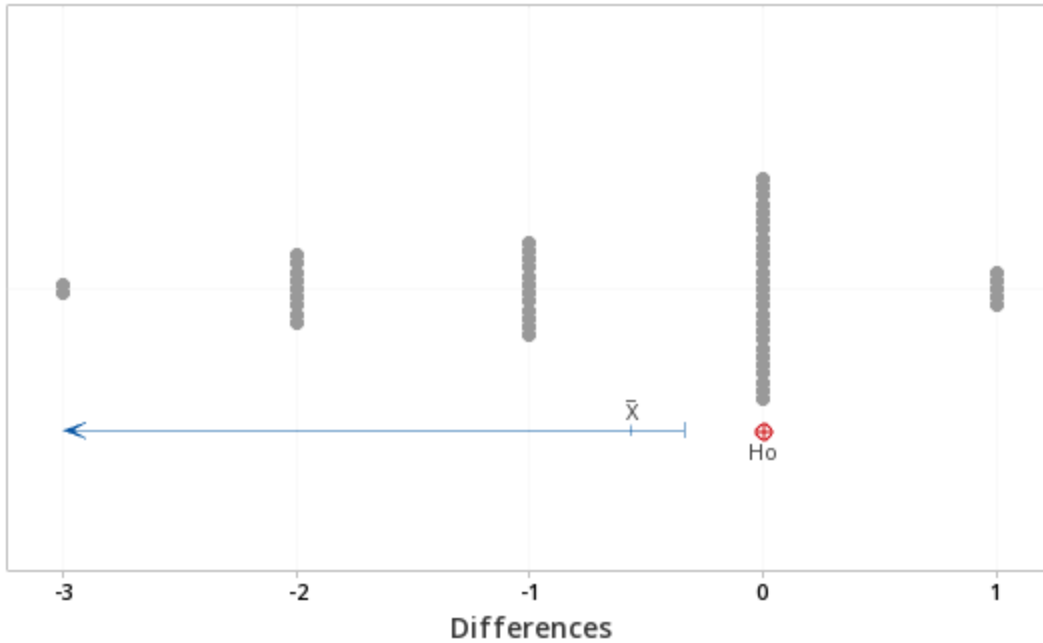
Figure 7: An example of the Minitab paired-sample hypothesis test's "Individual Value Plot of Differences" for Question F1 (n = 55). X-bar equals -0.564.

Question ID	Respondent Sample Size (n)	Hypothesis Test Probability-Value (p-value)
B2*	56	0.006
B3*	56	0.000
C1	34	0.101
C2*	34	0.001
C3*	34	0.007
D1	13	0.134
D2*	13	0.027
D3	13	0.169
E1*	56	0.051
F1*	55	0.000

Table 7: Statistical results of the paired-sample hypothesis tests conducted in Minitab. Asterisks denote the alternative hypothesis was accepted for that question's hypothesis test. The precision

of the p-value was set to the thousandths place.

Once again, the statistical results above help to solidify and confirm the efficacy of The CAR Strategy as an experimental teaching framework. MATLAB is utilized to produce alluvial diagrams which better visualize the overall effect of The CAR Strategy.

Of the six alluvial diagrams produced, three can be found below and the remaining three can be found in Appendix B. The left side and right side of the diagrams represent the pre-CAR and post-CAR survey responses, respectively. The lengths of the black bars on each side of the diagrams are approximate indicators of the distribution of responses for each survey. For the purpose of the alluvial diagram, "strongly disagree" and "disagree" responses are grouped into a singular "Disagree" category while "strongly agree" and "agree" responses are grouped into a singular "Agree" category. The diagrams holistically illustrate any shifts and trends amongst students who completed both surveys. Nearly all student shifts, except for a few outliers, either shifted towards promoting a more inclusive classroom setting or did not shift at all.
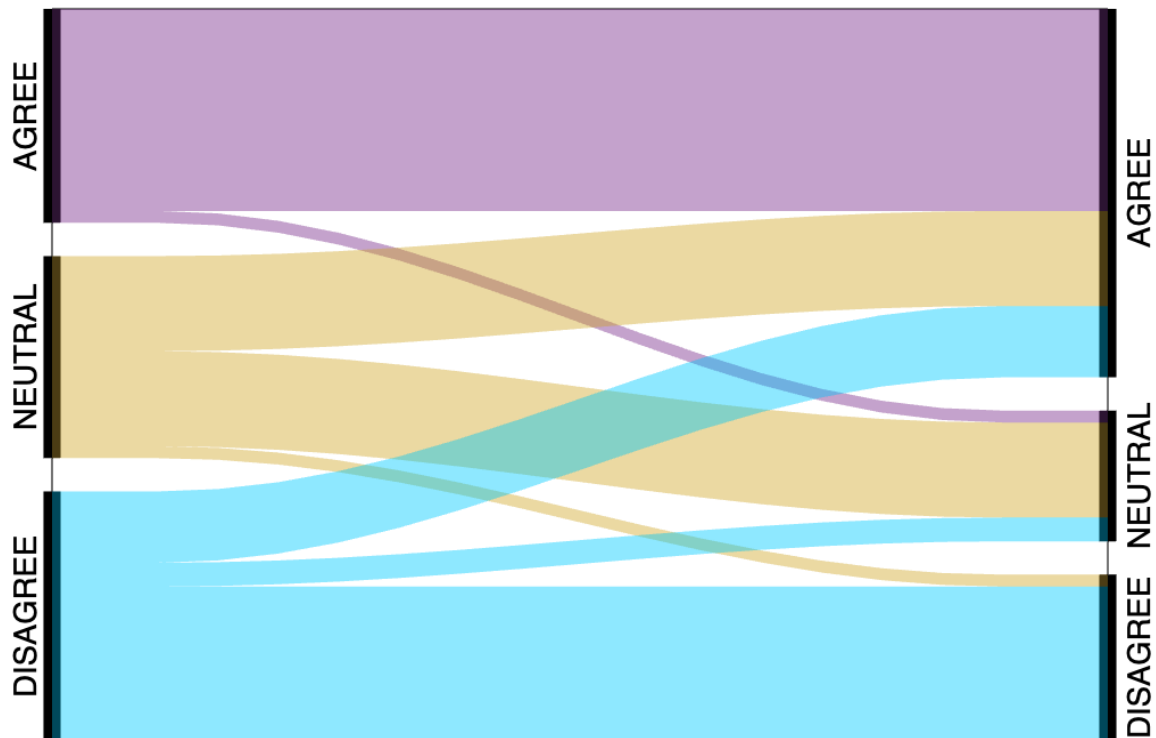

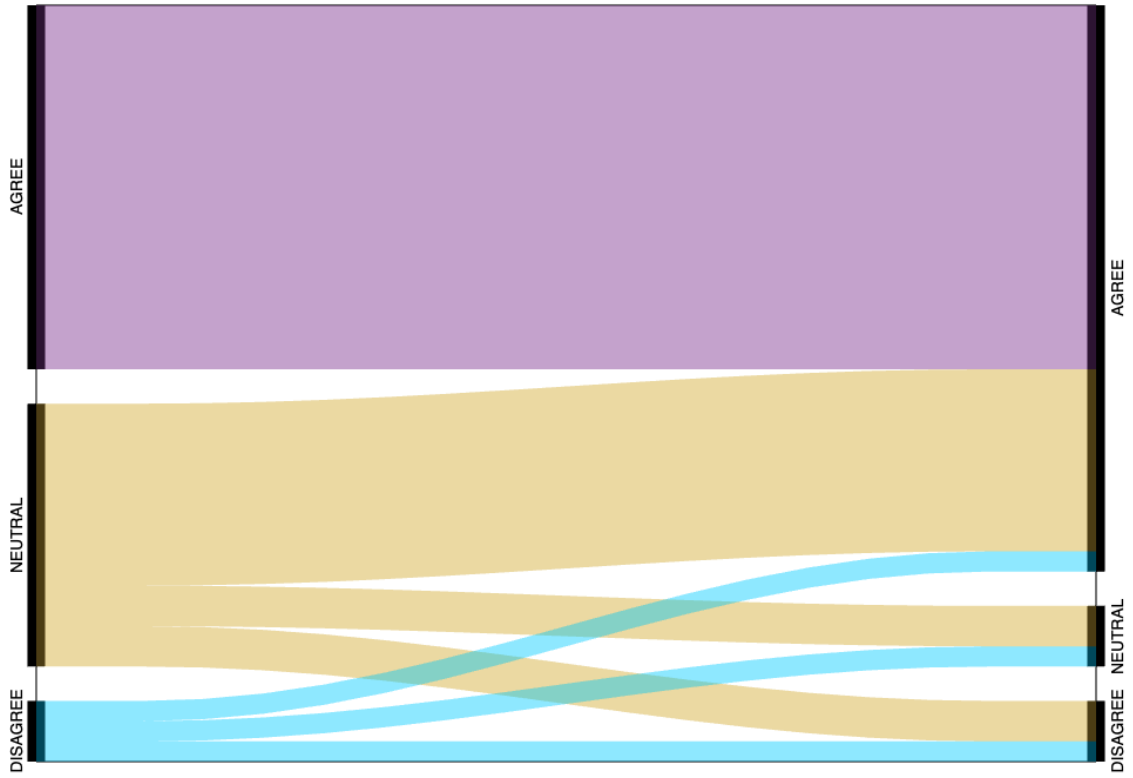Figure 8: Survey responses for question B3 (n = 56) before and after The CAR Strategy.

Figure 9: Survey responses for question C3 (n = 34) before and after The CAR Strategy.
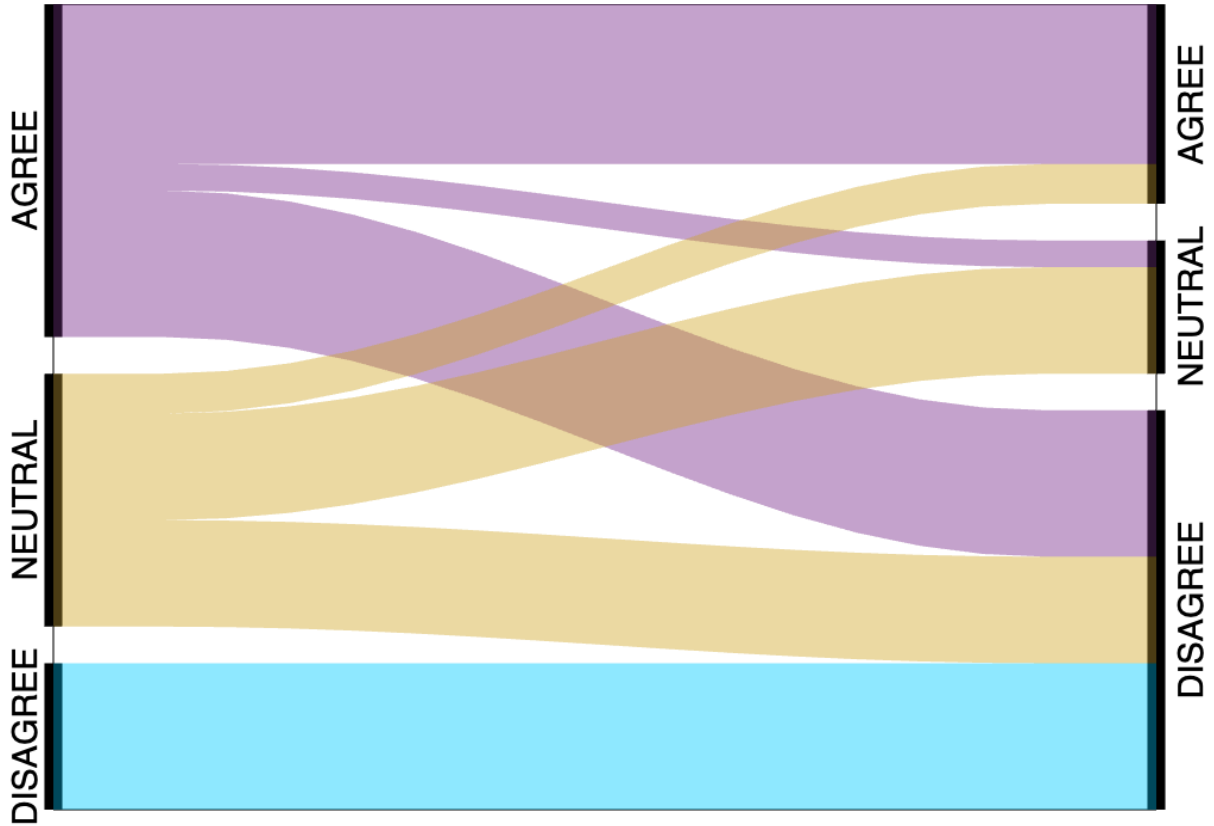
Figure 10: Survey responses for question F1 (n = 55) before and after The CAR Strategy.

Lastly, in question G1 students were asked which replacement terminology they prefer. As shown in Fig. 11, there was no dominating consensus in either the pre-CAR or post-CAR survey.
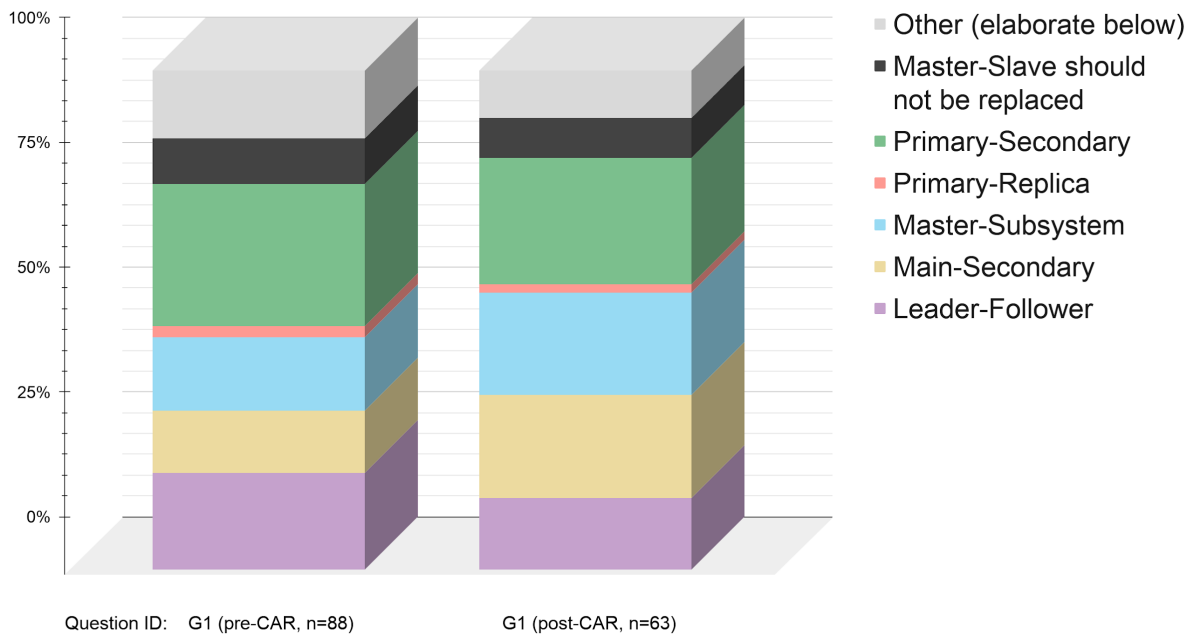
Figure 11: Distribution of responses for question G1 in the pre-CAR and post-CAR surveys.

Qualitative Results

In addition to the quantitative data above, qualitative data was collected from open-ended questions E2, F2, and G2. There were some responses in support of keeping the legacy terminology, but the majority of open-ended responses were in support of replacing "master-slave". However, in both surveys there was no consensus on one single replacement terminology. For context, only 37% and 18% of open-ended questions received responses from students in the pre-CAR and post-CAR surveys, respectively. There were exactly 100 and 48 separate open-ended responses in the pre-CAR and post-CAR surveys, respectively ranging from one-word to paragraph-long responses.

In the pre-CAR survey, several students voiced opinions such as "we should question our casual use of the term master/slave in embedded systems" and "it is better for teachers to address the elephant in the room instead of acting like [uncomfortable terminology] is no big deal." Others went further and suggested "they should just come up with a replacement [terminology]."

Many of the comments in the pre-CAR survey displayed thorough critical thinking skills by the students. Topics such as slavery, history, and personal experiences were mentioned in multiple different comments. Some notable words appeared frequently in questions E2, F2, and G2 of the pre-CAR survey such as "uncomfortable", "context", "offensive", and "connotation". Most

respondents in the pre-CAR survey shared the sentiment that they understand what "master-slave" technically means as an engineering terminology but there is likely a better way to describe it.

In the pre-CAR survey there were only a few students with opinions dissenting from the majority. These students made points such as "[going] over an entire history of slavery to be able to use the terminology would be a waste of class resources" and "I don't know if an engineering professor has the expertise to properly bring up [the historical significance of 'master-slave']." One student even goes as far as to say "these [terms] have to do with computers, which have no history of oppression."

It is interesting to note that in the pre-CAR survey several students recalled their first interactions with "master-slave" in engineering. One student said "I actually thought someone was making a weird joke on terminology" while another said "I found this to be a weird thing to see on a power supply, but after the initial shock I understood what it meant." A third student wrote "I first discovered this terminology in industry on [an] internship and it made me feel uncomfortable."

Furthermore, the post-CAR survey contained positive feedback along the lines of "I liked how the [CAR Strategy] video was a step by step solution to this societal issue" and "confronting the issue and acknowledging it in the classroom is a valuable learning experience"

There was also some negative pushback on the pedagogy such as "anthropomorphizing things is extremely common and can often help people understand new concepts faster" and "it is important to remember the violations of the past, and replacing anything that reminds us of [the past] helps obfuscate those violations."

But for the most part, students' comments in the post-CAR survey provided direction for future research related to The CAR Strategy and the gaps it currently does not address. "[The CAR Strategy] can be applied to many other engineering or non engineering related fields" said one student while another said "[The CAR Strategy] brings up an important issue that we should have been talking about a while ago." It is worth noting, one student voiced that "hearing master-slave reminds me of sexual relationships more than historic racial situations."

Discussion

Beginning with the quantitative data, the Likert-scaled survey results convey a telling story about students' experiences with The CAR Strategy. The pre-CAR quantitative dataset alone provided insight into students' initial reactions and feelings to potentially engaging in discussions on

problematic engineering vernacular. The pre-CAR survey also gauged student sentiments prior to exposure to The CAR Strategy. Overall, prior to exposure to The CAR Strategy, many students were open to confronting "master-slave" in a classroom setting.

Meanwhile, the post-CAR quantitative dataset alone yielded results on students' perceptions of The CAR Strategy when applied to "master-slave" terminology. The post-CAR survey also provided a glimpse at The CAR Strategy's potential future applications. Ultimately, the majority of students positively received the new pedagogy. We noticed that several students foresaw The CAR Strategy's future application on engineering terminologies related to gender, with one student even foreseeing non-engineering applications of The CAR Strategy. For instance, The CAR Strategy could be applied to pronouns in textbooks which use "he/him/his" as a default or standard and replace that with "they/them/theirs".

Seven out of ten of the hypothesis tests achieved a rounded p-value of less than or equal to 0.05. Five out of the seven passing hypothesis tests achieved p-values less than or equal to 0.01. This shows the strong statistical efficacy of the novel CAR Strategy, which still has room for refinement as this is its first ever formal study.

With that said, two of the three unpassing hypothesis tests, D1 and D3 (p-values of 0.13 and 0.17, respectively), had low sample sizes of thirteen respondents. It remains unclear if these two p-values would be repeatable with a larger sample size. The same presumption applies to the passing hypothesis test of D2 (p-value of 0.03) which also had a sample size of thirteen.

Furthermore, the qualitative data from both surveys strengthens the quantitative data. Although there were some dissenting opinions from the majority, it is clear that many engineering students are willing and capable of engaging in meaningful academic discourse. This is a notable observation because of the stigma that engineering students do not value critical engagement of the technologies they work with or create [26].

The qualitative data from the pre-CAR survey is significant because it confirms the demand among students for confronting, addressing, and replacing problems in educational institutions. The CAR Strategy is the supply to this demand. We found that some students even used the words confront, address, and replace in their open-ended responses prior to formal exposure to The CAR Strategy. It seems as though the new pedagogy is a natural progression and response for the engineering education field.

The qualitative data from the post-CAR survey is informative because it helps provide direction for future research related to The CAR Strategy. A few students alluded to the gaps the pedagogy currently does not address such as "female-male" connectors and "blacklisting-whitelisting" in

computer science element selection. One women-identifying student even admitted that "master-slave" makes them think about "sexual relationships." These qualitative data points suggest The CAR Strategy should attempt to tackle the uncomfortable terminologies within engineering education as it pertains to gender. The quantitative data, supported by the qualitative data, warrants attention from engineering educators as a new framework for approaching problematic terminologies within curriculum.

For the few students who felt anthropomorphism has its place within engineering systems, recent psychological research suggests otherwise. Anthropomorphism in modern industrialized societies is "more cute than critical" and it contains "individual differences" which pose "consequences for everyday life" [27]. In fact, these consequences have implications on human-computer interaction and "inform classic issues underlying person perceptions" [27].

Lastly, it is quite relevant to mention this data collection occurred during Fall 2019. In May 2020, after the murders of George Floyd, Breonna Taylor, Ahmaud Arbery, and many others, America and the world witnessed a several-month long protest against outdated ideologies and social systems. Generational movements like these do not come out of nowhere. They typically are rooted in years or decades of microaggressions and stagnancy by people and institutions. Perhaps "master-slave" terminology was one of the many microaggressive forms of institutional racism which contributed to the historic wave of public protests.

The CAR Strategy is meant to be a proactive and modern pedagogy which encourages discussion and thought on whether or not we should replace questionable aspects within engineering. The CAR Strategy does not force students to replace "master-slave" or any terminology from their vernacular—it simply welcomes it.

With that said, the "replace" step of The CAR Strategy is the part which still requires refinement for "master-slave" and application to other terms. Both the quantitative and qualitative data suggest this critique. But it seems that this is because it is difficult to come to a consensus on what should replace what. Until a study on a revised CAR Strategy is conducted, the researchers recommend leaving the replace step with room for debate. One way to go about replacing a terminology can be to conclude The CAR Strategy by administering a class vote on which terminology they democratically prefer. Even with a non-diverse student population like the one we had in this study, students seem ready for a shift within engineering and its advocacy for racial and gender equity.

Conclusion

Ultimately, the data confirms The CAR Strategy is an effective pedagogy when applied to "master-slave" terminology. The majority of respondents agreed all three steps (Confront, Address, and Replace) were effective in their specific purposes when applied to "master-slave". However, the Replace step warrants further research and improvement. The researchers thus consider The CAR Strategy a promising pedagogy worth further research applied to other potentially problematic terminologies in engineering education such as "female-male" (connectors) and "blacklist-whitelist" (element selection).

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