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HEADWATERS SCIENCE INSTITUTE Student Research Journal

Volume 1 • Issue 3 • Fall 2020

Kayla Brand collects water quality data during the summer research program.

Forward

The articles you see in this publication are the result of months of hard work from students in Headwaters Science Institute's 2020 Summer Research Program, While they are not peer-reviewed in typical journal fashion, they have been reviewed by Headwaters staff and professional scientists. The caliber of these projects speaks loudly to these students' accomplishments. Allow us to also highlight a few of the most special parts of this program here.

Part of what made this program possible was participation by a great array of professional scientists, post-docs, and graduate students from institutions across the country. These scientists not only brought great technical knowledge to the program but also shared with students their own invaluable experience in navigating the winding path of original scientific research. Thank you to all of the scientist mentors who made these student projects possible.

One of the unique outcomes of this course was that all of the articles in this text are the students' own original ideas. Each one of these manuscripts started as part of a list of scientific questions brainstormed by students. From there, students shaped and molded the questions they were interested in based on current scientific knowledge and access to field sites or existing datasets. Students revised their questions, collected preliminary data, and revised again, honing their scientific skills along the way. The diversity of research questions in this publication is not only evidence of the incredible creativity inside all students but also honors the wonderful job the scientist mentors did in nurturing this curjosity.

To the students who authored these papers: congratulations! All of you have worked incredibly hard to complete these manuscripts. More than having your name on this paper, be proud of all that it represents. Each one of you overcame setbacks, roadblocks, time crunches, and uncertainty to get to this point. The skills you practiced along the way will serve you well in whatever you choose to do next.

Spencer Eusden

Program Director - Headwaters Science Institute

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Is There a Correlation Between One's Views on Inequality and Combating Climate Change?

How Do Certain Factors Impact Peoples' Actions Towards Climate Change? By Annie Ping

Is There a Correlation Between One's Views on **Inequality and Combating Climate Change?**

Mahika Gupta¹ and Spencer Eusden²

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ABSTRACT

There are many social and environmental issues in the world. This study attempted to connect people's biases and actions surrounding various global issues, namely social discrimination and climate change. The main objective of this study was to find a correlation between people's racist and sexist biases and their willingness to combat climate change. My hypothesis was that those who are less likely to want to help solve climate change will have more racist or sexist biases in their behavior. This research was conducted using a In addition to racism, sex discrimination is another survey. The results supported the hypothesis, incredibly large issue. A study found that within showing that those who were less racist or 143 economies, it was found that 128 countries sexist were more knowledgeable about their still have at least one legal difference in how men environmental impact and were willing to and women are treated, which constraints women's help combat climate change. The connections economic opportunities (4). Another survey of 2,000 made in this study about people's biases and Americans found that half of the 1,000 women opinions on issues can help us understand how surveyed reported facing gender discrimination different people think, and will furthermore nearly every day (5). Finally, 50% of adults who allow us to effectively communicate and combat took the survey think that the country "hasn't gone climate change.

INTRODUCTION

In order to understand any correlation between one's Climate change is a very large and rapidly increasing views on social inequality and climate change, it is issue which impacts people around the world. As important to first understand the importance behind the temperature of the globe increases, it causes both issues. Race and sex-based discrimination are many problems for our environment and humans, very large issues. In this study, I attempt to discover from air pollution to severe weather. Moreover, a correlation between these issues and climate these impacts are likely to be most strongly felt by change to better understand people's attitudes poorer populations (7). These impacts can have lifetowards combating climate change.

Discrimination can be described as an action that contributed towards the unequal treatment of an individual (or group) based on their characteristics (1). In this research, I focus more specifically on race and sex based discrimination. Discrimination has been a large problem in society since the very beginning and still is a problem today. Sixty- All the data was collected with a survey which seven percent of the public feels that in the US, consisted of a majority of multiple choice racial and ethnic discrimination is a big problem guestions. The survey had four sections: climate

(2). Additionally, the Black Lives Matter movement has brought light to racial discrimination, as the percentage of Americans who feel BLM is helping has increased from a majority of 58% to 71%, indicating that awareness of racism is growing (2). John Dovidio, a Yale professor, focuses more on "aversive racism" which states that in current times, certain people's actions are developed from ingrained negative feelings and discomfort, resulting in indirect racism (3). He states that the majority of white Americans, about 2/3 to 3/4, have unconscious, implicit, racial biases (3).

far enough" in terms of giving women equal rights with men (6). These studies make it evident that racism and sexism, two very relevant types of discrimination, are very big issues in society.

threatening effects. Poor air quality can cause cancer, heart disease, stroke, and respiratory diseases (8). Many of these negative impacts of climate change are due to anthropogenic CO2 emissions.

METHODS

What is your sex? change, racism, sexism, and lastly a background demographic section. The climate change section 🗧 Female 🔮 Male 😑 Prefer aut to say 🌒 aca-hanay 🥊 aca conformin had guestions which ranged from how big of an issue one thought climate change was to nine multiple choice questions based on actions that were taken in the year 2019. The racism and sexism sections 110 733 9951 both consisted of statements playing on hidden biases, in which the respondents would state how 210 (62.9%) they felt on a scale of "strongly agree" to "strongly disagree". Finally, the background section asked for simple demographic questions such as gender, race, age, political stance (conservative or liberal), etc. and 58. The greater the climate change score, the The survey was anonymous and relied solely on the more likely they are to combat climate change. answers given by respondents for demographics. Similarly, through questions in the survey playing The survey was distributed online, through personal on respondents' biases, a racism and sexism score social media platforms, public facebook ads, various is formed. The greater the score, the less racist and family connections, and a Headwaters Science sexist biases the respondent has. Institute newsletter to their donors, studnets' parents, alumni, and teachers.

The results were furthermore analyzed on google sheets and SPSS Statistics Program. In google The total number of respondents was 333. We sheets, I created stacked and traditional bar graphs included responses from all over the world, although and cross-tabulation strategies were used to form they were mainly from the US and the majority a linear regression to show the correlations. I used from California. SPSS to conduct a plum ordinal regression in order to test the statistical significance between questions with non-continuous variables.

In order to analyze the opinions of all the respondents, I created a climate change (CC), racism, and sexism score for each respondent. The CC score is created by asking the respondent how **RESULTS** often they did an action in the past year (2019) and giving a certain number (1-7) of points depending The demographics of respondents are shown in on if that action impacts the environment positively the following figures. Figure 1 shows that the 333 or negatively. For example, if a respondent recycles respondents were of all ages with the biggest daily or weekly, they are given seven or six points, concentration of 26% being 11-20 years old and respectively. A respondent is given points based 27% who were 41-50 years old. The sexes of the on nine tasks, and the sum is the climate change 333 respondents are depicted in figure 2. Mainly score. Between the 333 respondents who took the comprising 63% female and 33% male. survey, the variety of CC scores were between 14



Figure 1: The percentage of respondents organized by age.







Figure 3 represents the current location of the





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Figure 4: The respondents self-describe their political beliefs.

respondents. A majority of 66% of the respondents are currently located in California. Figure 4 depicts the percentage of respondents who view themselves on a scale from highly liberal to highly conservative. The majority consists of liberals, with a total of 72% identifying as liberal, 16% as neutral, and 12% identifying as conservative.

Figures 5 and 6 compare the climate change score of the respondents with the average racism or sexism score. As the climate change score increases, the respondents' actions impact the environment more positively. The racist and sexist scores increase, the less racial or sex biases the respondent has. The mean, median, and standard deviation for the climate change score equal 35.8, 35, and 9.4, respectively. The mean, median, and standard deviation for the racism score are 67.2, 71, and 10.4, respectively. The mean, median, and standard deviation for the sexism score are 46.8, 49, and 7.6, respectively.

score with the average racism score for whoever got that specific Climate Change (CC) score. For example, 8 respondents had a 26 CC score, and the average of their racism scores is 62.5, which is plotted in figure 5. As depicted, the trendline helps to show that there is a positive correlation between the CC score and the average racism score. As the CC score increases so does the racism score, meaning that as respondents become more willing to help the environment, they have fewer racial biases.

Figure 6 compares all the CC scores to the average sexism scores. Similar to the pattern in figure 5, figure 6 shows that as the CC scores increase, so does the sexism score. Meaning that as respondents become more willing to combat climate change they have less sex-based biases.

The survey asked respondents how big of an impact



they think, as an individual, they have on the environment. Of the 333 respondents, 11% selected a 5 (showing they think they have a huge impact on the environment), 25% selected a 4, 42% selected a 3, 18% selected a 2, and 4% selected a 1 (showing they think they have close to no impact).

Figure 7 depicts this information compared to the average racism scores of everyone who selected either a 1-5, in a linear regression. The trendline shows that as the respondents believe they have a greater and greater impact on the environment, their racism scores also increase, although there is a dip in the rise at 5. Additionally, a plum ordinal regression shows that there is a correlation as the significance value is equal to 0.001. Respondents who rated their impact as 3 or 4, each had a significantly higher racism score as well as a p value of < 0.000 for both. Whereas there was not a Figure 5, specifically, compares every climate change statistically significant impact on the racism score of



Figure 5: The climate change score with the average racism scores. The correlation shows that as the climate change score goes up so does the average racism score. Linear regression $R^2 = 0.55$





Figure 7: The respondents' opinions on how big of an impact they have on the environment with the average race score. A plum ordinal regression with a p value of < 0.001.

people who chose a 1, 2 or 5 for the impact they had on the environment.

Figure 8 compares the same question to the and racism scores. Evidently, these trends hint that average sexism scores of everyone who selected those who are more knowledgeable about their either a 1-5. The trendline, again, shows that as the impact on the environment also tend to have less respondents believe they have a higher impact on racist and sexist biases, with the correlation being the environment, their sexism scores also increase, strongest amongst those who thought they had an although there is the same dip at 5. A plum ordinal impact of a 2,3, or 4. regression shows the correlation is significant with The demographics of the respondents is a factor that a significant value of < 0.000. Respondents who rated their impact on the environment as a 2 had could have an impact on these patterns. A majority a significant p value equal to 0.030, and those of the respondents identified as liberal and lived in who selected a 3 or 4 had a p value of < 0.000. California, meaning that the results found could be Additionally, respondents who chose a 2,3, or 4 skewed to only depict the views of a small portion had significantly bigger sexism scores, and each of society. Another source of error could have been bigger than the last. The choices 1 and 5 were not that the respondents felt pressured to respond with statistically significant. a socially acceptable answer or forgot the actions they took towards climate change.

DISCUSSION

The hypothesis for this project was that those who are more supportive of unequal biases will be less likely to combat climate change. The results support the hypothesis.

The majority of the respondents identified as liberals, were located in California, and also there was a bigger amount of females than males. Therefore, this survey is more informative towards a California-based, liberal crowd, since it compares their views to only a few conservative people. Although many responses were from around the 2 3 US and internationally as well, the percentage of conservatives remained low. Therefore, this limited Figure 8: The respondents' opinions on how big of an the reach into the views of people who have typically impact they have on the environment with the average conservative ideals. Despite this, the questions in sexism score. A plum ordinal regression with a p value the survey were able to play into people's racial and of < 0.000.



sex-based biases and there was still a wide range of racism and sexism scores. This shows that there is a large diversity in the views and biases across even the politically liberal spectrum.

There was a clear positive correlation between the racism or sexism score and the climate change scores. As one's climate change score increases, meaning they are more likely to take action towards combating climate change, both their racism and sexism scores increase, meaning they have less racial and sex-based biases. When comparing the racism and sexism scores with the question of how big of an impact the respondents think they have on the environment on a scale of 1-5, there is a similar correlation. Both the linear regression as well as the plum ordinal regression show that those who believe they have an impact of either a 3 or a 4 on the scale, have significantly higher sexism

The trends found show that respondents' opinions on climate change correlate with their hidden



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connects with racism directly as black and hispanic communities in the U.S. are exposed to more air pollution and hazards than white communities and these same people who are at higher risk have less resources to help (12, 13). Additionally, those who deny the existence of racism and climate change are connected through their similarity to deny science and follow their beliefs (14). Evidently, the 7. "Wait, Why Is Climate Change a Bad Thing?" The Climate patterns I discovered in my research hold true with the patterns other scientists have found.

Future scientists can use the data from this study to continue the battle against climate change. The data gathered shows that we can identify which people to focus on when combating climate change and more importantly how they think. Communication has been proven to be one of the most important things when trying to combat climate change, but unfortunately biases of people can interfere with the effectiveness of educating people about climate change (15). Therefore, my research, which helps us understand these biases, can be used to further improve communication by knowing which audiences to educate about combating climate change.

The results of this study clearly show that people's actions and knowledge towards combating climate 11. Hall, David. "Climate Explained: Why Some People change directly correlates with their racist and sexist biases. Understanding these connections is the key to effectively combating climate change with everyone.

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How Do Certain Factors Impact Peoples' Actions **Towards Climate Change?**

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ABSTRACT change (2). The burning of fossil fuels is one of the major human causes of climate change due to the A survey was conducted to research how age fact that greenhouse gasses are emitted during the and knowledge about climate change can process (6). Because humans have such a large impact people's actions regarding it. People impact on the environment, it would be beneficial have a large impact on the environment so to research how different demographics perceive knowing how different groups of people react climate change and how likely they are to take to climate change would help with knowing action combating it. For example, a person's age and how to effectively conduct outreach about political beliefs could give insight into how important climate change with certain groups of people. they think the topic is and how willing they are The hypothesis was that as age increased, to take action. Research from Yale University has more action would be taken to combat climate shown that younger generations are more likely than change. It was also hypothesized that as older generations to believe that climate change is background knowledge about climate change a real issue caused by humans (1). However, they increased, the amount of action taken would also found that younger generations are just as also increase. Three hundred and thirty-three likely as older generations to take action to reduce people filled out the survey. Results supported global warming (1). Moreover, a study comparing the hypotheses, showing that as age increased adults' knowledge about climate change and their action also increased and as background acceptance of anthropogenic global warming found knowledge increased more action was taken. that increased knowledge about climate change had a positive correlation with the acceptance of anthropogenic global warming (8).

INTRODUCTION

Furthermore, environmental policymakers can take In order to study how various factors can affect this information and create policies to increase peoples' views on climate change and their actions engagement within the general public (7). In a 2015 regarding it, we conducted a survey focussing on study, researchers argued that policymakers should the correlation between one's age and knowledge depict climate change as a personal and current about climate change and the actions they have issue in order to improve public engagement (7). taken towards combating it. Climate change has The researchers also argued that policymakers been an ongoing topic of discussion around the should emphasize the benefits that could come world and has a large influence on the environment with immediate action and create policies meant and human activities. to achieve long term goals (7). Their psychological As temperatures continue to rise, precipitation research suggested that by following these ideas, patterns will change, with stronger and more frequent environmental policymakers would be able to hurricanes (5). Ice in the arctic will continue to melt, improve public engagement with the issue of and sea levels will rise (4). Rising oceans will flood climate change (7). Knowledge about how certain coastal communities, which may affect the 10% of age groups view and act upon climate change could the world's population that lives in areas where they help policymakers communicate climate change in a are less than 30 feet above sea level (6). more personal way towards those groups. This could mean that if these approaches were taken specifically Additionally, human activities greatly impact the towards certain age groups, public engagement with environment and are major contributors to climate climate change could improve within all age groups.



Due to these studies, the hypothesis was that younger generations would take less action to limit their impact on the environment than older generations. It was also hypothesized that people who had more background knowledge on climate change would try to lower their impact on the environment more than people with less knowledge. Results from the survey revealed that as a person's age increased, the amount of action taken also increased. Additionally, it was found that people with more background knowledge about climate change generally took more action to combat it.

METHODS

The anonymous survey was built in collaboration with Mahika Gupta, another student researcher, in order to pool distribution efforts to reach more people since both surveys focused on similar topics. It was created using Google Forms and was sent out via a Headwaters Science Institute newsletter. It was also sent to various acquaintances and relatives of the student researchers in the California area along with several from Canada, Australia, Singapore, Taiwan, and China. Answers from China were written down on paper and later transferred to the online survey.

SPSS was used to analyze data by conducting ordinal and linear regressions along with ANOVA tests. When analyzing the data, certain types of answers were converted to a point system to make the data quantifiable. Questions with "Daily, Weekly,



Figure 1: The overall trend reveals that older people tended to take more action, but there was a large amount of variance within each age group. Error bars = 1 standard deviation from the mean climate score. Oneway ANOVA p-value <0.000 p-value between age groups 11-20 and >60 = 0.002

Age Groups	Age Groups	P-value
11-20	21-30	0.491
11-20	31-40	0.32
11-20	41-50	0.434
11-20	51-60	0.151
11-20	>60	0.002
21-30	31-40	1.000
21-30	41-50	0.999
21-30	51-60	0.998
21-30	>60	0.567
31-40	41-50	0.995
31-40	51-60	0.999
31-40	>60	0.523
41-50	51-60	0.928
41-50	>60	0.138
51-60	>60	0.799

Table 1: The Tukey post hoc test p-values between each age group.

Monthly, Every other month, A couple times a year, Yearly, Never" responses used a point system from 0 to 6. "Daily" responses were given an initial value of 6 points. "Weekly" responses were given an initial value of 5 points, and so on, which can be seen in Table 3.

Then, each action was given a specific fraction of those points that was proportionate to its carbon footprint. For example, flying in an airplane gave an average carbon footprint of about 561 kg, which would serve as the maximum carbon footprint. Composting and recycling saved about 0.136 kg of carbon each time the action was done, so only 0.024% of points would be earned. So if an individual recycled or composted daily, they would only earn .0876 points.

There is no direct carbon footprint for signing a climate change petition, donating to a climate change organization, or talking about climate change with another person, so estimates were made in relation to the other actions listed.

Additionally, while initially the question regardi political stance was split into seven categori with them being slightly liberal, moderately liber highly liberal, slightly conservative, moderate conservative, highly conservative, and neutral, three conservative options were grouped into o "conservative" group because there were only few respondents in each of the three conservati categories. Sixteen respondents answered "slight conservative", 18 respondents answered "moderate conservative", and 5 respondents answered "highly conservative".

RESULTS

The correlation between a person's age and the actions they have taken towards combating climate change and the correlation between a person's knowledge on climate change and the actions they have taken were studied by conducting a survey. The survey was completed by 333 people and had several questions regarding participants' thoughts Table 2: The Tukey post hoc test p-values of climate on climate change and how frequently they took score between different levels of background knowledge. climate change related actions in the past year in 2019. Other demographic information such with subcategories as slightly liberal, moderately as their age, sex, ethnicity, income, etc. were liberal, or highly liberal, and out of the 84.3% of the also recorded. The majority of respondents were respondents who live in the United States, about female, making up 62.5% of the respondents of 80.9% are from California. the survey. Seventy-three percent of respondents self-described themselves as leaning more liberally, Results showed that older participants were more



Figure 2: People with more background knowledge about climate change tended to have higher climate scores. Error bars = 1 standard deviation from the mean climate score. Between background knowledge scores of 1 and 5: p = 0.041, 2 and 5: p = 0.002, 3 and 4: p = 0.007, 3 and 5: p < 0.000, 4 and 5 p = 0.048.



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Background Knowledge	Background Knowledge	P-value
1	2	0.982
1	3	0.844
1	4	0.426
1	5	0.041
2	3	0.966
2	4	0.182
2	5	0.002
3	4	0.007
3	5	0.000
4	5	0.048

likely to take action on climate change (Figure 1). Each participant received a climate score depending on how regularly they did certain actions to limit their impact on the environment. The climate score increases as a respondent takes more actions to limit the impact on the environment. Using a Tukey post hoc test it was found that the difference between scores earned by the 11-20 age group and the older than 60 age group had a p-value of 0.002.

was 0.005 (Table 1).

Moreover, as an individual's background knowledge about climate change increased, their climate score also increased (Figure 2). A person's background knowledge was self-reported on a scale from 1 to 5, with 1 as having no knowledge and 5 as being extremely knowledgeable. A one-way ANOVA test p-value was < 0.000. And the difference in scores between people who had a 2 on the scale and a 5 on the scale had a p-value of 0.002 (Table 2).

The study also showed that people with more background knowledge about climate change tended to believe that climate change was a larger How Large Of An Issue Climate Change Is vs. Background Knowledge On Climate Change



Figure 3: The overall trend shows that a higher amount of background knowledge about climate change was positively correlated with the belief that climate change is a large issue. Error bars were 1 standard deviation away from the mean score; P-value from PLUM ordinal regression < 0.00; P-value between background knowledge scores of 1 and 4 = 0.005, 1 and 5 = 0.008

issue than people with less background knowledge (Figure 3). Respondents scored themselves on a scale from 1 to 5 with 1 as having no background

knowledge and 5 as having extensive knowledge about climate change. The p-value found from a PLUM ordinal regression was < 0.000, and the p-value between background knowledge scores of 1 and 5 was 0.005.

The study also revealed that as someone continued to lean more liberally in their political stance, they tended to believe that climate change was a larger issue (Figure 4). People who answered that they were highly liberal tended to rate climate change as a larger issue, while people who answered that they were conservative tended to score it at a lower value. The p-value from the PLUM ordinal regression was < 0.000. Due to low numbers of non-liberal respondents, people who self-described as strongly, moderately, and slightly conservative were grouped for this analysis. The large standard deviation in the conservative category could be due to the grouping of the three categories.

DISCUSSION

The study conducted has shown that knowledge about climate change and age have an effect on





Response	Points
Daily	6
Weekly	5
Monthly	4
Every other month	3
A couple times a year	2
Yearly	1
Never	0

Table 3: The initial number of points given to each response.

how much action a person takes to limit the impact on the environment. The first portion of t hypothesis regarding age is supported by result The difference between the points earned by the 1 20 age group and the older than 60 age group had p-value of 0.002 (Figure 1 and Table 1). In addition the second portion of the hypothesis regarding background knowledge about climate change also supported by the study (Figure 2). The p-val for the difference between people's climate scor who had a 5 in background knowledge and a for background knowledge was 0.002. The over p-value was less than 0.000 (Figure 2).

Nonsignificant results were also found. T relationship between someone's highest level education and yearly action was not statistica significant. However, because the relationsh between someone's climate score and the background knowledge about climate change w correlated, this implies that further study is need on the effect of education on climate-related actio Additionally, someone's political stance also did have any significant correlation with their year action. This means that there were factors oth than someone's political stance that affected the yearly action. Someone's income also didn't have Table 4: The ratio of points given depending on the any correlation with their yearly action or how large carbon saved/emitted from each action. of an issue they thought climate change was. This



also means that there were other factors other than income that contributed to their yearly action or how large of an issue they believed climate change was. This may also be because the climate score weighted air travel fairly heavily and wealthy people tend to have more opportunities to travel by plane.

One source of error could have been caused by the respondents self-scoring how much background knowledge they had about climate change. Because they were self-reporting their scores, the data regarding background knowledge might not have been as accurate as it could have been. A study regarding self-report bias in alcohol consumption found that self-reporting could lead to unreliable results (3). Also, while initially the survey did divide conservatives into three groups (slightly conservative, moderately conservative, and highly conservative), most respondents were liberal, so conservatives were grouped together in order to have a larger sample size. This is most likely due to the fact that most respondents were from California, a predominantly liberal state, and because

eir	Action	Ratio	Carbon Saved/Emitted
ts.	Flying in a Plane	-1	561 kg
l- da	Composting/Recycling	0.00024	.136 kg
on, ng is	Taking public transportation	0.016	9.17 kg
ue es 2	Ride a bike/skateboarded/ rollerbladed instead of driving	0.0016	.915 kg
all	Changing to a more eco-friendly diet	0.97	544 kg
he of Ily nip	Signing a climate change petition	0.003	
eir as	Donating to a climate change organization	0.009	
ea on. n't	Buying from a more eco-friendly brand	0.74	415 kg
rly Ier eir	Talking with others about climate change	0.0002	

survey about climate change.

In addition, although not all demographics were well represented in the experiment, significant results were obtained from demographics such as women and white people that were well represented in the study. Care should be taken when extrapolating results regarding people with lower amounts of background knowledge or people who leaned more conservatively to the general population as the sample group studied in this experiment underrepresented some parts of the public.

Based on the findings in this experiment, groups who are younger and have less knowledge about climate change would benefit from outreach the most. This could be done by educating people who are still in school by having classes or units dedicated to teaching about climate change, or by having scientists come in class to discuss it. It would also be beneficial to encourage students to change aspects of their daily lives to limit their carbon footprint. By targeting a specific demographic using certain techniques such as depicting climate change as a current and personal issue, more people would participate in combating climate change (7).

Further research would be beneficial to this study. Additional research could focus more on people's opinions in regard to climate change instead of focussing on their actions. Location could be a factor that could be analyzed further, such as a person's country, state, city, or even zip code. Since most respondents were from California, more information could be collected from people in other areas of the country and other countries around the world. Further research could also include other demographics that weren't well represented in this study, such as further research for conservatives or for older demographics. Further studies would be helpful in understanding people's engagement with regards to the environment.

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Full Cost Pricing's Effect on Human Behavior and the Economy

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ABSTRACT no direct benefit for mitigating the environmental impacts of their actions this can lead to widespread The impacts humans have on the earth are environmental issues and overuse of resources. not sustainable, the current rate of resource The tragedy of the commons is often viewed as use would need the equivalent of 1.6 earth's an environmental issue, but it is just as much an to be sustainable (1). When humans purchase economic issue. With the overuse of resources, products we are not held fully accountable we are limiting our ability to use or access these for the negative impacts of these purchases, resources in the future (5). because of this we fail to see and mitigate the impacts of our consumer actions. The process Full-cost pricing is the process of taking into account of including all the environmental costs of a all the costs of production when determining the product into its retail cost is called full cost price of a product--including negative externalities pricing. By paying the full cost price we can and environmental costs.(6) Businesses, driven by make the planet more sustainable. The full profits and lack of regulations to take into account cost price of 9 household products were negative environmental costs into the price of their calculated and surveyed a population to better items, fail to implement full-cost pricing as seen understand how willing they were to pay through artificially low prices of goods such as full cost pricing. I hypothesize that if people factory-produced meat. (7) Because of this, people were able to learn about full cost pricing and are unaware that we are using resources past their how it mitigates the negative impacts on the sustainable yield, which means future generations environment they would be more willing to will not have access to these resources. However, if pay higher prices for these items. Based on we all knew about the prices we should be paying, the results, people were willing to pay a higher perhaps our mentality and consumer choices would price for their goods to cover the traction of change. Full cost pricing could be an effective way environmental damages after learning about of reducing our impact on the environment such as: full cost pricing. Studying this behavior shows manufacturing, driving, wasting, etc. that when informed, people prefer their money How do we convince consumers to accept a higher to go towards reducing environmental impacts.

INTRODUCTION

price than they are used to paying in order to mitigate the impacts of their purchases? To investigate this, I studied how people changed their attitude towards the environment with the knowledge of full The economy and the environment are often viewed cost pricing to see how we could move towards a as mutually exclusive: corporations fuel climate more sustainable future. In this study, I estimated change to maximize profits and boost the economy the full cost price for 9 commonly used household while spending money to support the environment products based on their environmental impacts is considered to have no clear economic benefits(2). and restoration costs. I hypothesize that if people Businesses rarely have a direct financial incentive learned about full cost pricing and how it mitigates to reduce their environmental impact and maximize the negative impacts on the environment they would profits at the expense of the environment (3). But be more willing to pay higher prices for these items. perhaps the two sectors are more related than we A survey was used to measure people's reactions to imagine. The tragedy of the commons illustrates full cost prices of these 9 common items and how the common human practice of overusing resources learning about full cost pricing affected what people past their sustainable level (4). When people see were willing to pay for these items.



METHODS

In order to interpret the behavior of consumers with the implementation of full cost pricing, I made a three-part anonymous survey. Consumers were asked their price preferences, thoughts about full costs, their actions followed by questions about their demographics. Participants were asked to select which of the 9 household products featured in the survey they normally purchase. Then participants were asked 1. how much they were willing to pay for those items and 2. what they thought of a given price: too low, a little low, just right, a little high, or too high. The given price was the full cost price but was not labeled as such. After they provided answers for all the products they regularly purchase, I provided an explanation as to what full cost pricing is, why the given prices were higher than they may have expected and had them repeat the same set of 2 questions for each product again. Then, I asked some questions about the survey itself such as: If you did not approve of the full cost price, what was the reason, what are future actions takes to make a product from production to product you are willing to take apart from spending a higher price, etc. Lastly, there were a few demographic questions on household income, education, race, political inclination, and gender. The survey was constructed so that people could not go back and fix their answers to ensure their responses were not biased nor bought.

In order to build this survey, I had to estimate the full cost price of the 9 unique items featured in the survey. Determining the full cost price of a product was a 3 step process. 1st I determine the steps it



Figure 1: After being educated about full cost pricing of common household products, people were willing to pay more for most of these items. N=57,61,32,10,53,10respectively for each product type. * = p < 0.05.

Normal Retail Price (The price that you are used too)	The Full Cost Price Non-organic California grown heirloom Tomatoes-\$4.26/lb	
Non-organic California grown heirloom Tomatoes-\$4/lb		
White Rice \$1/lb	White Rice \$2.41/lb	
Beef \$4.50/lb	Beef \$9.80/lb	
Denim Jeans-\$34.00 per pair	Denim Jeans-\$50.80 per pair	
Michael Kors Wallet-\$50.00/item	Michael Kors Wallet-\$50.30/item	
Cotton Night shirts-\$15.00/pair	Cotton Night shirts-\$40.80/pair	
Oak floor from the Brazillian rainforest-\$6/sqft	Oak floor from the Brazillian rainforest-\$6.10/sqft	
Paper/Cleaning Hygienic Products-\$2.00/pack	Paper/Cleaning Hygienic Products-\$2.99/pack	
Sheepskin Carpet-\$4.00/sqft	Sheepskin Carpet-\$4.20/sq ft	

Table 1: On the left is the normal retail price and the right is the full cost price I calculated as described in the methods section.

on the shelf. 2nd at each step of production, I figured what resources were used and the environmental impacts of those resources used. 3rd figured out the cost to restore those environmental impacts per land area and divided that cost but how many of those products could be produced in an acre. For example, cotton fields are grown in a monoculture that affects the soil and other plants, (8) shipping has a low net energy yield and consumes fossil fuel (a non-renewable resource), etc. For example, activated charcoal helps alleviate the heavy use of



Figure 2: After being educated about full cost pricing of various material items, people were willing to pay more for most of these items. N=45, 23, 52 respectively for each product type. * = p < 0.05.



Figure 4: Fewer people think the costs are too high after Figure 3: Over here, we can see that people become more accepting of the full cost prices. We can see that learning about the full cost pricing. The Chi-squared more people think the price is just right for what they are P-value = 0.00966 paying. Chi-squared P-value = 0.009338

female, 43.48% were male, and 2.17% were pesticides. I would determine how much land was listed as other, 45,65% were conservative (Highly converted with pesticides to make the item and then conservative: 2.17%, Moderately conservative: calculated how much charcoal would be needed per 28.26%, Slightly conservative: 15.22%). 45.65% acre. I would then repeat this step for all of the were liberal (Highly liberal: 28.26%, Moderately other harmful processes of each household product. liberal: 10.87%, Slightly liberal: 6.52%). 61.7% have a Masters degree(MA, MS, MEd), 25,53% have a Bachelor's degree (BA, BS), 4.26% have RESULTS less than a high school diploma, and 6.38% have 54 people completed the survey. Out of these 54 some other form of education. My data on full cost people, 80.43% are Asian or Asian American, pricing is most representative of people in the 8.7% are white or caucasian, 2.17% are American 50k -150k range.

Indian Or Alaska Natives, and 8.7% are listed as other with the specifications of mixed race;. 63.04% live in a City or Urban community, 30.43% live in a Suburban community, and 6.52 percent live in a Rural community. 54.35% of them were



Figure 5: Everyone thought that the full cost price was too high at first, but some people were willing to pay the full cost afterward. Chi-squared P-value =0 .049496.







Figure 6: This figure showcases the reasons as to why people did not want to pay the full cost price. The leading reasons are because they would prefer to purchase a more environmentally friendly alternative to the product, the prices were higher than what they were used too, and that cheaper versions were available.



Figure 7: This figure showcases alternatives actions consumers agreed to do apart from paying the full cost price. The leading reasons are reusing, reducing, and recycling, using reusable items, and purchasing food from local farmers33.

is higher than what they pay, they are willing to pay a higher price. In figures one and two, once is higher than prices that we are used to paying. respondents realized that they pay more than what However, 100% of the people were willing to do is required for the full cost price, they prefer to any of the alternatives to lowering their ecological spend lower prices as seen with cleaning supplies footprints: support local farmers, upcycle, being and carpet. The p-value of all the items go as more conservative, educate one another, and reuse, followed: Tomatoes p=0.0256, Rice p=0.1593, reduce, and recycle, etc. (Figure 7). Meat p=0.0011, Wood flooring p=0.2361, Cleaning supplies p=0.1253, Carpet p=0.1412, Jeans p=0.0034, Wallet p=0.0001, T-shirt p=0.0001. In figures 3-5, we can see how people become more accepting of some of the full cost prices of goods. However, other products such as meat, cleaning supplies, wallets, wood flooring, and jeans were not statistically significant before or after learning about full cost pricing - The chi-squared p>0.05. When asked why they did not want to pay the full cost price of some of the items: 26.37% answered saying that they would prefer to purchase a more environmentally friendly alternative of the product instead, 17.8% say that there is a chapter version of the product available, and 16.48% answered saying they want to know more about full cost pricing before making a big decision of their payments. Apart

However, when they realize the full cost price from this, 29.67% answered saying that the higher price is not within the family budget or the price

DISCUSSION

After learning about full cost pricing the price respondents expected to pay became closer to the full cost price (Figures 1 and 2). This was the case for 5 of the 9 items in the survey (Tomatoes, Meat, Jeans, Wallets, and T-shirts). These products are purchased pretty regularly so we would expect the consumer to be more familiar with how much they are willing to spend. However, the non-significant difference in the price respondents gave for rice and cleaning supplies does not fit with this explanation. Furthermore, after learning more about full cost pricing people became more accepting of the higher prices to mitigate environmental impacts (Figures

3-5). Products that did not have many responses, **REFERENCES** wallet, flooring, and carpet, were not statistically 1. Wackernagel, Mathias and Beyers, Bert. Translated significant, which shows that our respondents were by Rout, Katharina Ecological Footprint Managing our less familiar with the prices of these items. Biocapacity Budget. New Society Publishers, 2019-09-03

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Overall, if I were to do this experiment again, I would ensure that more of the population was targeted as a whole to include a more diverse pool of different incomes, ethnicities, and education degrees. Additionally, the survey was guite long and several people did not finish it. Finding a way to study more people's behavior would require a shorter survey. Finally, I would spend more time and resources to more robustly calculate the full cost price. Though I was able to come up with an estimate of the full cost, there is room for improving this algorithm.



Challenge Advisory, Oct. 2018, www.challenge.org/

"Learning to analyze data was a big takeaway for me."

> -Colin Saltzgaber, Summer Research Program Student



Analyzing water quality during the summer research program.

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