High School Understanding of the Cradle-to-Grave Process of Electric Vehicles

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ABSTRACT

The existing shift from combustion engine vehicles to electric vehicles has created this perception that electric vehicles are flawless. The purpose of this study was to measure how aware people are of the cradle-to-grave process of electric vehicles, measuring their complete environmental footprint. This study conducted an experiment among high school students across all grade levels at one school to examine their understanding of the environmental effects of electric vehicles. Students (N=278) were asked to answer seven demographic questions, 7 environmental questions, 6 questions about the cradle-to-grave process, and 5 questions about combustion engine vehicles. Students self-reported their knowledge about each of these categories, on a 1-5 Likert scale. The results indicated that the students were not as aware about the cradle-to-grave process of electric vehicles, while they knew statistically more about combustion engine vehicles. The implications of this study suggest a need for better education regarding electric vehicles through schools and better online research, which in turn, will create a more informed society.

Introduction

With electric vehicles on the rise, it is important to know their true effect on the environment. Electric vehicles are portrayed to be a key solution to climate change due to their zero emissions. However, electric vehicles have much more of a negative impact on the environment than the media displays. This paper seeks to analyze to what extent high schoolers understand the cradle-to-grave process of electric vehicles. Cradle-to-grave is defined as "impacts at each stage of a product's life cycle, from the time natural resources are extracted from the ground and processed through each subsequent stage of manufacturing, transportation, product use, and ultimately, disposal" (European Environmental Agency, n.d.). This research hypothesizes that there will be a lack of understanding of the cradle-to-grave process of electric vehicles across high school grade levels due to an insufficient educational focus. However, the advanced placement environmental students (APES) will have a better understanding of the issue. APES is an environmental science class that allows students to deepen their understanding of various environmental topics (Las Virgenes Unified School District, n.d.). According to the Stanford Schools of Earth, Energy & Environmental Sciences, education can solve climate change and its problems. This research will show the overall lack of understanding of the effect of electric cars but more so the scarcity of climate change awareness in education. In the future, this can improve how climate change is taught in schools. As a high schooler, there needs to be more attention brought to climate change throughout high schools across the world. Since high schoolers and electric vehicles are significant parts of the near future, it is crucial to know the actual effects of both the students and vehicles on the environment.

Literature Review

This study aimed to determine the High school perceptions of the cradle-to-grave process of electric vehicles. The hypothesis for this study was as follows: Students will not be aware of the cradle-to-grave process of electric vehicles,

and APES students will be more educated. The theoretical biases of this paper include the socioeconomic area, being surrounded by electric cars, and the education that respondents may have received regarding electric vehicles.

Where do Students Receive Information About Climate Change

Different political parties have been arguing over climate change issues for decades. The discrepancies in arguments primarily arise due to the fact that each side is arguing over different aspects of climate change. Yu Luo, an associate psychology professor at the University of British Columbia, and Jiaying Zhao found that multiple factors affect this, from the source of information selection to the selective reading of information (Luo et. al, 2021). One aspect that continues to grow, whether it is because of environmentally conscious decisions or not, are electric vehicles. As electric cars grow in popularity, large companies will continue to control the electric car market. Moreover, one of the most successful chief executive officers of electric vehicle companies, Elon Musk, has begun to branch out into various fields as well. His most recent purchase included "Twitter," a popular social media platform in 2023. Many researchers acknowledge the growing trends in social media use to gather information on climate change throughout their articles. However, many also discuss the lack of credible information and biases on climate change issues on various social media platforms. "Credibility of climate change denial in social media," by Abhishek Samantray and Paolo Pin, specifically discussed how Twitter's platform has a strong ability to influence beliefs at a large scale (Samantray et al., 2019). As Elon Musk purchased forty-four billion dollars of Twitter stock, the positively skewed Tesla tweets will likely rise (Wong et. al, 2022). It is important to acknowledge where people are getting their information about climate change as social media, especially Twitter, can have disinformation about the science behind electric vehicles. This could be why some are unaware of the harmful effects that are part of the cradle-to-grave process. Although zero emissions are produced on the road, various factors of vehicle construction and destruction are often overlooked by the mass media. This is why it is essential to teach children about electric vehicles and their harmful effects on the environment, from lithium mining to manufacturing to battery disposal. Education is the key to solving climate change issues (United Nations, n.d.). Continuing to improve climate change education will create an informed generation on climate change issues and how to solve them.

Harmful Effects of Lithium Mining

The first step in constructing a new electric vehicle includes gathering the necessary Earth metals to create the battery. Lithium is a lightweight metal used in the cathodes of lithium-ion batteries, which power electric vehicles. "High demand and prices for lithium send mines into overdrive", an article NPR by Camila Domonsoke, stated that the rise in electric car popularity has caused a massive surge in lithium mining (Domonoske, 2022). Furthermore, Zacume's study found that lithium mining harms the surrounding environment through air contamination, water pollution, soil degradation, and more (Zacune, 2013). These negative environmental effects are also lowering the quality of life for people in the surrounding area. "The Side Effects of Lithium Mining" by Laura Simpkins discusses the harmful effects of lithium mining on farming because of the large amounts of water that are used, as well as everyday experiences because of the toxic fumes that are released into the air throughout the mining process (Simpkins, 2021). Although this is not as much of a problem in developed countries, people in developing countries seem to struggle more with this issue. Many live in close proximity to these mines because they often do not have any other option. This part of the electric vehicles is rarely covered in the media as it would ruin the "zero emission" narrative that large companies have created in order to boost sales and prove combustion vehicles to be outdated. This information is vital to consumers because they have been sold on the wrong idea, moving towards a world where one can be part of the solution by driving an electric vehicle is not necessarily true. Both Zacune and Simpkins' studies reiterate the negative effects of the lithium mining process regarding electric vehicles. Although there are many problems with oil mining and refining that are no longer a factor in electric vehicle production, there are an entire new set of issues that need to be addressed in just the preoperative stage of the vehicles.

Negative Impacts of Battery Disposal

At the end of the cradle-to-grave process, the disposal of the batteries also has negative effects that people are unaware of. Jean-Paul Skeete mentions that due to the many different materials that make up a battery, a battery is assessed for the quality of materials it still has to offer (Skeete et. al, 2020). Gavin then discusses how the future of battery recycling is shaky because of the large increase in battery waste due to the rise in electric vehicles. Recycling batteries was already difficult enough with only small parts of these batteries being feasible for use, an overflow of batteries will likely result in finding these batteries throughout landfills and incinerators. This is continually hazardous as the Environmental Protection Agency (EPA) already views smaller, household lithium-ion batteries as toxic waste and does not recommend people to dispose of at home, but rather at a recycling plant or hazardous waste collection facilities (EPA, n.d.). The reason it is so bad to find lithium-ion batteries in regular waste management facilities is because of the hazards they create as they are very flammable and fire prone, which in turn will create fires that can burn for years. Fredrick Larsson found that the smoke and fumes emitted from these fires can be highly toxic because of the release of hydrogen fluoride (Larsson et. al, 2016). When looking at this on a bigger scale, the Centers for Disease Control and Prevention described the negative effects of low levels of hydrogen fluoride can irritate the eyes, nose, and respiratory tract. However on a larger scale, breathing high levels of hydrogen fluoride can even cause death due to an irregular heartbeat or from built up fluid in the lungs (CDC, n.d.). The effects of unsafe battery batteries shows the importance and negative effects that these large car batteries have on the environment and humans.

Gap in the Research

Many studies have looked into the different types of environmental issues, and how much highschool students know about them. The best representation of both that fit the topic ended up being the foundational source "The Status on the Level of Environmental Awareness in the Concept of Sustainable Development Amongst Secondary School Students" by Arba'at Hassan, Tajul Ariffin Noordina, and Suriati Sulaimana. This study used a quantitative research method where the researchers administered a questionnaire to secondary school students in Malaysia. The research concluded that the respondents' understanding of environmental issues was "high" (Hassan et. al, 2010). Since this research was largely focused on general environmental aspects, it was important to base the study on research that also more closely focused on electric cars as well. Various reputable sources were used to construct the self-defined questions. The Oxford article "Global Warming Emissions from Manufacturing Electric Vehicles" by Rachel Nealer, David Reichmuth, and Don Anair gave the researcher the knowledge to form self-defined questions. The article discussed all the negative effects associated with the manufacturing of electric vehicles and extraction of materials, such as lithium, for production (Nealer et. al, 2015). To focus specifically on the vehicles, "Cumulative Emissions of CO2 for Electric and Combustion Cars: A Case Study on Specific Models" by Maciej Neugebauer, Adam Żebrowski, and Ogulcan Esmer was used. This case study found how detrimental electric cars really are to the environment when looking at CO2 emissions, and then allowed the researcher to build the questions (Neugebauer et. al, 2022). This source chose these sources because they were the closest to the gap that was trying to be identified. Hassan's study allowed the researcher to ask the general environment while the other two studies allowed the researcher to create questions regarding electric cars, addressing the gap in the research.

Methods

The goal of this study is to determine what respondents do and do not know about the cradle-to-grave process of electric vehicles. A quantitative survey was used to gather the information. This study most closely aligns with Hassan's study, which looked at the level of environmental awareness in the concept of sustainable development. Many of the survey questions from this study were based on and derived from Hassan's study. This method of data collection

allows the data to be collected specifically from each respondent and then compared in order to find correlations across questions.

Population

This study was conducted across all grade levels at Calabasas High School (CHS), where 278 responses were collected. CHS is a large, high-performing public high school with 2,005 students. The school is made up of 78.5% White, 9% Latinx, 5.5% Asian, and 5% African American students. It is a high-income school, in a high socioeconomic area, with only about 10.6% of the student population on Free-Reduced Lunch. CHS is a co-ed, offering grades 9, 10, 11, and 12. Of those who participated in the study, 51.8% of respondents were in 9th grade, 9.4% of respondents were in 10th grade, 14.4% of respondents were in 11th grade, and 24.5% of respondents were in 12th grade. In addition, the respondents were 55.4% White, 9.7% Middle Eastern, 8.7% Latinx, 4.35% mixed, 1.8% African American. 52.2% of the participants were female and 45% were male, while the rest opted not to say. This study's demographic was made up of 51.8% freshman (9th grade), 9.4% sophomores (10th grade), 14.4% juniors (11th grade), and 24.5% seniors (12th grade).

Instruments

All of the questions from this survey were based on Hassan, et al. (2010) or self-defined based on knowledge from Nealer (et. al) and Neugebauer's, (et. al) studies (2022). The survey consisted of four main sections: demographics, environmental questions, electric vehicle questions, and combustion vehicle questions. These three sections each had ten, eight, and five questions respectively. Throughout the survey, there were 278 responses used to form the data analysis.

Sample Selection

The sample of students taking the survey was a stratified random sample. The survey was presented to all English classes, of all grade levels. This meant every student at CHS had the ability to take the survey as English is a 4 year requirement at the school. This was the most effective way of accessing all students. With an approximate 2,000 student body, 278 respondents means a 13.9% response rate. This sampling method allowed for all members of the targeted population to be equally as likely to be chosen to take the survey. The data was collected throughout two weeks, through this process, 278 responses were used in the study.

Implementation

The survey was created using Google Forms, a survey administration software offered by google. The survey was then posted on the Google Classroom streams of every English class at CHS. Students were then able to respond to the survey using computers, tablets, smartphones, or any other electronic device. Once a respondent was identified, the student was assigned a number in order to ensure anonymity in an attempt to avoid bias and pressure. The data was analyzed with Google Sheets and XLMiner data analysis toolpaks to analyze the data.

Findings and Analysis

This section explains the findings of the experiment about the high school understanding of the cradle-to-grave process of electric vehicles. The students responding to this survey were asked questions via a survey in order to demonstrate their understanding of the topic. Students who completed the survey answered questions regarding the source of their

knowledge, their understanding of the cradle-to-grave process, and various perceptions. Various questions were asked each of these in regards to the general environment, electric vehicles, and combustion engine vehicles. The responses were then evaluated and calculated for their significance using Social Science Calculators.

Upon the completion of this experiment, the research primarily consisted of quantitative analysis of the data collected. The analysis began by looking at how much students felt they knew about general environmental issues, then looked at electric vehicle knowledge, and finally combustion vehicle knowledge. Using the histogram creation feature of Google Sheets, a visual representation of the data was created.

Findings: Knowledge on Environment

In this first section, students were asked questions regarding general environmental issues. This was used to gauge what students knew about environmental issues so that the responses in other sections could be compared to the responses in this section. This allowed the researcher to get a better understanding of how students would respond in other sections, based on their scores in this section.

The first question to be analyzed, *I feel aware of environmental issues*, demonstrates the students general understanding of environmental issues. The researcher is able to see how students' knowledge across all environmental issues affects their understanding of the impact of electric vehicles.
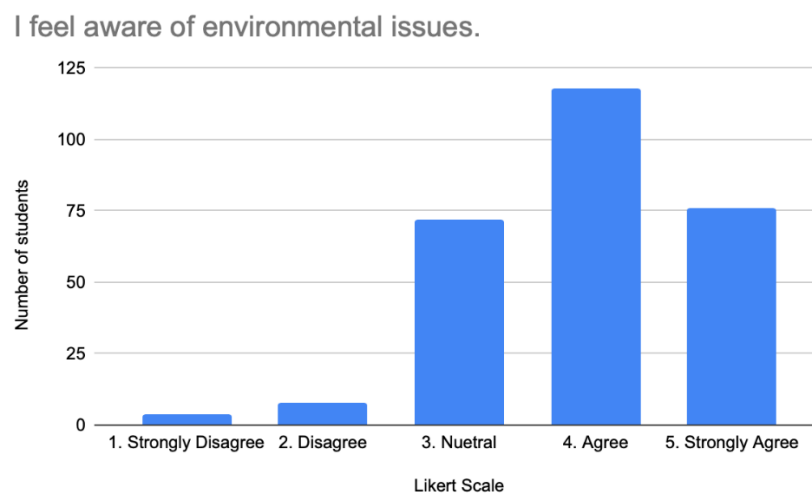

Figure 1. A histogram of responses displaying how aware students feel regarding environmental issues rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

As seen in Figure 1, most students rated their knowledge on climate change as a three, four or five (neutral, disagree, strongly agree respectively). Meaning that the overall consciousness of students taking this survey feel that they do know about environmental issues. This demonstrates that the students taking this survey feel that they have been properly educated on such topics regarding the environment. The average answer of this question was 3.91 with a standard deviation of .88. Furthermore, APES students had an average answer of 3.98 while non-APES students had an average answer of 3.89, meaning that APES students felt more aware, likely due to their education. However, this difference was not enough for it to be statistically significant. Since climate change is a key factor in science and research today, it is important that the younger generation is informed about the topic. The next generation is key to solving the world's climate change crisis and it can not be done without educating these students on the problems presented.

To get a better understanding as to how students responded individually, question eight can be broken down into male and female responses. This breaks the respondents almost in half to allow the researcher to better understand how individuals are responding to the survey.
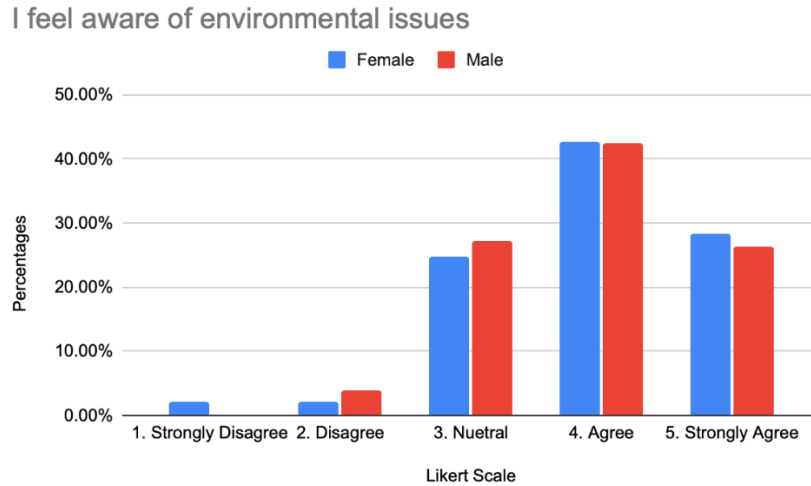

Figure 2. A histogram of responses displaying how aware male and female students feel regarding environmental issues rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 2 demonstrates that regardless of gender the overall consciousness across students is still between the numbers three, four, and five on the Likert scale. However, no female respondents answered "1," meaning none of the female respondents feel unaware of environmental issues. There was also no significant gap in the distribution of genders among answer choices. This can be seen through the graph as the respondents answered similarly at each point of the Likert scale, regardless of gender.

The same question can be broken down into grade levels, splitting the respondents between upperclassmen and lowerclassmen. Upperclassmen are defined as juniors and seniors (11th and 12th graders) while lowerclassmen are defined as freshman and sophomores (9th and 10th graders).
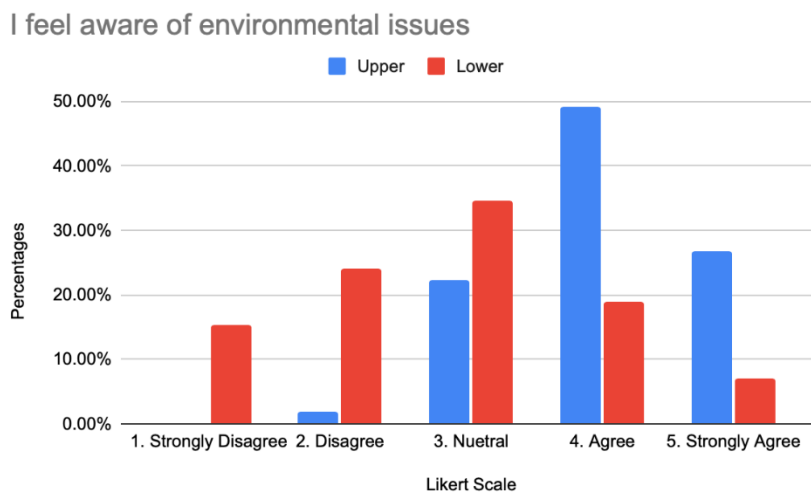

Figure 3. A histogram of responses displaying how aware upperclassmen (11th & 12 grade) and lowerclassmen (9th & 10th grade) feel regarding environmental issues rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 3 demonstrates that lowerclassmen saw themselves as less knowledgeable on the environmental issues while the upperclassmen thought they knew more about the topic. This could be for a variety of reasons. Lowerclassmen may have begun to realize the severity of the environmental crisis and acknowledge they are not aware of all the issues. Another explanation could be because of the higher extent of education that upperclassmen have received. Regardless, upperclassmen believed to have a better understanding of environmental issues is promising because it shows that the education that these students are receiving is effective.

The second question to be analyzed was question 9, *I read about environmental issues and solutions in the mass media*, allowing the researcher to see where students taking the survey are getting their information. This will help the researcher understand the credibility of the information about general environmental issues, which would then translate into the impacts of electric vehicles.
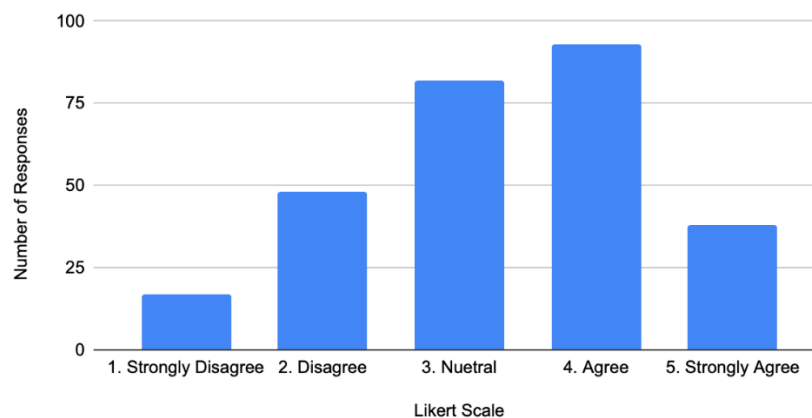

Figure 4. A histogram of responses displaying how aware students feel regarding environmental issues rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 4 shows that people are not getting their information from the mass media. Mass media was defined as "the main means of mass communication, such as broadcasting, publishing, and the internet, considered collectively," per the Oxnard Dictionary. The average answer for this question was 3.31 and had a standard divination of 1.1. APES and non-APES students both had an average answer of 3.31 as well, meaning that there is no statistically significant difference between the two groups of students at the school. Therefore, most students felt that they did not get their information from online websites and television broadcasts, rather other sources of information. This implies students looked into their information through credible sources, meaning their claims and answers later in the survey will be stronger and more developed based off of deeper research, rather than just shallow answers based on the general media.

In order to take a deeper look into how students responded based on different demographic groups, this question was broken down into male and female responses. This separation by gender may allow the researcher to create inferences based on the gender of each respondent.
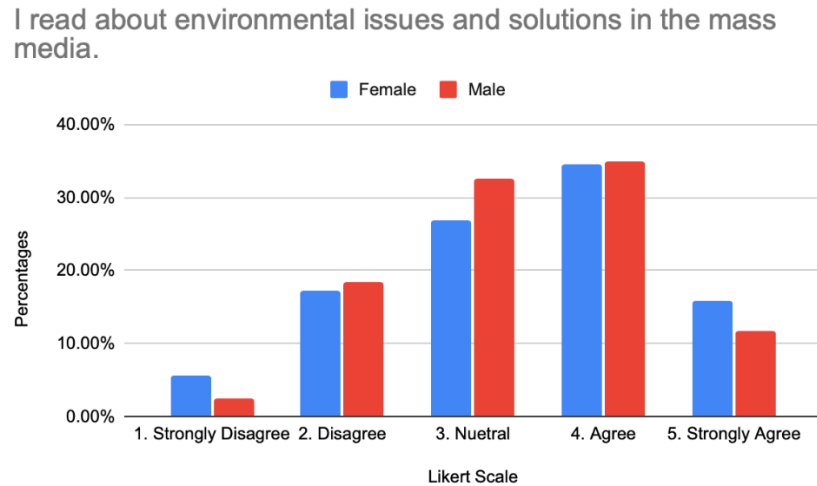
Figure 5. A histogram of responses displaying whether or not male and female students read about environmental issues and solutions rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

The figure above demonstrates that gender does not play a role in where students get their information due to the fact there is no statistically significant difference between the two groups. Throughout every likert scale option, the answers were statistically similar throughout the different genders. This means that students would look into their information from sources that require a deeper dive with more research to reach, likely increasing the credibility of the knowledge that they have.

The same question was further broken down into grade levels, with responses divided into upperclassmen and lowerclassmen.
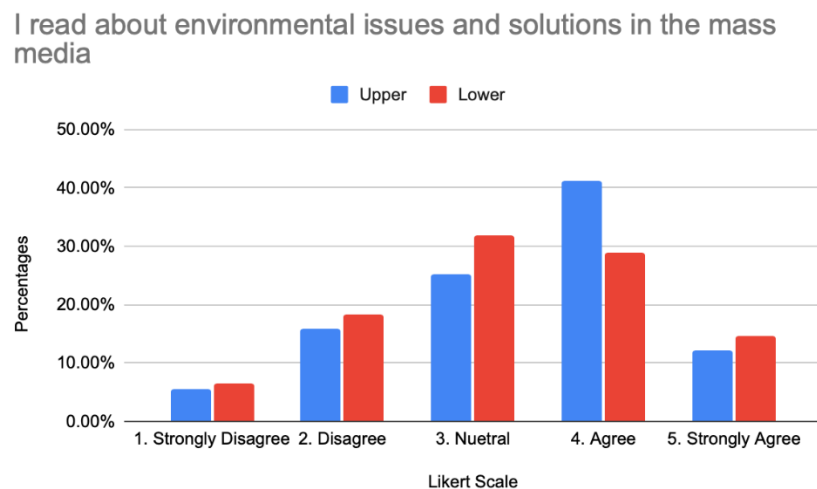

Figure 6. A histogram of responses displaying whether upperclassmen (11th & 12 grade) and lowerclassmen (9th & 10th grade) read about environmental issues and solutions regarding the cradle-to-grave process rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Similarly to previous comparisons, there was no significant difference between the different grade levels. All points on the Likert scale were similar, with only about ten percent more of the upperclassmen rescinded with "4" on the Likert scale. However, even this slight difference was not enough to be deemed statistically significant, meaning

that where the students get their information from regarding the environment is generally the same. This either means that the students are not learning new ways to conduct research and find better media sources, or they have been taught this at a young age and do not need to further their skills.

Findings: Electric Vehicle Knowledge

In this section, students were asked about their knowledge regarding electric vehicles. This section was a predominant part of the research as it allowed the researcher to see how students felt about environmental vehicles. This section was compared to section two, general environmental knowledge questions, and section four, combustion vehicles questions.

The first question to be analyzed in the second section regarding electric vehicles was, *I feel aware of the cradle-to-grave process of electric vehicles*. This question demonstrates the students general understanding of electric vehicles and the pollution they cause.
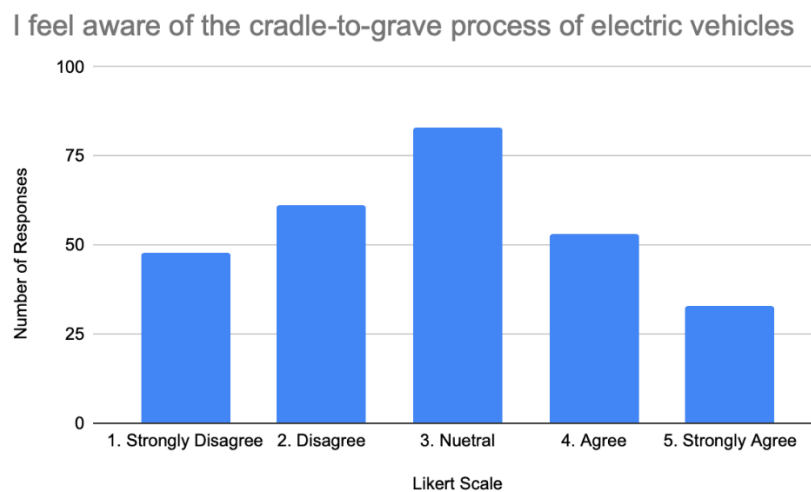

Figure 7. A histogram of responses displaying how aware students feel regarding the cradle-to-grave process of electric vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 7 demonstrates a relatively even distribution of students who understand the importance of the cradle-to-grave process of electric vehicles. The average answer of this question was 2.86 with a standard deviation of 1.25. Student responses were evenly distributed among Likert scale points, but most students answered "3" or "neutral" on the Likert scale. This demonstrates that across the respondents, some students are more aware of the cradle-to-grave process than others. Some respondents could be more interested in the topic then others, making them more likely to do their own research on their own. However, since only 33 respondents feel that they are fully aware of the cradle-to-grave process of electric vehicles, it means that the respondents are uneducated on the topic. Since 83 respondents answered "3", 61 answered "2", and 48 answered "1" on the Likert scale, 192 of the respondents feel they are not aware of the process. Since there is such a wide range of knowledge for students, this likely means that the education these students receive is not sufficient enough for them to feel that they have a good understanding of the process. It forces students that are interested in the topic to do research on their own in order to gain a better understanding of the topic. Furthermore, APES students had an average answer of 2.92 while non-APES students had an average answer of 2.84, meaning that APES students felt more aware of the process, likely due to their education. Although the APES students did know more, this was not found to be statistically significant. In addition, due to CHS being in a relatively high socioeconomic area, the probability that students encounter an electric vehicle on a day-to-day basis is higher

than in other areas. This could affect their understanding because students may be more likely to be knowledgeable since they are surrounded by these vehicles on a daily basis.

In order to get a better understanding as to how students responded individually, question eight can be broken down into male and female responses.
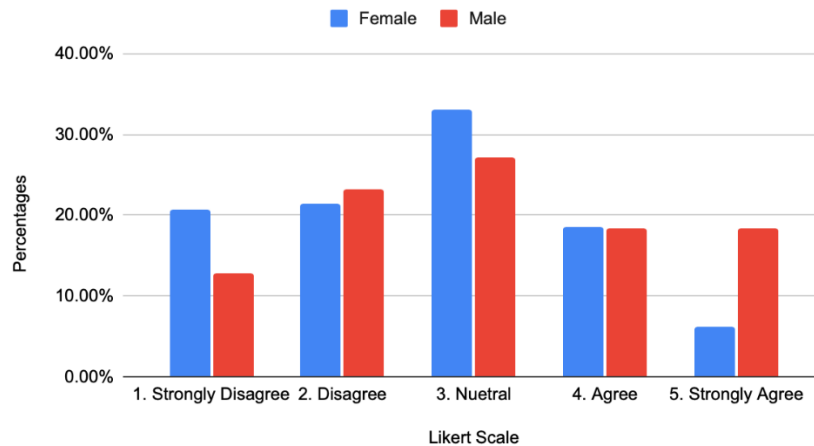

Figure 8. A histogram of responses displaying how aware male and female students feel regarding the cradle-to-grave process of electric vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Again, regardless of gender, the overall consciousness across students is still evenly distributed across the Likert scale regardless of gender. There was a small difference in gender at "1" and "5" on the Likert scale. This could be because males are more interested in electric vehicles, which may allow them to be more knowledgeable. This would explain why males are more likely to answer that they were knowledgeable and females to answer that they were not knowledgeable on the cradle-to-grave process. However, there was no statistically significant gap in the distribution of genders among answer choices.

This same question can be broken down into grade levels again, splitting the respondents between upper-classmen and lowerclassmen.
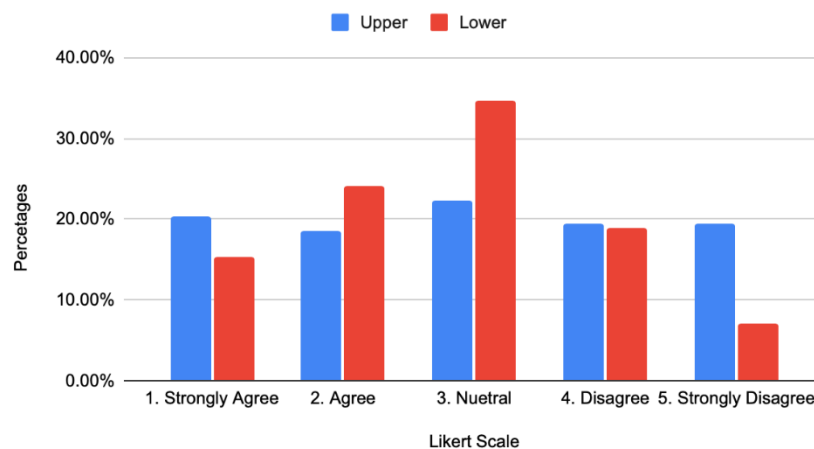

Figure 9. A histogram of responses displaying how aware upperclassmen (11th & 12 grade) and lowerclassmen (9th & 10th grade) feel regarding the cradle-to-grave process of electric vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Again, regardless of grade, students were evenly dispersed in knowledge, with students evenly ranging from one to five on the Likert scale. Only point "5" on the Likert scale saw less lowerclassmen selections, meaning there are not as many lowerclassmen that view themselves as very knowledgeable on the topic. This is likely because lowerclassmen have not had as much education as the upperclassmen.

The next question to be analyzed was, *to my understanding, electric vehicles are much better for the environment than combustion vehicles.* This question allows the researcher to see how many of the students believe that there are many more benefits to EVs, seemingly ignoring the negative effects of them in the meanwhile.
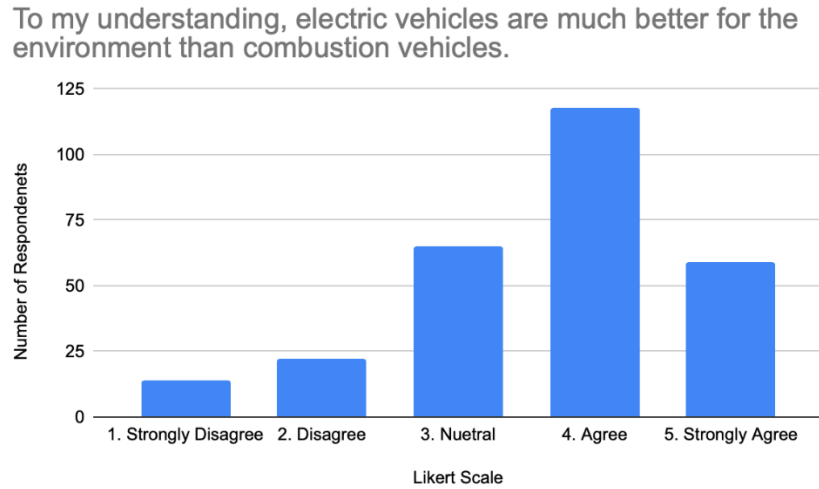

Figure 10. A histogram of responses displaying how much students understand the comparison between eclectic vehicles and combustion engine vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 10 demonstrates that most students agreed with the statement above, that electric vehicles were much better for the environment than combustion engine vehicles. This means that many of these students likely do not understand the harmful effects of the electric vehicle cradle-to-grave process, since they only see these electric vehicles in use. The average answer was 3.67 with a standard deviation of 1.05. Only 14 respondents selected strongly disagree, which could have been fluke answers, or students that were hyper-aware about the issue.

In order to gain a deeper understanding, the same question was broken down into male and female responses. This allows the researcher to see a demographic breakdown of the answers.
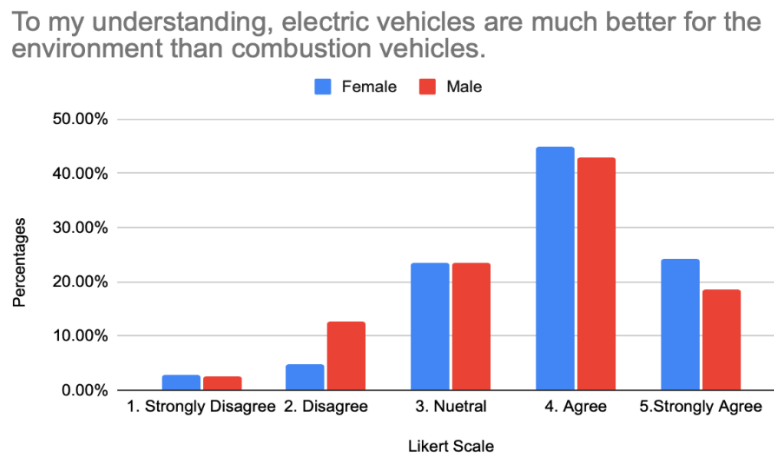

Figure 11. A histogram of responses displaying male and female understanding of the comparison between eclectic vehicles and combustion engine vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 11 demonstrates no statistically significant difference between the two demographic respondent groups. All respondents responded relatively similarly to each other, showing that no matter what gender someone identifies as, their understanding of the effects of electric vehicles does not differ. Overall, this follows a common pattern among respondents so far.

The same question was now broken down into upperclassmen and lowerclassmen demographics as well.
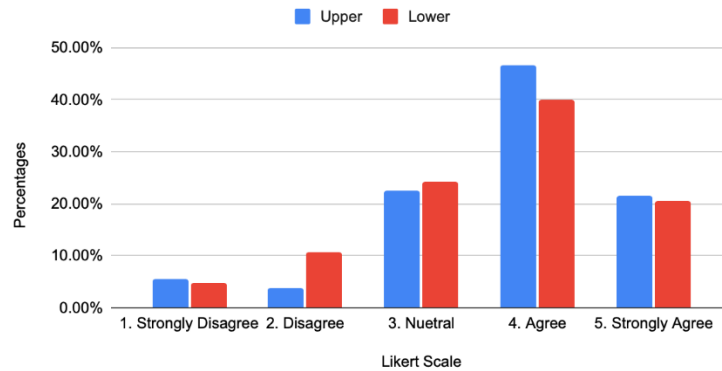

Figure 12. A histogram of responses displaying whether upperclassmen (11th & 12 grade) and lowerclassmen (9th & 10th grade) the comparison between eclectic vehicles and combustion engine vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

This breakdown between grade levels once again comes to be inclusive. There is no statistically significant difference between the two groups of students, once again proving that the education at the school needs to be improved so that as students get older, they are learning about more real-world problems which are applicable in everyday life.

Findings: Combustion Vehicle Knowledge

This final section asked respondents a few questions regarding combustion vehicles. This was used to compare the answers of the previous section, the electric vehicle questions, to see what students knew about these different vehicles in comparison to one another.
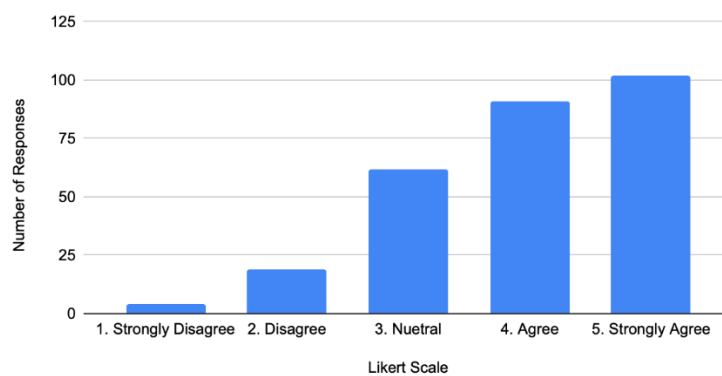

Figure 13. A histogram of responses displaying how aware students feel regarding the environmental effects of combustion vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 13 demonstrates that the most students answered a three, four or five (neutral, disagree, strongly agree respectively), on their knowledge of the environmental effects of combustion vehicles. This demonstrates the overall understanding of students taking this survey feel they are knowledgeable on the effects of combustion vehicles. The average answer of this question was 3.96 with a standard deviation of .99. Furthermore, APEs students had an average answer of 3.98 while non-APES students had an average answer of 3.96, meaning that APES students were more aware, but not enough for it to be statistically significant. In comparison to figure 4, most students are more knowledgeable on combustion vehicles in comparison to electric vehicles.

In addition, this question can be split into male and female responses in order to see how each group answered the question.
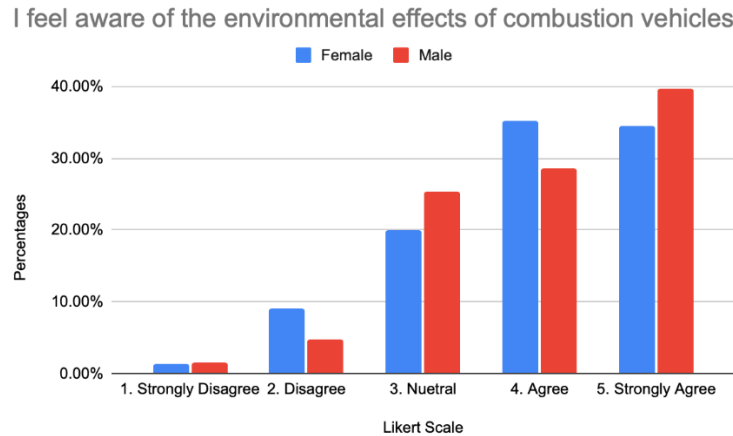

Figure 14. A histogram of responses displaying how aware male and female students feel regarding the environmental effects of combustion vehicles rated on scale from 1 (Strongly Agree) to 5 (Strongly Disagree).

Figure 14 demonstrates that there was no difference between answers among male and female respondents. Since all respondents answered relatively similarly at each point of the Likert scale, it shows that respondents are educated well on the environmental effects of combustion vehicles as most students responded three, four, and five.

Finally, this question can be split into upperclassmen and lowerclassmen to see how each group answered the Likert scale respectively.
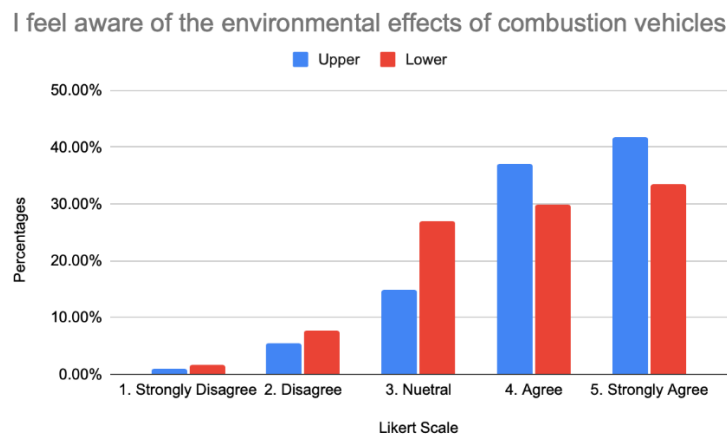

Figure 15. A histogram of responses displaying how aware upperclassmen (11th & 12 grade) and lowerclassmen (9th & 10th grade) feel regarding the environmental effects of combustion vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

This final breakdown can see the upperclassmen and lowerclassmen and lowerclassmen have similar responses across the Likert scale. Figure 15. Demonstrates that the student understanding is generally high, however upperclassmen do seem slightly more knowledgeable as they were more likely to answer "4" or "5" on the Likert scale. This again demonstrates that students, regardless of grade level, have more knowledge on combustion vehicles than electric vehicles.

The final individual question that needs to be broken down will be- *I am aware of the cradle-to-grave process of combustion vehicles*. This question allows the researcher to compare the results from Figure 10. to see if any conclusions can be made.
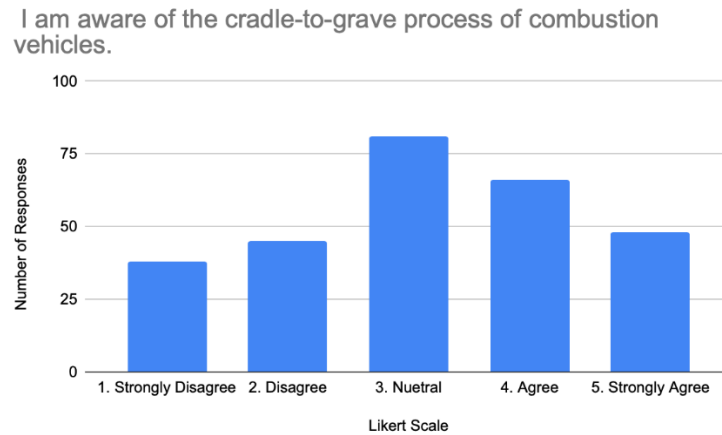

Figure 16. A histogram of responses displaying how aware students feel regarding the cradle-to-grave process of combustion engine vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Figure 16 demonstrates the relatively neutral selection of responses on the 5 point Likert scale. Although there is a slight shift to the right side of the scale, it is overall dominated by the 3, "Neutral", selection. The mean is 3.15 and the standard deviation is 1.27. This means that most students felt as if they did not know too much about the cradle-to-grave process of combustion vehicles. In turn, this means that students were more aware of the cradle-to-grave process for combustion engine vehicles than electric vehicles because the average answer was .3 higher on the Likert scale. Overall, more students felt aware of the process than those that were not familiar with the process.

Similarly to previous questions, this question was also broken up into male and female demographics to get a better understanding of the respondents.
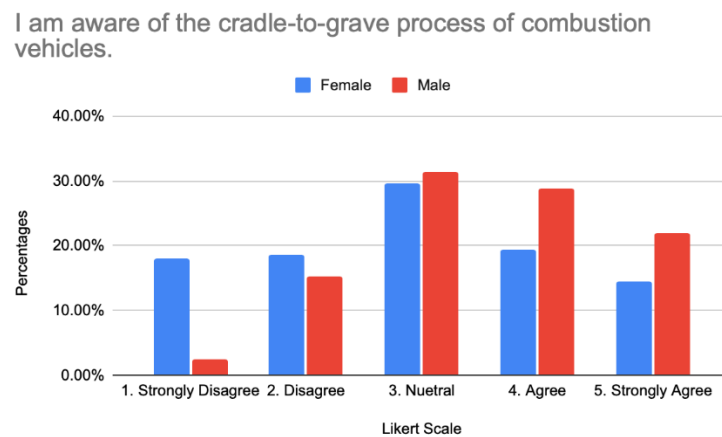

Figure 17. A histogram of responses displaying how aware male and female students feel regarding the cradle-to-grave process of electric vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Overall, most of the respondents answered similarly, with the exception of answer 1, "Strong Disagree", on the Likert scale. For number 1, there were 6 times the female respondents that answered compared to the male respondents. This could be for a variety of reasons from different levels of education to different interests. One speculation may be because males stereotypically tend to be more interested in motor vehicles, vehicle customization, and vehicle building, which may cause them to feel more educated about the process that these combustion engine vehicles go through. Overall, this has been one of the only questions where there has been a discrepancy between male and female respondents.

Finally, this same question will be broken down based on the responses of upperclassmen and lowerclassmen.
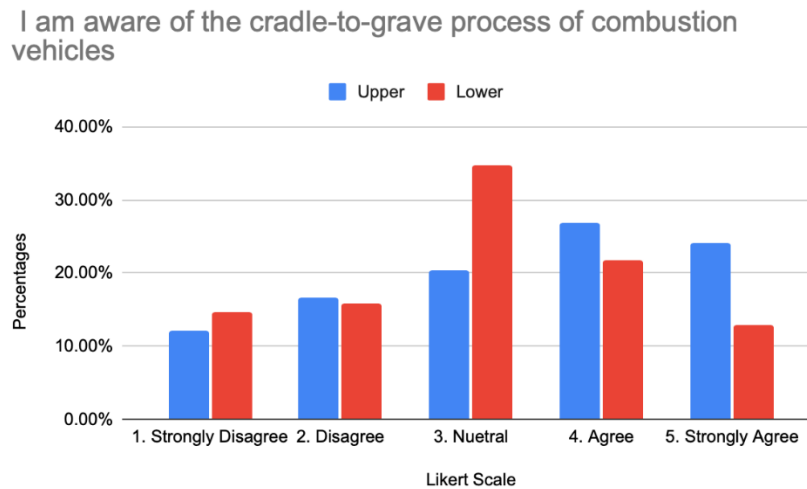

Figure 18. A histogram of responses displaying how aware upperclassmen (11th & 12 grade) and lowerclassmen (9th & 10th grade) feel regarding the cradle-to-grave process of combustion engine vehicles rated on scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

This histogram demonstrates that most of the respondents answered relatively similarly, regardless of age. There is one slight upscale in answers from lowerclassmen that felt neutral, answering 3, but the overall answer selections were relatively even. Although may not be statistically significant, this may have been because lowerclassmen are not as familiar with the topic and therefore not comfortable placing any more than a "3" on the Likert scale.

Findings: Correlation

There was a correlation between a few questions, the first questions that had a correlation were between question six and nine.

Table 1. The R and p-values of the Pearson Correlation Coefficient test run between Question 6, "I would like to help with climate change but do not know how to" and Question 9, "I would like to help with air pollution but do not know how to."

Correlation Results (Q6 & Q9)	
T	0.7047668737
P	<0.00001

After running a Pearson Correlation test, there is a weak positive correlation, and p is determined to be statistically significant and <.00001. This means that if they own an electric vehicle, they are more likely to read about environmental issues and solutions in the media.

The next set of questions that a correlation was found was between questions seven and ten.

Table 2. The R and p-values of the Pearson Correlation Coefficient test run between Question 7, "I would like to help with climate change but can not afford to do so" and Question 10, "I would like to help with air pollution but can not afford to do so."

Correlation Results (Q7 & Q10)	
T	0.7427773208
P	<0.00001

The Pearson Correlation also found a correlation between questions seven and ten. It was determined that there is a weak positive correlation, and p is determined to be statistically significant at <.00001. This may mean that respondents who own more electric vehicles are more likely to be involved in environmental awareness, however it may also mean that respondents who are environmentally aware are more likely to own an electric vehicle.

Finally, there was a correlation found between question eleven and twelve.

Table 3. The R and p-values of the Pearson Correlation Coefficient test run between Question 11, " I feel aware of the environmental issues that electric vehicles cause." and Question 12, "I feel aware of the cradle-to-grave process of electric vehicles."

Correlation Results (Q11 & Q12)	
T	0.7364415499
P	<0.00001

The Pearson Correlation found a weak positive correlation, and p is determined to be statistically significant. At <.00001. People who discuss environmental problems with their friends and family are more likely to be aware of their responsibility towards environmental issues.

Findings: APES

In the final portion of this research, the results from APES students to non-APES students were compared. The main focus of this part of the research was to determine if the APES students knew more about questions asked.
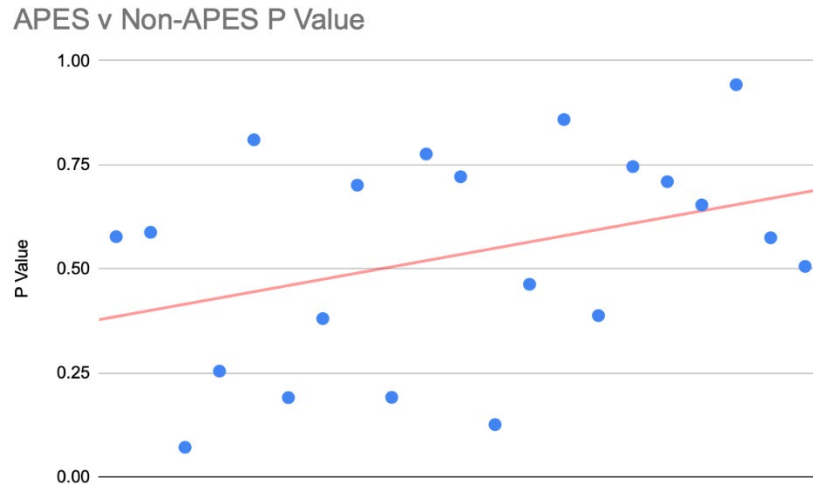
Figure 19. This graph demonstrates how APES students answered the questions they were asked; however, it was determined to be statistically insignificant.

Figure 19 demonstrates how APES students answered the questions .11 higher on the 1-5 Likert scale as APES students answered 3.23 on average while non-APES students answered 3.12 on average. Although the average answer was higher, this was not enough to be determined as statistically insignificant. This can be seen through the P-Value displayed in the scatter plot chart on figure 19.

Summary and Discussion

To summarize, there were three main questions analyzed. Question eight asked about environmental awareness, question nineteen asked about cradle-to-grave awareness, and question twenty-eight asked about combustion vehicle awareness, all on a 1 through 5 (1: Strongly Disagree-5: Strongly Agree) Likert scale. These three questions were chosen because they most accurately represented the blanket of information found within this study. These three questions showed that students felt more aware of environmental issues and the effects of combustion vehicles than they did of electric vehicles. Overall, most students did not feel aware of the cradle-to-grave process of electric vehicles. Moreover, these questions were dissected into two categories, comparing male and female responses, as well as upperclassmen and lowerclassmen responses. These demographic breakdowns showed that although there were a couple instances where grade level affected answers, there was no significant difference between male and female responses nor upperclassmen and lowerclassmen responses. Finally, the APES student responses showed an overall better understanding for environmental issues and the cradle-to-grave process; however, these results were not enough to be statistically significant.

Returning to the hypotheses made earlier, students did show an overall lack of understanding of the cradle-to-grave process of electric vehicles in comparison to the effects of general environmental awareness and combustion vehicle effects. Furthermore, although not statistically significant, APES students did show a better understanding than non-APES students across all topics. This aligns with Hassan, Noordin, and Sulaiman's study as they found that the understanding of environmental issues across environmental issues was "high" in their study. When asking about environmental awareness, this study found an average answer of 3.91 with a standard deviation of .88, while Hassan, Noordin, and Sulaiman's study saw an average answer of 3.82 and a standard deviation of .86. In addition, Hassan, Noordin, and Sulaiman's study saw an average answer of 3.88 and standard deviation of .97, while this study found an average answer of 3.96 and standard deviation of .99 when asking about combustion vehicles. Although no other research has researched high school understanding of the cradle-to-grave process, these were the expected findings

based on previous research. Overall, most results from this study supported the results of other literature, but further research may be conducted to further understand the topic.

Conclusion

Ultimately, this study found that high school students are not as aware of the cradle-to-grave process as they are about general environmental awareness and the effects a combustion vehicle has on the environment. Although APES students do seem to be slightly more aware, in all aspects, it was not found to be enough to make it statistically significant. These findings highlight the need to improve the current education focus as it aligns with Hassan, Noordin, and Sulaiman's study, as both studies showed a better understanding from students taking environmental focused-classes and good understanding of general environmental issues. However, the results demonstrate that most of the respondents are not aware of the cradle-to-grave process of electric vehicles.

Limitations

This study may have been limited due to incentives offered by teachers. Some freshmen English teachers offered their classes extra credit to complete the survey, this may have been why more than half of the students responding to this survey were freshmen. This may have affected results because freshmen may not be as knowledgeable. Additionally, the number of APES student responses may have also limited the data. Since only 84 APES students responded, this is unequally proportionate to the 194 non-APES student responses. Therefore, the non-APES student responses were more varied than the APES student responses. Furthermore, there were aspects of the research that could not be covered to the fullest extent in this paper, such as the manufacturing and economic effects of electric vehicles. Finally, there was no way to test whether student responses were correlative or causative, so further research must be done.

Implications and Next Steps

The implications of this study can be seen in the fact that there needs to be more education on climate change issues implemented into the high school curriculum. It is important to do this because these are the students that will be making a difference in the climate change issues to come. There seems to be a misconception that electric vehicles produce zero emissions because they produce zero emissions on the road. However, the mining for lithium and the production of batteries almost always seems to be disregarded, so people fail to realize the true environmental effects of these vehicles.

The next steps regarding climate change education would be to have a more environmental focus in all science classes, not just APES. This would ensure that even students that are not taking the advanced placement class are still receiving a good education on climate change issues, allowing them to make a difference with their knowledge. Finally, more research similar to this study with a bigger sample size, more time, and more resources is necessary to determine if a correlation exists between the knowledge and perceptions of high schoolers. To conclude, the results indicate that students are not aware of the cradle-to-grave process of electric vehicles.

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