UNIVERSITY OF CALIFORNIA SAN DIEGO

# What College Biology Students Know about How Vaccines Work

# and

# Its Relationship to Vaccine Refusal

A Thesis submitted in partial satisfaction of the requirements for the degree Master of Science

in

Biology

by

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Professor Emily Troemel

2020

The Thesis of Gavina Kahlon is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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Chair

University of California San Diego
2020

DEDICATION

I dedicate this Masters thesis to my parents, Harinder Singh Kahlon and Manjinder K Kahlon, grandparents, Harcharan Singh Kahlon and Sukhvinder Kahlon, and brother, Arjun Singh Kahlon. Their love and support has always been unwavering, and sacrifice grand to ensure I had everything and anything I ever needed to succeed. They are my inspiration. I will be forever grateful.

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ABSTRACT OF THE THESIS

What College Biology Students Know about How Vaccines Work

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Gavina Kahlon

Masters of Science in Biology

University of California San Diego, 2020

Professor Melinda Tsaoying Owens, Chair

Vaccination is a major controversial public health issue and is laden with great controversy in today's political landscape. It is unclear how much people know about vaccines and how their knowledge influences their beliefs (Jacobson et al., 2007). Therefore, we ask: to what extent do college biology students have an accurate and complete understanding of how vaccines work, and to what extent is there a correlation between this knowledge and vaccine refusal?

College students at an urban, public comprehensive university taking a biology course for non-majors (n=295) were asked to write a response to the prompt, "How does a vaccine work?"

They were also asked whether they would vaccinate their children. Biology faculty (n=24) were also asked the same questions as an expert control. To analyze their responses, we created a rubric based on authoritative sources to gauge their *completeness* and *accuracy*. We defined a *complete* response as three main ideas: 1) vaccines contain a pathogen-like substance, 2) vaccines provoke an immune response, and 3) vaccines give some immunological memory.

We found that advanced biology majors score significantly higher in completeness and accuracy when compared to all other student groups, but there exists a difference between entering biology majors, pre-health majors, and non-pre-health majors. We also found that vaccine refusal does not strongly correlate with lack of knowledge which suggests that education alone may not reverse vaccine refusal

## **Introduction**

Vaccines have proven to be an effective tool in guaranteeing public health. However, they continue to face growing skepticism from the public (Poland & Jacobson, 2001; Wilson & Marcuse, 2001). As vaccine opposition rises, it poses a risk to individual health and the collective herd immunity which hurts people of all ages (Hussain et al., n.d.). It is unclear how much people know about vaccines and the way in which their knowledge influences what they believe about vaccines (Jacobson et al., 2007). Thus, it becomes the job of those with influence, such as researchers, educators and health-care professionals, to step forward and find a way to combat this vaccine refusal movement. This is because the only way to reap the full potential of vaccines is if parents recognize vaccines as a means to build the body's natural defense against diseases and therefore will ensure their children are vaccinated (Achievements in Public Health, 1900-1999 Impact of Vaccines Universally Recommended for Children -- United States, 1990-1998, n.d.).

### *Origin of Vaccine Refusal:*

Why would many people choose not to vaccinate if vaccines have been shown to be generally safe and effective? (Jacobsen et al 2007). Vaccinations have always been strongly contested. In nineteenth-century England, the enforcement of the smallpox vaccine disproportionately targeted poor working class citizens; thus, provoking opposition against vaccination (Durbach, 2004). Today's vaccine refusal movement was shaped by two major events (Clift & Rizzolo, 2014). The first was the film *DPT*: *Vaccine Roulette* that claimed to link diphtheria, pertussis, tetanus, (DPT) vaccine to neurodevelopmental disorders (Clift & Rizzolo, 2014). The second was a 1998 paper by Andrew Wakefield that alleged a link between the measles, mumps, rubella (MMR) vaccine with autism (Clift & Rizzolo, 2014). Many studies have disproven both connections, and the paper by Wakefield was retracted due to proof of falsified data.

Wakefield's license was revoked as a result of the study as well (Clift & Rizzolo, 2014). Despite these misconceptions being disproved, many still believe them to be true, therefore perpetuating beliefs that vaccines are more harmful than the disease itself (Schwartz, 2012). Many vaccine refusers also feel that mandatory vaccination infringe on their rights (Schwartz, 2012). It has been shown that vaccine-accepting parents can also become befuddled by the ongoing media debates on vaccine safety, thus leading them to question the health decisions they have made and will make (Hussain et al., n.d.).

*Vaccine Misconceptions:*

It has been proven that many parents lack basic understanding of how a vaccine works and the importance of routine vaccination, leaving room for false claims to perpetuate fear into parents when making decisions about vaccination (Hussain et al., n.d.). There are many misconceptions that parents have about the biology of vaccines, but here we discuss two that are common and have been analyzed before in research studies. The first of these misconceptions is that the DPT vaccine causes Encephalitis. The second is that the MMR vaccine causes autism (Clift & Rizzolo, 2014).

These common misconceptions, while individually disproven, also perpetuate the assumption that all vaccines cause neurological complications. The DTP vaccine was initially introduced in 1991, there were some side effects where 1-10 patients out of 1 million would risk acute encephalitis because of fever induced convulsions. However the vaccine has been changed, and there have been no links to encephalitis anymore (*Pertussis Vaccination: Use of Acellular Pertussis Vaccines Among Infants and Young Children Recommendations of the Advisory Committee on Immunization Practices (ACIP)*, n.d.). As for the MMR vaccine and links to autism, the paper by Andrew Wakefield created a widespread conversation within science communities and in larger public communities on the linkages between vaccines and autism. This study, however, had serious scientific and ethical errors and was retracted. Further scientific research highlights there is no link between the MMR vaccine and autism (Clift & Rizzolo, 2014).

In addition to these two common misconceptions, many parents distrust vaccines based on the idea that vaccines are “artificial, unnatural, unwelcome, and unnecessary”(Jacobson et al., 2007). These parents believe that vaccines inhibit the natural process of development and the medical intervention of giving several artificial vaccines at once or in a series would overburden the immune system (Jacobson et al., 2007). The consequences of such ideas are that parents often distrust vaccines in general, further distrust vaccines administered in multiple doses such as Hepatitis B (Nelson et al., 2009). In reality, vaccines decrease the amount of antigens a person is exposed to than what we would be otherwise exposed to in the natural pathogen (Halsey, 2001). For example, the Hepatitis B vaccine has one antigen compared to the natural exposure, Hepatitis B virus, which has four (Halsey, 2001).

*Student Knowledge of Vaccines*

Many people believe that it is imperative that misconceptions surrounding vaccines are addressed so that parents are able to better understand the importance of immunizations and agree to vaccinate their children (Jacobson et al., 2007). In addition to educating parents, we can educate students taking biology courses about how vaccines work. From education literature, we know that students learn best when their instructors have prior knowledge (Sadler et al., 2019). However, it is unclear how much students know about vaccines and how their knowledge influences what they believe (Jacobson et al., 2007). Studies that have been published state that students lack information on vaccines (Mellon et al., 2014; Sandler et al., 2019). This includes knowledge about the difference between vaccines and the diseases they prevent, and their personal vaccination history (Mellon et al., 2014; Sandler et al., 2019). However, scholars do not actually know whether biology majors have a more accurate understanding of how vaccines work than non-biology majors. Some instructors might assume they do, but for many biological misconceptions, that is not necessarily the case (Coley & Tanner, 2015). It is worth noting that much of the discourse around educating people about vaccines implicitly assumes that those who have more knowledge on the science behind vaccines would become more accepting of the science itself. However, this assumption might not be true. By better understanding student knowledge, we are not only better able to teach about vaccine, but also find how a lack of knowledge or the presence of misconceptions has correlates with vaccine refusal.

*Our Study:*

This thesis seeks to understand how much students at various levels of biology education know about how a vaccine works. It seeks to address how this knowledge correlates with vaccine refusal or acceptance. In this study, we begin by assessing student knowledge on vaccines (i.e. how does a vaccine work). By correlating each student's rubric scores related to their working knowledge on vaccines and with their confidence in their knowledge and vaccine coursework, this study argues we can better understand how students know what they know. Through this assessment, we can correlate vaccine refusal or acceptance to their knowledge. Finally, we can explore what misconceptions they have and how these misconceptions correlate with vaccine refusal or acceptance. In all, to address these concepts, this thesis will cover eleven research questions. These include:

1. To what extent do college biology students have a complete and accurate understanding of how vaccines work?
2. Does taking a course that covers vaccines correlate with a complete and accurate understanding of how vaccines work?

3. Does student confidence in their knowledge about vaccines correlate with a complete and accurate understanding of how vaccines work?
4. What percent of students at different levels of biology expertise are vaccine acceptors or refusers?
5. Does a complete and accurate understanding of how vaccines work correlate with whether a student is a vaccine acceptor or refuser?
6. Does taking a course that covers vaccines correlate with vaccine acceptance or refusal?
7. Does a student's reference to personal experience with vaccines in their explanation of how a vaccine works correlate with vaccine acceptance or refusal?
8. What are the common misconceptions students have about how a vaccine works?
9. Does the presence of common misconceptions correlate with whether a student is a vaccine acceptor or refuser?
10. Does endorsement of the essentialist misconception that, "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease." correlate with knowing that vaccines are pathogen-like?
11. Does endorsement of the essentialist misconception that, "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease." correlate with the belief that vaccines contain unmodified pathogens?

## Methods:

### *Data Collection:*

The data analyzed here was collected in 2017 and 2018 from college students (n=635) and faculty in biology (n=24) at a diverse urban, public comprehensive university.

To recruit students, course faculty were asked to provide permission to interview and survey their students. This allowed the survey to be administered as a class activity where all students participated. Completion of the class activity was mandatory for class credit, but students could opt out of being a part of the research study. Three large classes were recruited: a non-majors course focused on human health (non-biology majors, NBMs) (97% recruitment); the first biology course in an introductory sequence for biology majors (entering biology majors, EBMs) (97% recruitment); and an upper-division biology required course (advanced biology majors, ABMs) (98% recruitment).

Once the data was collected, we grouped each student by self-reported major and class standing. In particular, the NBM course was a prerequisite for the pre-nursing and pre-physical therapy majors allowing us to split the NBM students into two groups: pre-health majors (PH, n=111) which consisted of these pre-nursing and pre-physical therapy majors, and non-pre-health majors (NPH, n=183) which consisted of all non-biology, non-pre-health majors. In addition, student surveys included entering biology majors (EBM, n=237) and advanced biology majors (ABM, n=104). All undeclared majors were included in the NPH category. Data was cleaned by excluding students whose major did not align with the course they were taking (for example: a biology major taking non-majors biology).

Biology faculty members (BF) were recruited to have expert control. BF were recruited by email based on whether their research or teaching focused on immunology, physiology, microbiology, or cellular and molecular biology (BF, n=24) (73% recruitment). BF that were present during the student surveys or on leave were excluded from the study. The survey was given on a one-on one basis in the faculty participant’s office. All BF that participated were given a $25 gift certificate. All data from BF was included in this study.

This study was approved by the Human-Animal Protections (HAP) program of San Francisco State University under protocol #E17-257.

*Survey Design;*

The data I analyzed was part of a larger survey with many questions. However the prompts for this project, in the order analyzed, are in the following table:

Table 1: Prompts in Survey

| **Prompt or Challenge statement** | **Response format** |
|---|---|
| How does a vaccine work? | Open-ended response |
| "I would vaccinate my children" | Yes / No |
| "I have taken one or more courses where I learned about how vaccines work." | Yes / No |
| "I am confident in my understanding of how vaccines work." | Yes / No |
| "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease." | 4-point Likert scale and open-ended response |
| Demographics: Major | Open-ended response |

The initial parts of the study primarily focuses on student responses to the open-ended question, "How does a vaccine work?" (The full survey is included as Appendix 1.) For logistical reasons, ABMs were not asked to respond to the statements, "I would vaccinate my children," "I have taken one or more courses where I learned about how vaccines work," and "I am confident in my understanding of how vaccines work." So, the ABM group was excluded from all analyses involving these three prompts.

*Rubric Design and Validation:*

After collecting and organizing the data, we assessed students for their knowledge about vaccines. This was done by creating a rubric for the prompt "How does a vaccine work?" First, I analyzed commonly used authoritative sources on vaccines, which included the website of the National Institute of Allergies and Infectious Diseases, the website of the Centers for Disease Control and Prevention, and two commonly used immunology textbooks, *The Immune System 4th edition* by Peter Parham and *Janeway's Immunobiology 9th edition* by Kenneth Murphy and Casey Weaver (*How Do Vaccines Work? | NIH: National Institute of Allergy and Infectious Diseases*, n.d.; *Understanding How Vaccines Work*, n.d.; Murphy et al., 2017; Parham, 2015). Next, we analyzed the responses of the biology faculty members (n=24), as these were the expert controls. By studying authoritative sources and the expert control groups I was then able to formulate what the scientific consensus is and what an expert might be able to write under similar conditions as a student, giving what the possible maximum expectation could be for students. From this analysis, we decided assessment of the responses would be split into two parts: 1) Completeness of Response and 2) Accuracy of Response. For a response to be ***complete***, it would need to address these three main concepts: 1) a vaccine contains part or all of a (modified) pathogen or something that mimics or is shaped like the pathogen (pathogen-likeness), 2) vaccines stimulate an immune response (immune response), and 3) if the actual pathogen is encountered in the future, the body will have a more effective response to it than without the vaccine (memory). For a response to be ***accurate,*** it would need to have the absence of any false claims. If a student had a misconception, I recorded which ones were present. In addition, I recorded whether the student referred to personal experience.

To validate the rubric, we then used it to assess the responses of a randomized group of non-biology majors (n=100). We chose non-biology majors as we thought this would be the group of students with the lowest knowledge of biology. With every change to the rubric, the responses would be re-assessed until all students were graded with a consistent rubric. Then to further check, we scored a random set of all students from each varying level of biology (NPH, PH, EBM, and ABM, n=100), and the rubric was again assessed until all students were graded with a consistent and unchanging rubric. This allowed us to solidify the rubric by making a detailed coding guide. Once the rubric and coding guide were finalized, we tested for inter-rater reliability using two other coders. All three of us took around ~10% of a new randomized group of students (n=75) (n=635) and graded them separately. We then compared how often we agreed or disagreed with one another's responses, and our percent agreement for both completeness and accuracy was over 90%. Note: All students and BF were scored using this rubric.

Our rubric and scoring is included as Table 2.

Table 2: The Rubric for "How does a vaccine work?" Prompt

| **Evaluation of Completeness:** | | **How to score:** |
|---|---|---|
| 1) "Pathogen-Like" | A vaccine contains part or all of a (modified) pathogen or something that mimics or is shaped like the pathogen. | • If present 1 point<br>• If missing 0 points |
| 2) "Immune Response" | Vaccines stimulate an immune response. | • If present 1 point<br>• If missing 0 points |
| 3) "Memory" | If the actual pathogen is encountered in the future, the body will have a more effective response to it than without the vaccine. | • If present 1 point<br>• If missing 0 points |
| | | **Total Points Possible: 3** |
| **Evaluation of Accuracy:** | | |
| 1) Accurate | There are no false claims present. | 1 |
| 2) Inaccurate | There are false claims present | 0 |
| | | **Total Points Possible: 1** |

| | | |
|---|---|---|
| **Personal Experience:** | | |
| 1) Personal Experience | The student refers to their own personal experience. | 1 |
| 2) No Personal Experience | The student does not refer to their own personal experience. | 0 |
| | | **Total Points Possible: 1** |

*Categorization of Misconceptions:*

To analyze the most common misconceptions, we used grounded theory to pull out the most common misconceptions from the data set. Thus, we were able to create a coding guide for our common misconceptions as well. Once the misconception coding guide was complete and all students had been coded, we tested for inter-rater reliability. To assess inter-rater reliability, another coder graded 10% of a new randomized group of students (n=66) from the total students (n=635), and graded them separately. We then compared how often we agreed or disagreed with one another's responses. For each type of misconception and overall, the two raters had over 80% agreement.

*Statistical Analysis:*

To analyze correlations, we used a Chi-square test with Bonferroni correction to test for significance and Cramer's V to measure effect size. For two of the prompts that asked students to respond yes or no, a small number of students either did not respond or circled both yes and no (n=11) for "I would vaccinate my children," and n=3 for "I am confident in my understanding of how vaccines work.") These responses were not included in correlational analyses.

**Results:**

Our analysis has produced eleven findings. Broadly, they can be grouped together as follows. First, we discuss how much students know about how a vaccine works, whether it correlates with confidence and whether or not a student has taken a course on vaccines. Second, we discuss how many students are vaccine refusers and whether vaccine refusal correlates with knowledge, whether or not a student has taken a vaccine course, or use of personal experience in their explanation of how a vaccine works. Third, we learn the common misconceptions students have and if they correlate with vaccine refusal, the completeness score, and their response to an essentialist prompt.

*Factors that affect completeness and accuracy of how a vaccine works:*

Research question one: "To what extent do college biology students have a complete and accurate understanding of how vaccines work?":

We used chi-square analysis to compare scores for completeness for all levels of presumed biology expertise (NPH, PH, EBM, ABM, BF). We then used the same methods for the accuracy scores.

We found that non-biology majors (NPH, n=183), pre-health majors (PH, n=111), and entering biology majors (EBM, n=237) were not significantly ($p>.05$) different in completeness or accuracy of response to the question "How does a vaccine work?". However we did find that advanced biology majors (ABM, n=104) were significantly ($p<.002$) greater in both completeness and accuracy when compared to NPH, PH, and EBM. As expected, faculty were significantly ($p<.0001$) better in completeness and accuracy than all student groups (NPH, PH, EBM, ABM). (Fig. 1 & 2)

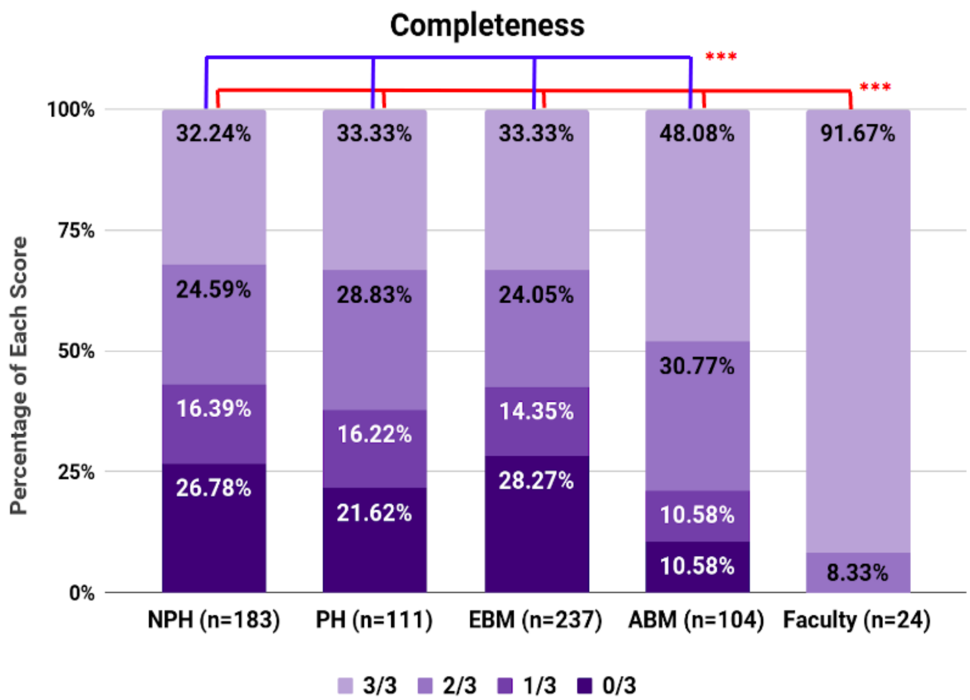


Figure 1: Completeness scores of students (p<.002 for ABM vs NPH/PH/EBM & p<.0001 for Faculty vs. NPH/PH/EBM/ABM)

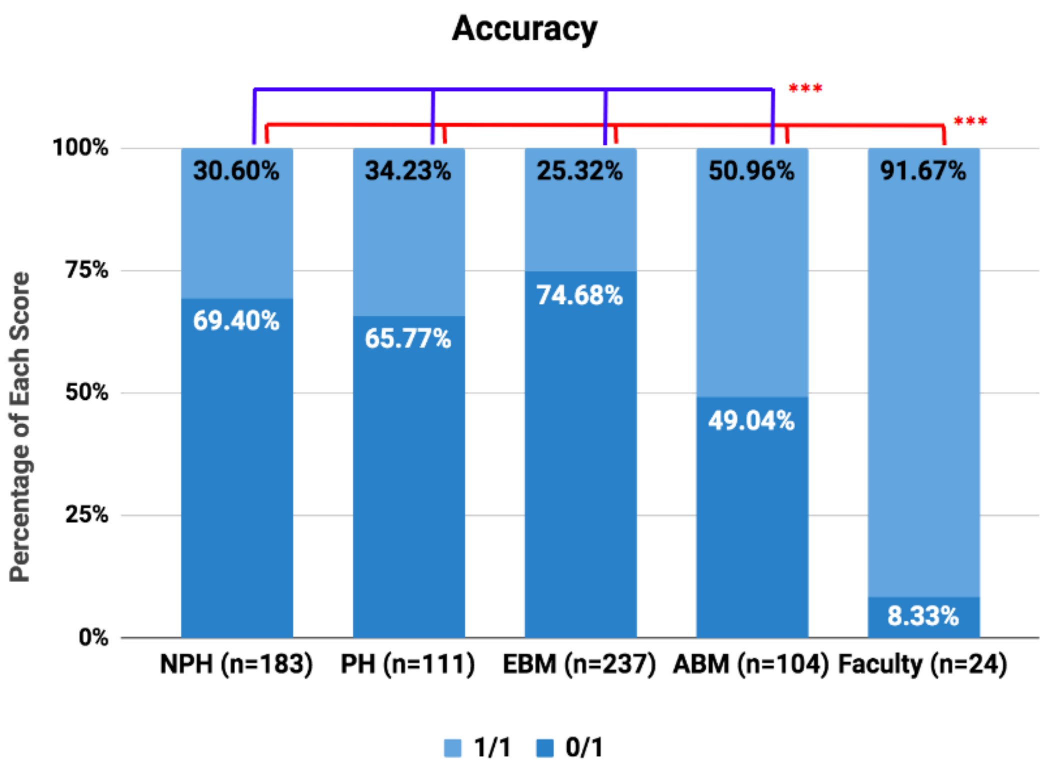


Figure 2: Completeness scores of students. (p<.002 for ABM vs NPH/PH/EBM & p<.0001 for Faculty vs. NPH/PH/EBM/ABM)

This suggests that ABMs do gain a better understanding of how a vaccine works as they proceed in their biology careers but that entering biology majors and pre-health majors do not necessarily know more than non-pre-health majors.

<u>Research question two: "Does taking a course that covers vaccines correlate with a complete and accurate understanding of how vaccines work?"</u>

We correlated the completeness and accuracy scores with responses of yes or no to the survey statement "I have taken one or more courses where I learned about how vaccines work." As expected, we found that students who have taken a course on vaccines (n=290) are significantly more likely to score higher for completeness ($p<.001$) and accuracy ($p<.01$) than those who have not taken such a course(n=241). (Figure 3 & 4) This suggests that overall, students who have taken a vaccine-related course gain a more complete and accurate understanding of how a vaccine works as compared to those who have not.

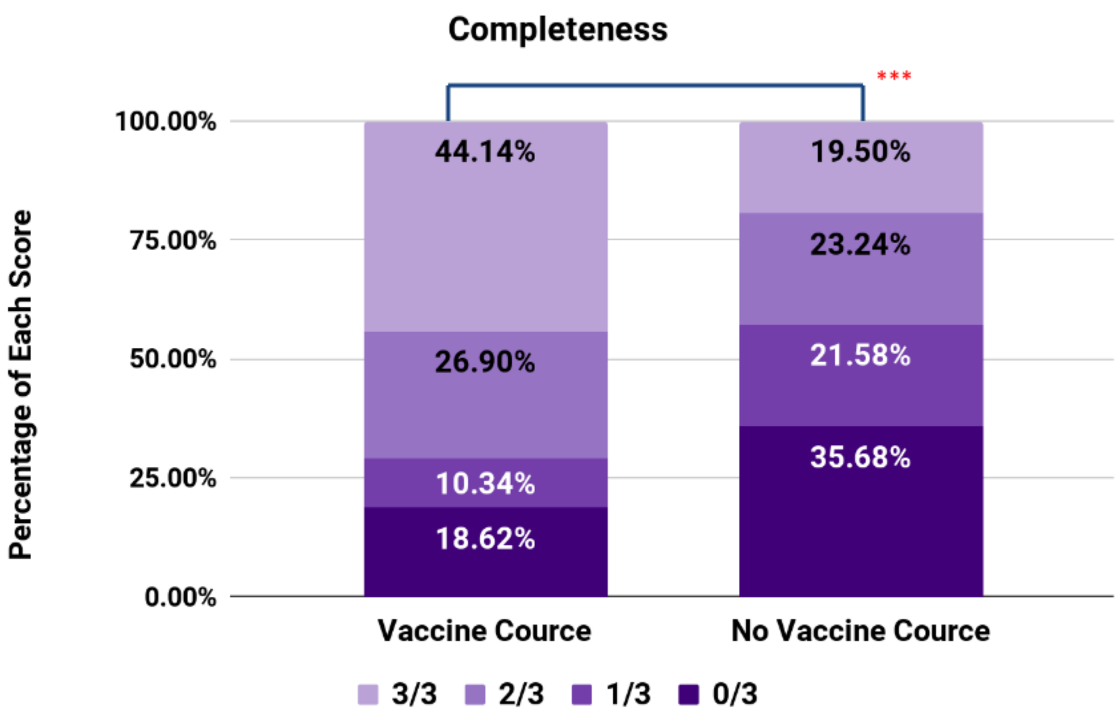


Figure 3: Student Vaccine Completeness Scores With and Without Vaccine Course ($p<.001$)

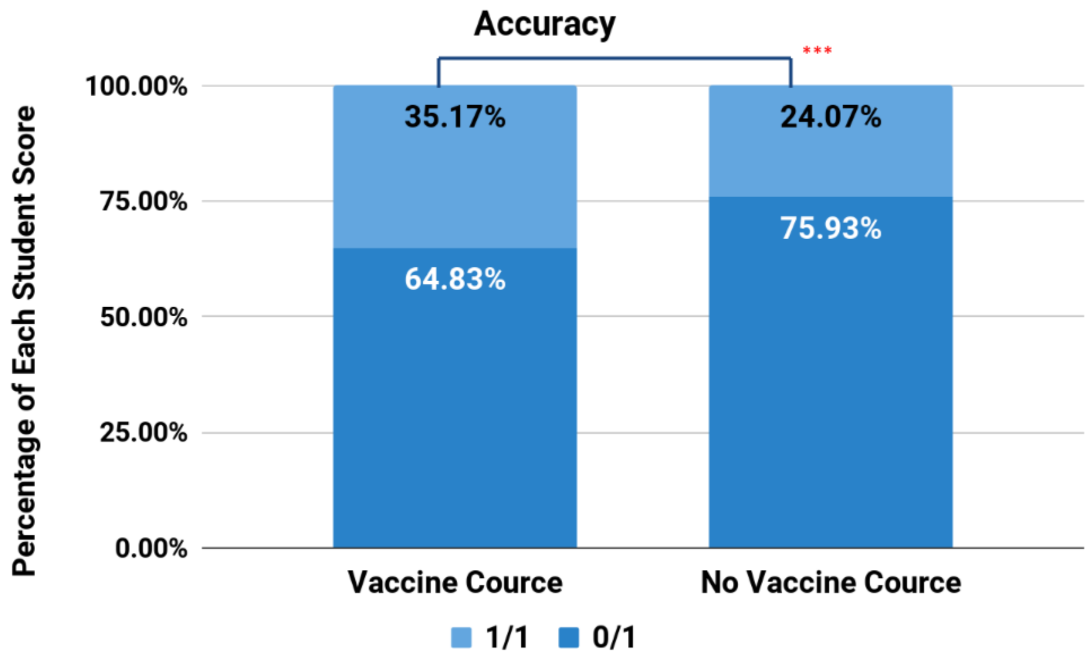


Figure 4: Student Vaccine Accuracy Scores With and Without Vaccine Course (p<.01)

Research question number three: "Does student confidence in their knowledge about vaccines correlate with a complete and accurate understanding of how vaccines work?"

We used the completeness and accuracy scores and correlated this with the response to the yes or no survey statement "I am confident in my understanding of how vaccines work." We found that students who are confident (n=205) in their knowledge of how a vaccine works are significantly ($p<.001$) more likely to score better on completeness than those students who are not confident (n=323) (Fig. 5). However, students who were confident in their knowledge of how a vaccine works were not significantly ($p>.05$) more likely to be more accurate than those students who are not confident. (Figure 6)

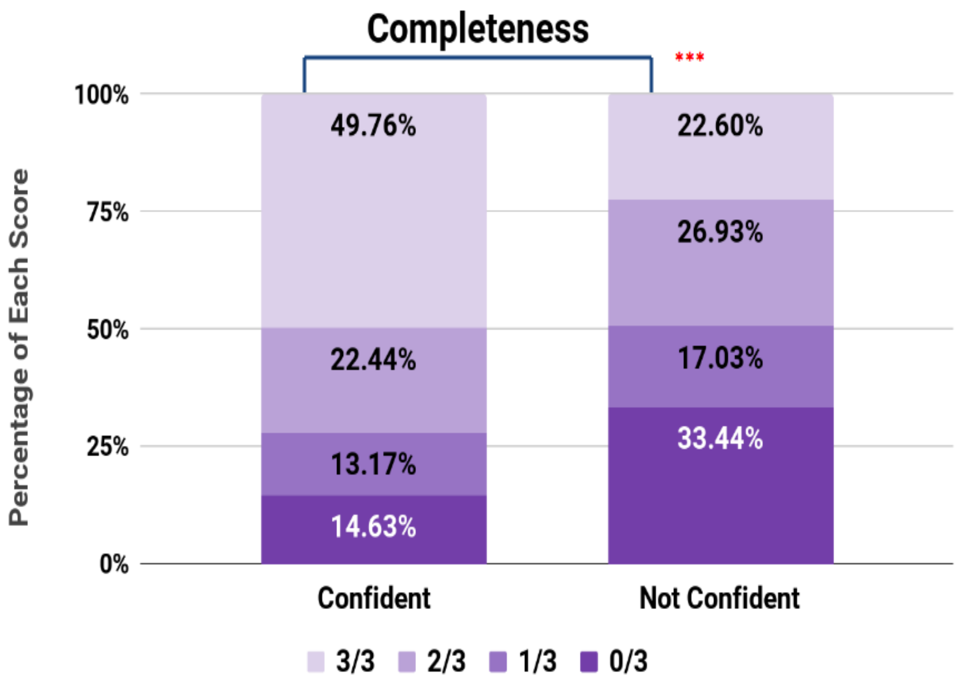


Figure 5: Student Vaccine Completeness Scores With and Without Confidence (p<.001)

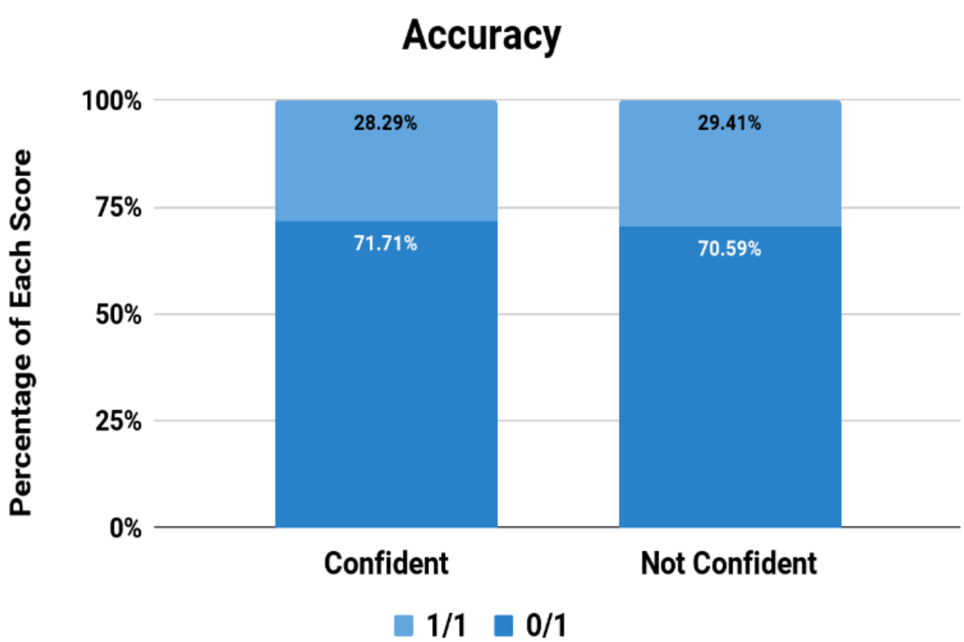


Figure 6: Student Vaccine Accuracy Scores With and Without Confidence (p>.05)

Overall, students who were confident were more likely to be complete in their understanding of how a vaccine works, but they were not less likely to have false claims.

*Factors that Correlate with Vaccine Refusal:*

Many authors have assumed that accurate knowledge about vaccines relates to vaccine refusal and acceptance. Our study set out to examine this relationship.

Research question four "What percent of students at different levels of biology expertise are vaccine acceptors or refusers?"

We collected our data from the yes or no survey statement "I would vaccinate my children." We found that for all student groups examined (NPH, PH, and EBM), around 10% of students from each group were vaccine refusers. This shows that EBM and PH are not significantly (p>.05) less likely to be vaccine refusers than NPH majors. (Figure 7)

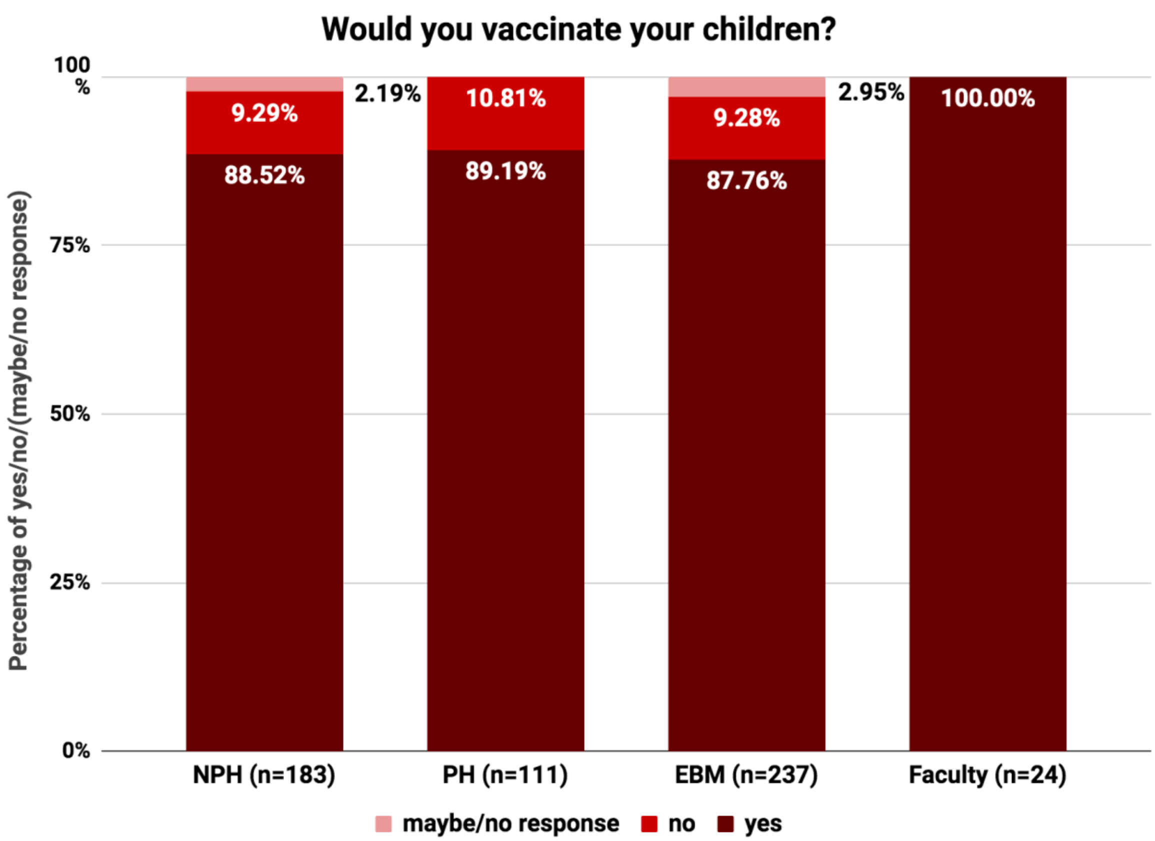


Figure 7: Vaccine Refusal Amongst Students

Research question five: "Does a complete and accurate understanding of how vaccines work correlate with whether a student is a vaccine acceptor or refuser?"

We found that vaccine acceptors are not significantly (p=.053) more likely to score better than vaccine refusers in completeness, but there is a trend. (Fig. 8) We also found that vaccine acceptors are not significantly (p>.05) more likely to score better than vaccine refusers in accuracy. (Figure 9).

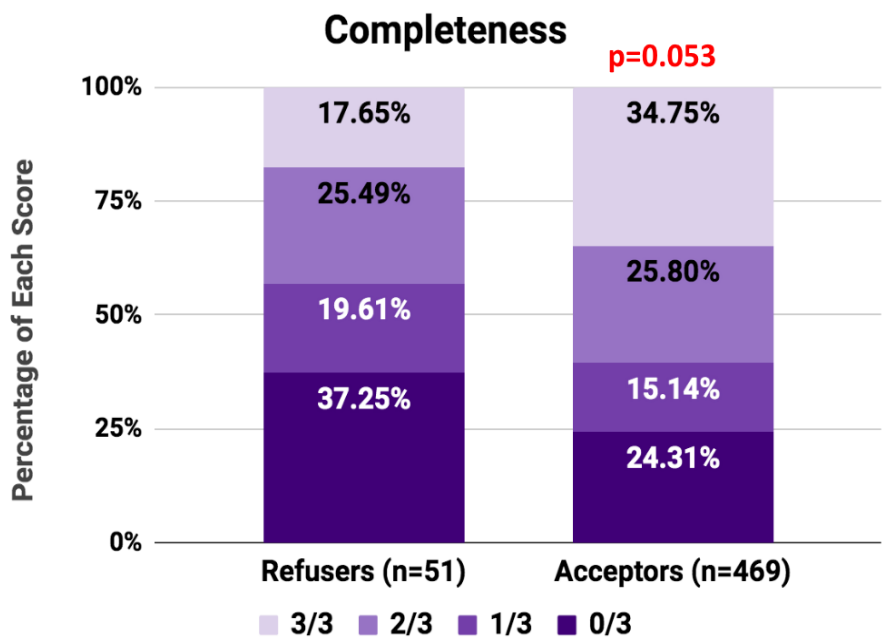


Figure 8: Student Vaccine Completeness Scores vs. Vaccine Refusal

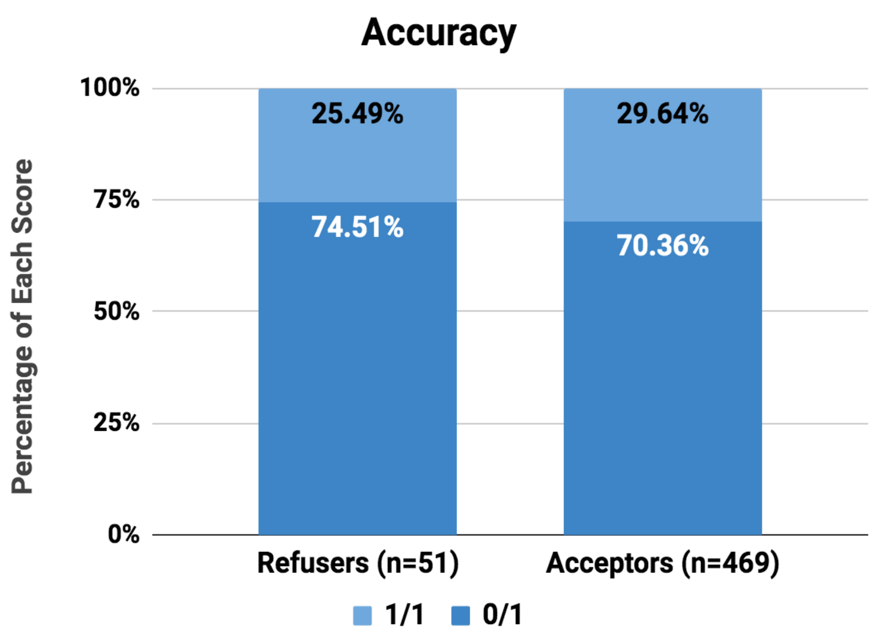


Figure 9: Student Vaccine Accuracy Scores vs. Vaccine Refusal

We then decided to break down each part of the completeness rubric to see if there were correlations between vaccine refusal and the knowledge of a vaccine being pathogen-like, provoking an immune response, and allowing a person to have some immunological memory of the pathogen. We found that vaccine acceptors are significantly ($p<.001$) more likely to know that a vaccine resembles a pathogen than vaccine refusers. (Figure 10) However vaccine acceptors are not significantly ($p>.05$) more likely to know that a vaccine provokes an immune response or leaves some form of immunological memory of the pathogen. (Figures 11 & 12).

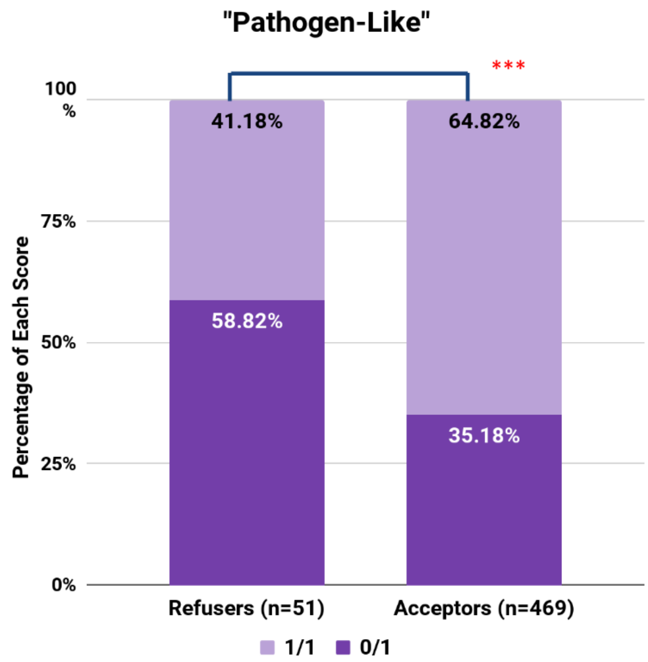


Figure 10: Vaccine Completeness Pathogen-likeness Score vs. Vaccine Refusal

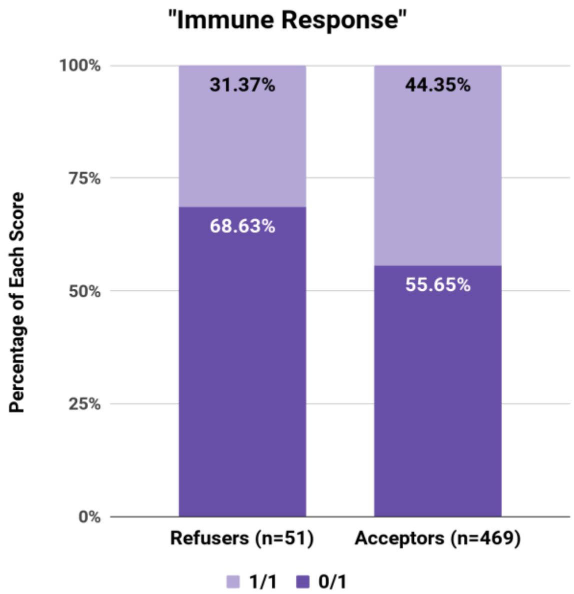


Figure 11: Vaccine Completeness Immune Response Score vs. Vaccine Refusal

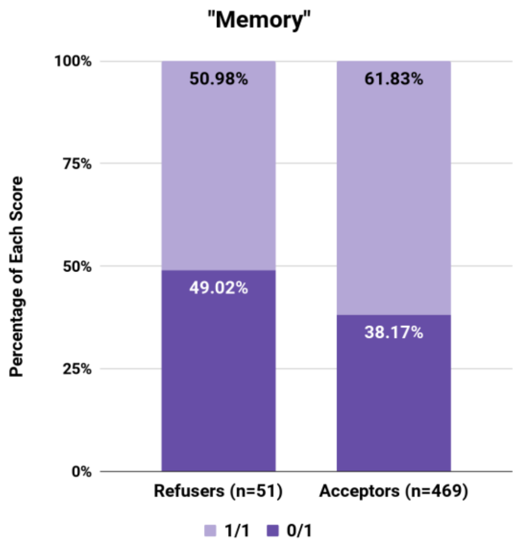


Figure 12: Vaccine Completeness Memory Score vs. Vaccine Refusal

<u>Research question number six: "Does taking a course that covers vaccines correlate with vaccine acceptance or refusal?"</u>

We correlated the response to the yes or no survey statement: “I have taken one or more courses where I learned about how vaccines work.” with the yes or no survey statement: “I would vaccinate my children.”

We found that vaccine acceptors (n=469) were not significantly (p>.05) more likely to have taken a course on vaccines when compared to vaccine refusers (n=51), suggesting this is not a strong factor for vaccine acceptance (Figure 13).

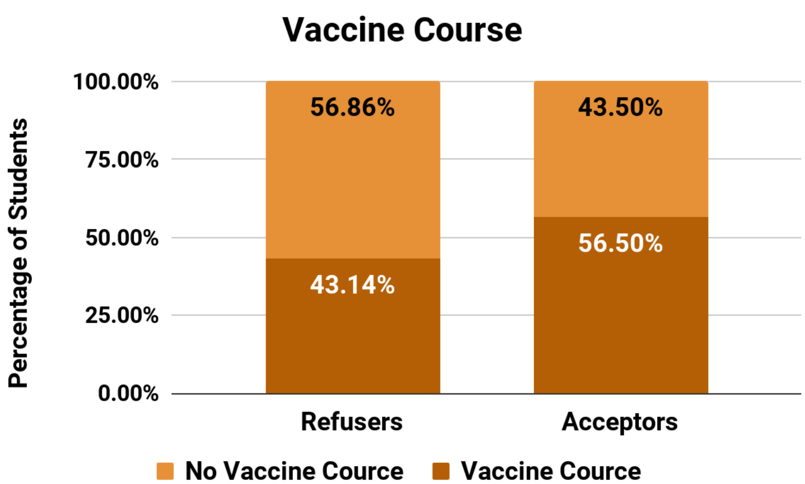


Figure 13: Vaccine Course-Work vs. Vaccine Refusal

<u>Research question number seven: “Does a student’s reference to personal experience with vaccines in their explanation of how a vaccine works correlate with vaccine acceptance or refusal?”</u>

We correlated whether students used personal experience to explain how a vaccine worked with the yes or no survey statement “I would vaccinate my children.” We found that the vast majority of people did not bring up personal experience in their explanations. Vaccine refusers (n=51) were not significantly (p>.05) more likely to have the presence of personal experience in the response to the “How does a vaccine work?” prompt then vaccine acceptors (n=469) suggesting that overall, this is not a strong factor for vaccine refusal. (Figure 14)

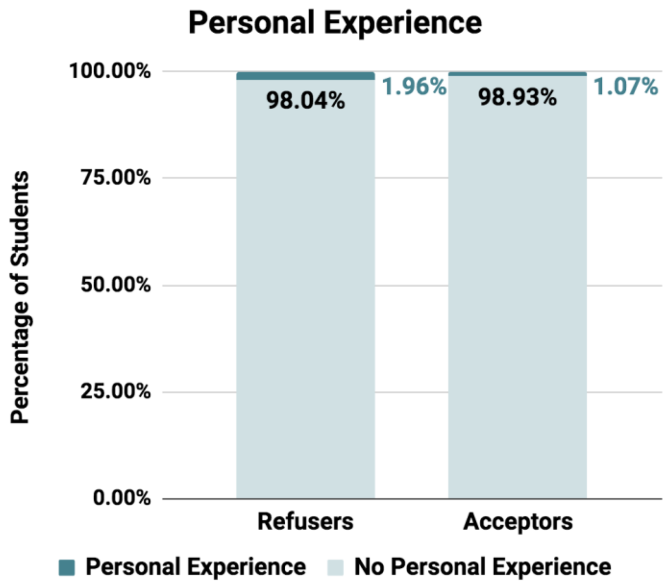


Figure 14: Personal Experience vs. Vaccine Refusal

*Analysis of Misconceptions:*

Research question number eight: "What are the common misconceptions students have about how a vaccine works?"

We used grounded theory to classify common misconceptions found in student explanations. Many students had multiple different false claims and misconceptions. We then found out which misconceptions were common amongst inaccurate students by selecting those that were present in more than 10% (n=42) of the total inaccurate responses (n=420).

We found seven common misconceptions. The most common, present in 42% of inaccurate responses was that vaccines introduce an *unmodified* disease or virus to the body (n=179). Next, 28% of students thought a vaccine uses a small or non-harmful dose of a pathogen, often the unmodified pathogen (n=118). Also, 16% of students thought that a vaccine is a treatment or cure given to a sick person (n=67). Next, 14% of students thought that vaccines allow the immune system to build antibodies which then stay in the body and are "waiting" for the true pathogen (n=58). Finally, 10% of students thought vaccines directly harm or fight the pathogen/disease (n=44), 10% of students thought vaccines provide immunity to all pathogen or diseases, (n=43), and 10% of students thought vaccines are injected directly into skin or bloodstream (n=43). (Figure 15)

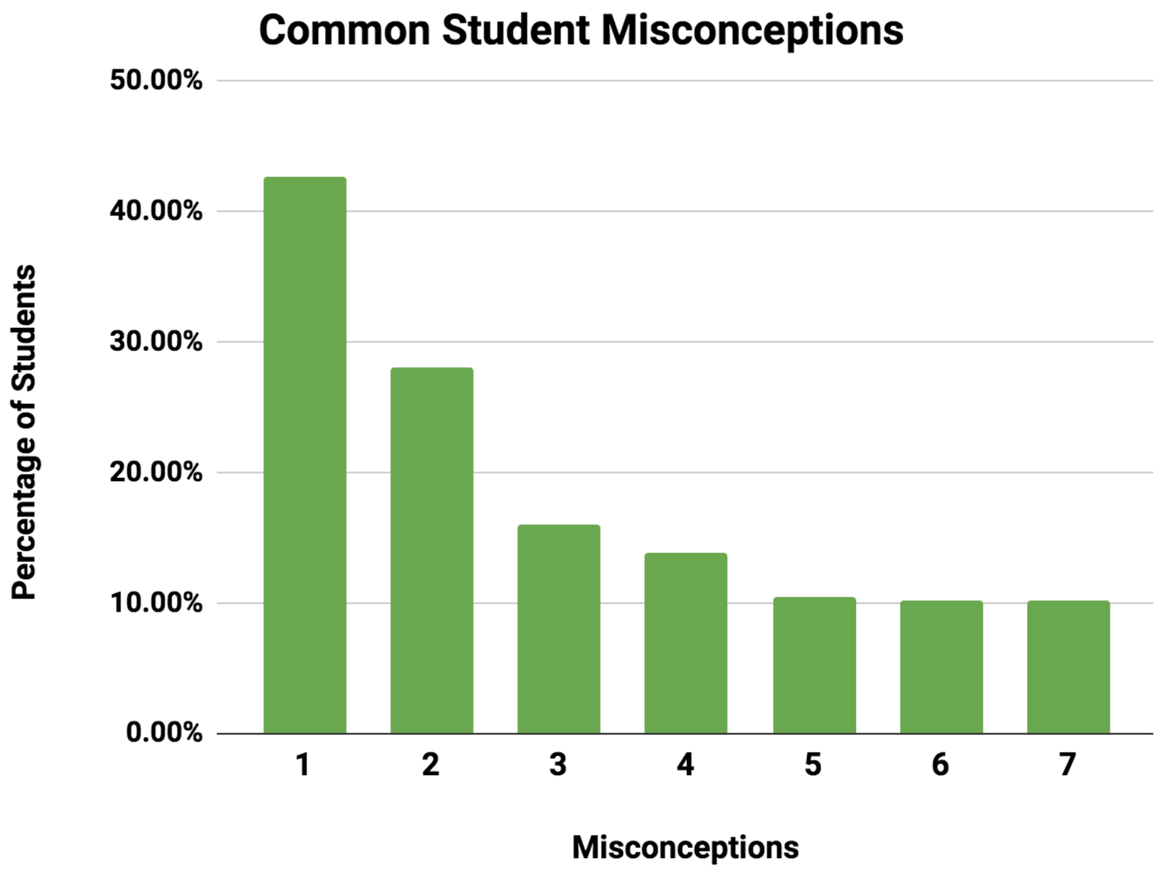


Figure 15: Common Misconceptions
Note:
1.Vaccines introduce disease/virus to the body without the mention of modification or state that vaccines are unmodified pathogen/original pathogen.
2. Vaccine is a dose/small/non-harmful amount of the original pathogen.
3.Vaccine is a treatment/cure given to a sick person.
4. Vaccines allow the immune system to build antibodies which then stay in the body and are ready/ "waiting" for the true pathogen.
5.Vaccines directly harm/fight the pathogen/disease.
6. Vaccines provide immunity to all pathogens/any foreign invader/diseases.
7. Vaccines are injected into the skin or bloodstream.

Overall, there were many common misconceptions amongst students, but the two that stand out the most are that students believe that a vaccine is an unmodified version of the pathogen and that a vaccine's dosage or amount is what dictates it being not harmful to the body.

Research question number nine: "Does the presence of common misconceptions correlate with whether a student is a vaccine acceptor or refuser?"

We used the seven common misconceptions found in the previous analysis and correlated their presence with responses to the yes or no survey statement "I would vaccinate my children." We tested all seven of our common misconceptions and found only one misconception correlated with vaccine refusal and acceptance. We found that vaccine acceptors were significantly ($p<.05$) more likely to believe the common misconception that vaccines introduce a disease or virus to the body without the mention of modification or state that vaccines are an unmodified pathogen/the original pathogen (n=179) than vaccine refusers. (Figure 16) The data for all other common misconceptions that have no significant correlations are in Table 3.

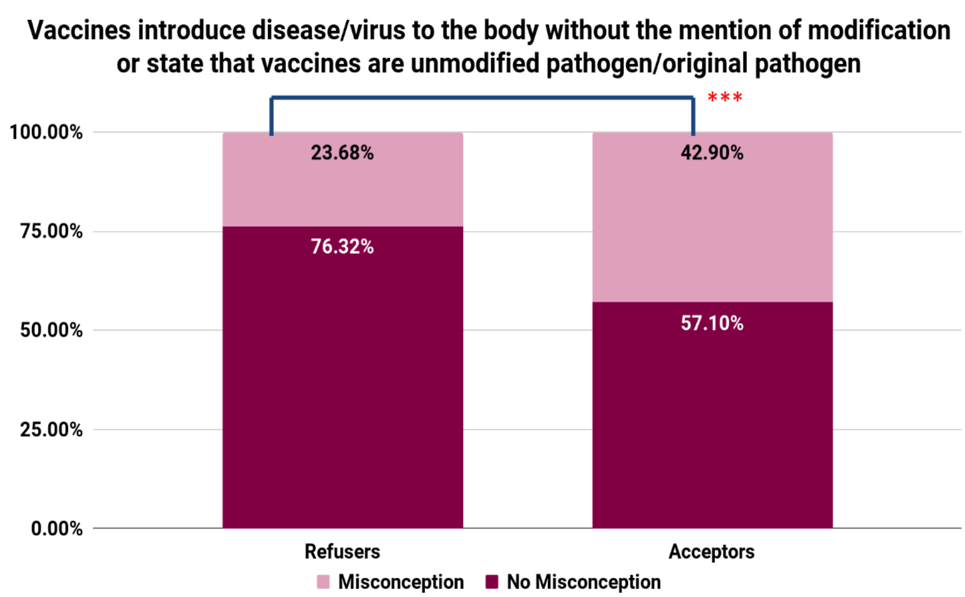


Figure 16: Misconception Vaccine Contains Unmodified Pathogen vs. Vaccine Refusal

Table 3: Not significant Common Misconceptions for Vaccine Refusal (p>.05)

| Misconception | p value |
|---|---|
| Vaccine is a dose/small/non-harmful amount of the original pathogen. | p=.11 |
| Vaccine is a treatment/cure given to a sick person. | p=.78 |
| Vaccines allow the immune system to build antibodies which then stay in the body and are ready/ "waiting" for the true pathogen. | p=.13 |
| Vaccines directly harm/fight the pathogen/disease. | p=.87 |
| Vaccines provide immunity to all pathogens/any foreign invader/diseases. | p=.61 |
| Vaccines are injected into the skin or bloodstream. | p=.33 |

Research question number ten: “Does endorsement of the essentialist misconception that, “Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease.” correlate with knowing that vaccines are “pathogen-like?”

We correlated the Likert scale response (1 or 2 being disagreed and 3 or 4 being agreed) for "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease." with the student scores for completeness, part 1: "Pathogen-Likeness".

We found that students that knew that vaccines were pathogen-like (n=411) were significantly (p<.05) more likely to disagree with the essentialist prompt that states "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease.". (Figure 17)

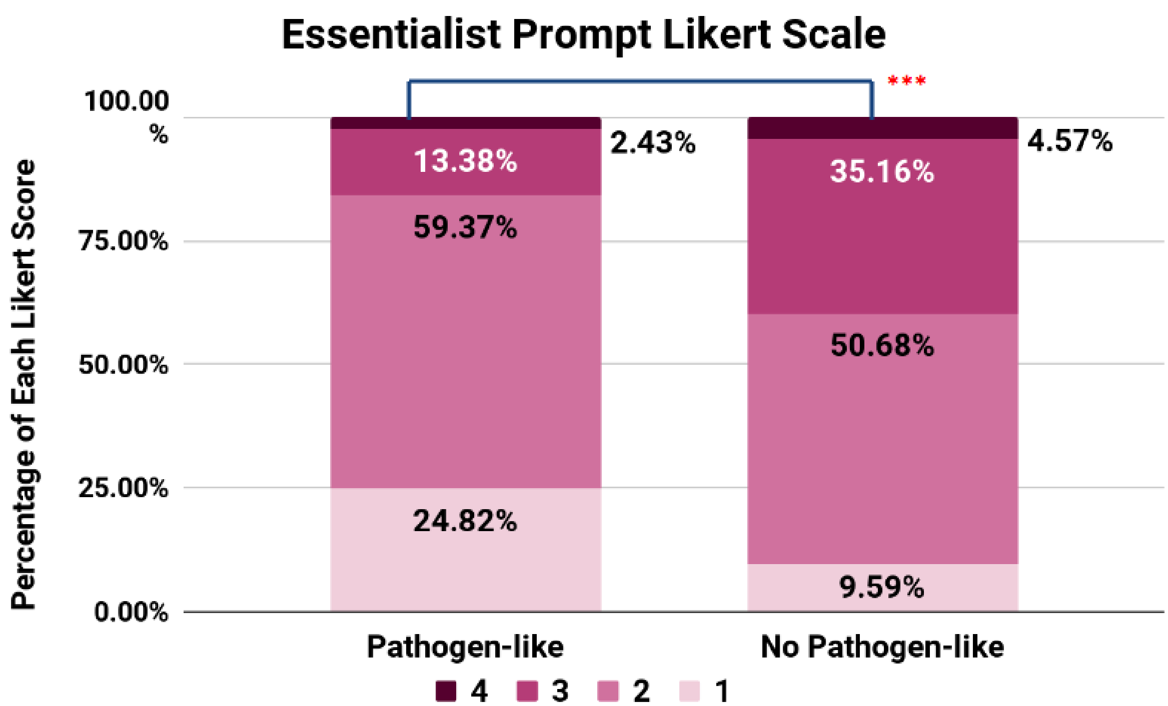

Figure 17: Essentialist prompt vs. Vaccine Completeness Pathogen-likeness Score

Overall, this shows that students who know a vaccine is pathogen-like are less likely to think a vaccine is a synthetic/artificial compound or disease.

Research question number eleven: "Does endorsement of the essentialist misconception that, "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease." correlate with the belief that vaccines contain unmodified pathogens?"

Based on the previous two results, we correlated the Likert scale response (1 or 2 being disagreed and 3 or 4 being agreed) for "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease." with the presence of the misconception that a vaccine introduces a disease/virus to the body without modification. We found that students who had this misconception (n=177) were significantly ($p<.05$) more likely to disagree with the essentialist prompt that states "Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease" (Figure 18).

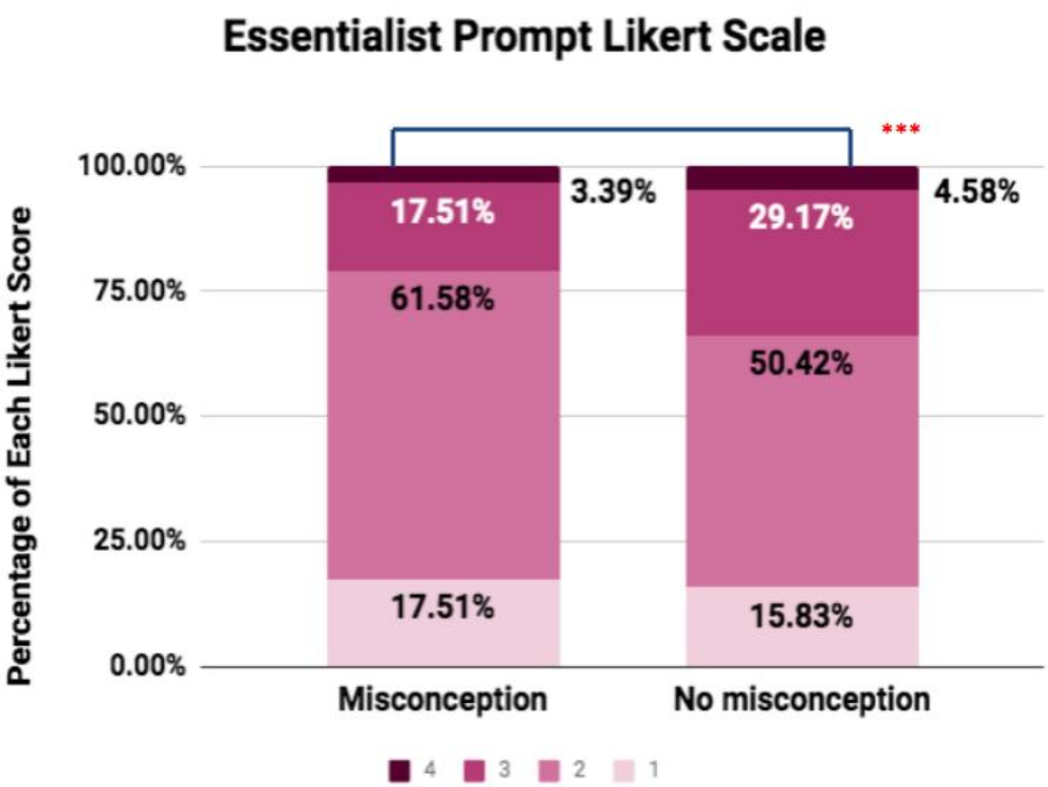


Figure 18: Essentialist prompt vs. Misconception Vaccine Contains Unmodified Pathogen

Overall, students that believe the misconception that a vaccine contains an unmodified pathogen are less likely to think vaccines are artificial.

**Discussion:**

Our work allows us to better understand student knowledge about vaccines and how it correlates with refusal. First, we have a better understanding of the knowledge students have about vaccines and the correlations that contribute to that knowledge. Second, we know better how this knowledge correlates with vaccine acceptance or refusal. Lastly, we know more about what misconceptions students may have about vaccines and if these misconceptions correlate with vaccine refusal. By knowing these, we are further able to speculate about the reasons why students are vaccine hesitant and thus combat their hesitancy.

*Creation of a Rubric for Understanding how a Vaccine Works.*

In our study, we created a rubric to assess students for their knowledge of how a vaccine works. We used multiple authoritative sources which included two reliable and commonly used websites, two commonly used immunology textbooks and the biology faculty members. We also decided to split assessing the completeness of a student's knowledge from assessing the student's accuracy. Completeness was found to have three subsections: (1) a vaccine contains part or all of a (modified) pathogen or something that mimics or is shaped like the pathogen (pathogen-likeness), 2) vaccines stimulate an immune response (immune response), and 3) if the actual pathogen is encountered in the future, the body will have a more effective response to it than without the vaccine (memory). In contrast, accuracy was scored for false claims present or not present. By doing this, we found that many students with complete responses also had misconceptions, suggesting that many students have a mix of correct and less correct ideas.

This rubric was key in understanding the knowledge of a student and then further being able to assess where the disconnect was in knowledge for both completeness and accuracy. We were able to see what misconceptions students had in further detail by using the accuracy score to identify which students had false claims. This rubric can be used to assess any population within the US, as it is comprehensive of general knowledge that is available to any student within the US.

*Student Knowledge of Vaccines:*

Courses for biology and pre-health majors often assume that entering biology and pre-health majors have a better understanding of biology than the general student population. However, previous studies have suggested that in some student populations, that is not true; in fact, for some misconceptions, even advanced biology students do not have a better understanding (Coley & Tanner, 2015). Thus, our first interest was to understand what knowledge students did have about vaccines and compare each student group to one another to see if certain groups of students knew more or less about how a vaccine worked. We had previously assumed that NPHs would have the least amount of knowledge about how a vaccine works when compared to all other student groups (PH, EBM, ABM). We thought PHs would score higher than NPHs and possibly even EBMs given they are students interested in going into the healthcare industry. However our result showed that NPHs, PHs and EBMs all had the same average level of knowledge for both completeness and accuracy. Therefore, instructors should not assume that PHs and EBMs have a more complete and accurate understanding of how a vaccine works than the general public. We had hoped that ABMs would have gained some vaccine knowledge as they had taken many biology classes and were also taking upper division biology coursework, which fortunately did turn out to be the case. ABMs had a significant increase in both completeness and accuracy over other student groups. This may be because students who take a course that covers vaccines are not only more complete but also more accurate than those students who have not taken any related coursework. However, it is important to remember that even ABMs are far from expert, as compared to faculty controls.

We also became interested to test the Dunning-Kruger effect on our sample population. The Dunning-Kruger effect is defined as a cognitive bias any person may have where they are overconfident in their knowledge but in reality lack knowledge on a given subject (Dunning, 2011). For example, a student will state they are very confident in their response and think they wrote the correct answer when in reality they got the question completely wrong. To test whether this is present in our population, we correlated their stated confidence in their response to their completeness and accuracy scores. Our results did not completely replicate the Dunning-Kruger effect because it showed that students who were confident in their responses were actually more likely to score higher for completeness of the "How does a vaccine work?" prompt. However, there were still many students who were confident in their response and scored very low for completeness. We also saw that students who were confident were not any less likely to be inaccurate in their response, which means that many confident students had inaccuracies.

*Students Vaccine Refusal and Knowledge:*

Many people believe that it is important that students gain knowledge on important health related topics so they are then able to make an educated decision about the health of themselves and their children. Thus, we needed to first figure out what percent of students were vaccine refusers. We found student vaccine refusal to be around ~10% in all examined student groups. This is not as bad as it could be, but remember that for measles, we need more than 90% vaccination rate for herd immunity.

Now that we had figured out which students were vaccine refusers or acceptors, we then were able to split the data in a new way, by vaccine refusal status. We found that vaccine acceptors were not more likely to score higher for completeness or accuracy for knowledge of the "How does a vaccine work?" prompt. In addition, despite the fact that students who have taken a course that covers vaccines know more on average, students with prior vaccine coursework are just as likely to be vaccine refusers. This may suggest that simply teaching students how vaccines work in general may not influence whether they accept them.

We then proceeded to see if there were trends in the individual sections of the completeness score. We split students based on vaccine acceptance or refusal and tested against all three completeness points such as:1) Pathogen-likeness, 2) Immune Response and 3) Memory. We did not see any correlations between vaccine refusal or acceptance for the immune response and memory completeness scores. However, we did find one for pathogen-likeness. It was found that vaccine acceptors are more likely to understand that a vaccine is pathogen-like as compared to a vaccine refuser. Therefore, for the large part, vaccine knowledge did not correlate with vaccine hesitancy except in the regard of understanding a vaccine is pathogen-like. In addition, vaccine refusers were *less* likely to believe in the misconception that a vaccine consists of an unmodified pathogen which is understandable if they do not know that vaccines contain anything pathogen-like at all. Furthermore, vaccine refusers were more likely to believe that vaccines are artificial and therefore harmful. These findings raise the possibility that if instructors focus on the fact that vaccines mimic pathogens, it might influence vaccine acceptance.

What other factors may influence why students are vaccine hesitant? Some people have argued that people make decisions about vaccines based on their personal experience. However, when we tested this we found students who were vaccine refusers were not more likely to mention a personal experience for the "How does a vaccine work" prompt. However, it may be the case that although they do not mention personal experience in this prompt, it may still play a role in their decision.

*Common Misconceptions About Vaccines:*

In the media we see countless misconceptions spread by the “Anti-Vaccine Movement”. These include “Vaccines Cause Autism,” “Vaccines are harmful to the body” and many others (Jacobson et al., 2007). Therefore, we wanted to systematically study what false claims students made about how vaccines work and correlate these with vaccine acceptance or refusal. Ours is the first study to systematically collect misconceptions about how vaccines work in a student population.

We found seven common vaccine misconceptions that were present in at least 10% of the total population of students that were inaccurate. Some of these were fundamental misunderstandings of how vaccines work. These included the idea that vaccines directly fight off the pathogen in the body or that they are a treatment or cure for a disease. Others were more incidental. These included the idea that vaccines are injected into the bloodstream instead of into a muscle. Of particular interest were the most common misconceptions: (1) vaccines consist of unmodified pathogens, (2) vaccines work because they are a small dose of a pathogen. This suggests that instructors who want their students to have an accurate view of vaccination may want to focus on the fact that vaccines mimic pathogens. For example, by consisting of dead or weakened pathogens, instead of having the pathogen itself. These results also warn against highlighting the artificial nature of vaccines. As discussed above, vaccine refusers were less likely to incorrectly believe that vaccines consist of unmodified pathogens; instead, they were more likely to believe that vaccines are artificial and therefore harmful.

These findings further highlight that the relationship between knowing more about vaccines and accepting them is not straightforward. Many students hold misconceptions about vaccines and yet are still willing to vaccinate their children. In fact, for all but one of the misconceptions, holding the misconception is not related to whether the student would vaccinate their children. Other students do not have those misconceptions and still distrust vaccines.

*Limitations:*

This project had some limitations. First, we were unable to collect data for certain statements for ABMs, most notably the statement, “I would vaccinate my children.” Therefore, all of our analysis on vaccine refusal and acceptance was done in students with less biology expertise. It would have been interesting to see how vaccine refusal, confidence in their knowledge, and coursework related to each other in more advanced students. In addition, we were limited to our one sample. As the reasons for vaccine refusal may differ in different areas, with different populations may come different results.

In addition, this study would have been strengthened by the inclusion of other data that may influence vaccine refusal. For example, we were unable to collect details of prior coursework such as what courses were taught or what other sources a student used to collect information on how a vaccine works. Also, further information on the socioeconomic background of students would be useful whether students themselves were immunized, and parental characteristics such as immunization view and status. A previous study showed that most students have substantial parental influence when it comes to decision-making (Sandler et al., 2019). We also did not analyze free response data for why students responded to, “I would vaccinate my children.” the way they did, which could further illuminate how knowledge affects vaccine refusal.

**Conclusion:**

In this study, we were able to create a rubric to assess knowledge of how a vaccine works and found that there was little correlation between the completeness and accuracy of a person’s response with their acceptance or refusal of vaccines. In addition, we were able to discover and catalog new misconceptions about how vaccines work and correlate those with vaccine refusal.

Our data has implications for how vaccines are taught. Naively, many people assume that knowing more about science leads to being more accepting of science. Our study shows instead that the relationship between knowledge and acceptance is more complicated. Simply teaching students accurate and complete information or even working to correct all their misconceptions may improve knowledge but may not increase acceptance. Instead, our study suggests that we may instead need to find and focus on particular ideas that correlate with vaccine hesitancy.

In the future, we hope to replicate this project in different populations including diverse political and religious views. Collecting data from advanced biology majors would also show how knowledge and acceptances changes with more biology education. It is worth also looking into knowledge of the creation of vaccines itself and seeing if this knowledge may be correlated with vaccine acceptance or refusal. Finally, if we are able to identify the source of vaccine refusal in any given population, we may be able to create and test educational interventions to combat vaccine refusal in each student population and perhaps in the long term improve public health.

APPENDIX 1:

**Secret Code:** ______________________________

(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

If asked by another student in your major,
how would you respond to the following question…

---

**What risks are associated with vaccines?**

---

In the space below, please **explain** your response
with as much detail as possible.

1SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code:** ________________________________
(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

Please read the statement below and circle a response on the scale:

**"Children need to get sick from diseases in order to build their immunity."**

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| **1** | **2** | **3** | **4** |

In the space below, please **explain** your response
with as much detail as possible.

2SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code:** ________________________________
(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

Please read the statement below and circle a response on the scale:

**"Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease."**

| Strongly Disagree | Disagree | Agree | Strongly Agree |
| --- | --- | --- | --- |
| **1** | **2** | **3** | **4** |

In the space below, please **explain** your response with as much detail as possible.

3SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code:** ______________________________
(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

Please read the statement below and circle a response on the scale:

**"The immune system can get stressed if too many vaccines are given at once."**

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| **1** | **2** | **3** | **4** |

In the space below, please **explain** your response
with as much detail as possible.

4SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code:** ________________________________
(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

Please read the statement below and circle a response on the scale:

**"Vaccines can cause autism in children."**

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| **1** | **2** | **3** | **4** |

In the space below, please **explain** your response
with as much detail as possible.

5SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code:** ________________________________
(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

If asked by another student in your major,
how would you respond to the following question…

---

**How does a vaccine work?**

---

In the space below, please **explain** your response
with as much detail as possible.

6SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code: ______________________________**
(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

Please circle YES or NO in response to the following…

---

**I have taken one or more courses where I learned about how vaccines work.**

**Yes** **No**

*Write one or two sentences to explain your choice.*

**I am confident in my understanding of how vaccines work.**

**Yes** **No**

*Write one or two sentences to explain your choice.*

**Vaccination conflicts with my religious or spiritual beliefs.**

**Yes** **No**

*Write one or two sentences to explain your choice.*

**I would vaccinate my children.**

**Yes** **No**

*Write one or two sentences to explain your choice.*

In the space below, please **explain** your response
with as much detail as possible.

7SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

**Secret Code: ________________________________**

(Your permanent mailing zip code, middle initial, and last four digits of your cell phone number)

***Demographics Form-UNIVERSITY STUDENT***

***Please circle an answer for each question***

**1.What is your CURRENT educational status?**

a) Undergraduate student

b) Graduate student

c) Other (please describe) ____________________

**2. What is your CURRENT class standing?**

a) Freshman (0-29 units)

b) Sophomore (30-59 units)

c) Junior (60-89 units)

d) Senior (90 or more)

e) Other (please describe) ___________

**3. Did you transfer to SFSU from a community college? (please circle)**

Yes No

**4. Please circle the option(s) that best describe(s) your current or anticipated academic concentration:**

**BIOLOGY**

a) BS Botany

b) BS Ecology

c) BS Microbiology

d) BS Zoology

e) BS Cell & Molecular Biology

f) BS Marine Biology

g) BS Physiology

h) BA General Biology

**OTHER MAJOR(S)**

Please describe ________________________________________________

**5. Anticipated Semester and Year of graduation: ____________semester ________ year**

**6. What year were you born? _________**

**7. How many children do you have? _____**

**8. The gender I identify as is______________**

**9. Are you a member of the first <u>generation</u> in your family to attend college? (please circle)**

Yes No

**10. I most closely identify as (circle all that apply)….**

a) African American

b) Filipino/a

c) Latino/a

d) White

e) Asian

f) Native Hawaiian/Pacific Islander

g) Native American

h) Decline to state

i) __________________ (please describe)

8SEPAL Data Collection
BIOL101 Human Biology
Spring 2018

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