UNIVERSITY OF CALIFORNIA SAN DIEGO

Vaccine Misconceptions and Intuitive Reasoning

in

College Students Who Accept or Refuse Vaccines

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

in

Biology

by

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Professor Ella Tour

2020

The Thesis of Fareshta Waheed 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

Alhumdulilah

To my family whose untiring support and love have made possible the fruition of my efforts. This thesis is humbly dedicated to *my father,* Abdul Q. Waheed, - for being my first teacher, and to *my mother,* Romina Waheed- whom I owe everything.

To *Waheeda* and *Fareeda*- you have made this possible, I am indebted to you. To *Sajad* and *Sadaf*- you have been both my inspiration and motivation.

I am grateful to my friends who have been shining lights on some of my darkest days.

I hope I have made you all proud. I am eternally blessed to be surrounded by you all.

And most of all to our great creator, **Almighty God**, the author of knowledge and wisdom. My success is only by **Allah** (s.w.t.).

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ABSTRACT OF THE THESIS

Vaccine Misconceptions and Intuitive Reasoning
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Vaccines face growing skepticism (Poland & Jacobson, 2001; Wilson & Marcuse, 2001). Intuitive reasoning, including teleological, essentialist, and anthropic thinking, can complicate students' ability to learn core concepts in biology (Coley & Tanner, 2015). As previous studies found that unvaccinated children were more likely to have mothers with a college degree (Smith et al., 2004; Yang et al., 2016), we wanted to explore the relationship between vaccine misconceptions, intuitive reasoning, and vaccine refusal in college biology students.

Our study uses data previously collected at a diverse public comprehensive university. We asked non-biology majors, entering biology majors, and biology faculty whether they would vaccinate their children. We also asked whether and why they endorsed for intuitive-reasoning-based misconceptions about vaccines.

Approximately 10% of students would not vaccinate their children. We found intuitive reasoning was prevalent across all levels of expertise. Vaccine acceptors were more likely to use teleological reasoning overall, but vaccine refusers were more likely to use essentialist reasoning to answer 3 of the 4 prompts. Finally, we found that endorsement of the essentialist, anthropic, and autism misconceptions was significantly correlated with vaccine refusal. In our data set, we did not find any differences in the proportion of vaccine refusers by gender, white vs. non-white race, or first-generation college student status.

In the future, we hope to explore this relationship in more depth with examples of intuitive reasoning that are pro- and anti-vaccine. Eventually, we would like to design educational interventions to combat misconceptions and vaccine hesitancy.

Introduction:

Despite the fact that vaccines are generally safe and effective, **many people choose not to vaccinate** (Jacobson et al., 2007). It has been observed from other areas of biology that alternate conceptions regarding core concepts in biology, including *intuitive reasoning,* can complicate students' ability to learn (Coley & Tanner, 2015). These types of reasoning include teleological thinking (explanations based on purpose or goal), essentialist thinking (explanations based on core properties or essences), and anthropic thinking (explanations based on ascribing human traits and emotions to non-human entities). Previous studies have also found that unvaccinated children were more likely to be white, with higher income, and with a mother with a college degree (Smith et al., 2004; Yang et al., 2016). Therefore, our project seeks to understand the ways in which students who reject vaccines (vaccine refusers) are different from students who accept vaccines (vaccine acceptors), especially when it comes to intuitive reasoning.

Vaccine hesitancy

Vaccines are an effective tool for public health, but they still face growing skepticism (Poland & Jacobson, 2001; Wilson & Marcuse, 2001). Vaccine hesitancy is defined as a "delay in acceptance or refusal to vaccinate despite availability of vaccination services" (MacDonald, 2015). The public's view of vaccine preventable diseases has decreased, and fears of their possible side effects have gained in popularity. Requests for exemptions for vaccines for non-medical reasons have risen (Olive et al., 2018). Vaccine attitudes today have the ability to pose a global threat (WHO, n.d.). Vaccines are a public tool that protect individuals as well as communities by reducing transmission. Some individuals are immuno-compromised and cannot get vaccinated. Thus, is it necessary to make sure we vaccinate as many people as possible so we can establish

community immunity. We need to better address the public's concerns about vaccination.

Despite the importance of this issue, researchers have found it difficult to persuade people with anti-vaccine views to change their minds. Previous research has shown education about herd immunity can be used as a successful aid in increasing positive vaccine attitudes and thus have both direct and indirect effects on people (Logan et al., 2018). There has been limited educational research addressing vaccine hesitancy in students. In one previous research study, students were told to interview a family or community member with vaccine-preventable disease (VPD). Those students who were vaccine-hesitant were slightly more likely to change their views to view vaccines more positively (Johnson et al., 2019). Another study found that asking students whether they were committed to acting in line with the truth and presenting them with statistics about vaccine-preventable diseases make students more likely to advise another hypothetical person to vaccinate their children (Darner, 2019). However, neither of these interventions reached every student.

What we know about vaccine misconceptions

The literature shows that there are many widely believed misconceptions about vaccines, which can be categorized as either cognitive, motivational, and or social in nature (Jacobson et al., 2007). They have spread because of the anti-vaccine movement and social media posts. Some of these beliefs are related to biological concepts. These include that it is necessary for children to develop immunity by getting sick, artificial exposure is more dangerous than naturally acquiring diseases, the immune system can be overloaded with multiple vaccines, and that vaccines cause autism (Jacobson et al., 2007). Some researchers have connected vaccine misconceptions with decreased immunization rates in children and measles outbreaks (Doja & Roberts, 2006).

Alternative conceptions in biology and intuitive reasoning

Alternative conceptions regarding core concepts in biology, including *intuitive reasoning,* can complicate students' ability to learn (Coley & Tanner, 2015). Intuitive reasoning refers to ways of reasoning that are common and easy to use when thinking in order to explain biological processes, especially in children and societies without formal science, that are not necessarily grounded in science. In conjunction with these conceptualizations, it is easier to misunderstand biological information. Examples of intuitive reasoning including teleological, essentialist, and anthropocentric reasoning are further explained below.

Teleological reasoning is reasoning that assumes that a goal, need, or purpose is a cause for a change or event (Coley & Tanner, 2012). The statement "Plants give off oxygen so that animals can breathe," depicts a purpose-based explanation. Although animals do breathe the oxygen given off by plants, this is not the reason plants give off oxygen. When considering vaccines, one common misconception that shows evidence of teleological thinking is, "Children need to get sick from diseases in order to build their immunity"(Jacobson et al., 2007). Children do not get sick for the purpose of creating immunological memory.

Essentialist reasoning involves the assumption that "a core property or feature of a biological structure, species, or system determines its overt features and identity," (Coley & Tanner, 2012). For example, "Changing a single gene in an organism results in a new kind of organism," (Coley & Tanner, 2012). Individuals think that genes are the core property of organisms, thus when a change occurs, regardless of magnitude, they believe the organism is entirely different. When it comes to vaccines, one common type of misconception that may use essentialist reasoning is that, "Because vaccines are artificial, they can cause more harm in their effects compared to natural

exposure to a disease," (Jacobson et al., 2007). Once again, people believe there is an essence of "artificiality" which contributes to the harmfulness of an object, whereas something in essence of "naturalness" means safe to trust.

Anthropocentric reasoning describes a form of intuitive reasoning in comparison to human beings. It is common to see biological importance given to humans in this language or observing biological entities or processes in analogous to human characteristics (Coley & Tanner, 2012). As stated here, "Bacteria develop resistance to antibiotics because of changes within humans in response to an antibiotic medication," (Richard et al., 2017). Here, it is bacterial changes that cause resistance to antibiotics, thus the emphasis on humans is unnecessary. When considering vaccines, one common misconception that shows evidence of anthropocentric thinking is, "The immune system can get stressed if too many vaccines are given at once," (Jacobson et al., 2007). The immune system responds to an immense quantity of foreign pathogens daily and can handle multiple vaccines. Some more examples of this type of reasoning when applied to non-vaccine biological topics are in Table 1.

Previous research has found that undergraduates routinely use intuitive reasoning to explain topics that they have learned about in biology (Richard et al., 2017). It can help explain why undergraduates face challenges with biological topics and why some misconceptions are appealing, which in turn affects their capability to learn correct information and stop further spreading misconceptions (Coley & Tanner, 2012). Therefore, knowing this the extent to which intuitive reasoning is used when thinking about vaccines will help us understand how it complicates students' abilities to learn and how it might be taken into consideration when teaching.

TABLE 1: Forms of Intuitive Reasoning with definition and example. (Coley & Tanner, 2015)

Definition	**Teleological Thinking** Explanations of a process, behavior, or trait based on a goal, purpose, or function.	**Essentialist Thinking** Assumption that members of a class are relatively uniform, static, and predictable due to shared underlying factors	**Anthropic Thinking** Distorting the place of human beings in the natural world and over-attribution of human characteristics
Example of student idea	"Species adapt in order to survive."	"Different cells contain different DNA."	"Plants get their food from the soil"

What we know about people who are vaccine hesitant

Unlike other misconceptions, vaccine hesitancy has been linked to higher levels of education and privilege. Previous studies have found that unvaccinated children were more likely to have a mother with a college degree (Coley & Tanner, 2012; Smith et al., 2004; Yang et al., 2016). There is also data showing that "personal belief," or non-medical, exemptions from vaccination are more common with individuals who are White and of higher income (Coley & Tanner, 2012; Smith et al., 2004; Yang et al., 2016). This supports the existence of demographic differences between vaccine refusers and acceptors and suggests that targeting college students might be useful when combating anti-vaccine ideas.

In this study, we wanted to explore how intuitive reasoning might affect student thinking about vaccines. Even though no vaccine is completely risk free, vaccines are thoroughly tested and have met high levels of safety with side effects being minimal and rare (Petrovsky, 2015). Despite

that, fears about vaccines have translated into a rise of more non-medical exemptions by reluctant vaccine parents (Wang et al., 2014). Although an individuals' decision to vaccinate and skepticism of vaccines is influenced by many factors, including their sources of information, personal experiences, political orientation, religious background, and orientation towards knowledge (Baumgaertner et al., 2018; Darner, 2019; Joslyn & Sylvester, 2017; Spier, 2001), no one has explored the potential influence of intuitive reasoning on the understanding of the biology of vaccines and vaccine refusal. Our study seeks to add another factor that might add to our understanding of how people, particularly students, think about vaccines. To that end, we wanted to explore the relationship between vaccine misconceptions, intuitive reasoning, and vaccine refusal in college biology students by investigating the following research questions:

1. What proportion of biology students across expertise levels **refuse vaccination?**
2. How prevalent is each type of **intuitive reasoning** across expertise level?
3. To what extent does endorsement of **intuitive-reasoning-based misconceptions** about vaccines correlate with use of **intuitive reasoning**?
4. To what extent does use of **intuitive reasoning** and **endorsement of misconceptions** correlate with **vaccine refusal**?
5. To what extent do the **demographic characteristics** of vaccine refusers and acceptors differ?

Methods:

Data collection

Our sample size consisted of 295 non-biology majors (NBM), 231 entering biology majors (EBM), 104 advanced biology majors (ABM) and 24 biology faculty (BF) at a large diverse urban public comprehensive university. For students, recruitment consisted of a written survey given during class time, with the instructor's permission. These classes were a course focusing on human physiology for non-biology majors (NBMs); the first introductory biology course for entering biology majors (EBMs); and an upper-division core biology course for advanced biology majors (ABMs). The classes were chosen because they had large enrollment and matched the expertise levels we needed. Completion of the activity was mandatory for course credit, but participating in the research component was optional, as students could choose to opt out. Faculty recruitment was done over email and incentivized with a $25 gift certificate. All biology faculty at the institution whose research or training involved molecular biology, cellular biology, immunology, microbiology, physiology, or disease were recruited, except for faculty on leave or who were present in the classroom during the student survey. The survey was given one-on-one in faculty participant's offices. All biology faculty (BF) responses were included in my research as a comparison with the student participants. Details about recruitment rates and the demographic characteristics of the sample are given in Table 2.

Data was cleaned by removing participants whose stated majors did not match the course group they were in (for example, biology majors out of the NBM course or an environmental science major taking introductory biology). The student population that were undeclared were categorized with non-biology majors.

To protect privacy and anonymize participants, each participant generated a unique secret code instead of giving personally identifiable information. This study was approved by the Human-Animal Protections (HAP) program of San Francisco State University under protocol #E17-257.

TABLE 2: Participant populations ** $p<0.001$ by chi-square analysis

Participant group	Number invited	Sample size	Participation rate	Participants of color	Participants identifying as female or other	Participants with children
NBM	303	295	97%	83%	73%	1%
EBM	244	237	97%	88%	74%	1%
ABM	106	104	98%	83%	66%	3%
BF	33	24	73%	46%**	38%	63%**

Survey Design

In the survey we asked the participants (all but ABM) to respond with a Yes/No to **"I would vaccinate my children."** All participants were also asked whether they endorsed several intuitive-reasoning-based misconceptions about vaccines and asked them to explain their responses in writing. The misconceptions are stated in Table 3.

TABLE 3: Misconception prompts on survey that promote respective intuitive reasoning.

Teleological Misconception (T)	**"The immune system can get stressed if too many vaccines are given at once."**
Essentialist (E)	**"Because vaccines are artificial, they can cause more harm in their effects compared to natural exposure to a disease."**
Anthropic (A)	**"Children need to get sick from diseases in order to build their immunity."**
Autism (Aut)	**"Vaccines can cause autism in children."**

There was also another section of the survey that asked about demographic information, such as first-generation college status, class level, ethnicity, and gender. The full survey can be found as appendix I.

Analyses

We generated a coding guide in order to have a tool which can be utilized to identify cognitive construals (teleological, essentialist, and anthropocentric thinking) in the misconception prompts. It was based on preliminary work generated by two previous coders, but as we initially

explored the data, we heavily revised it after discussion between two coders. To validate our coding, we measured inter-rater reliability where responses were blinded. A second coder re-coded 10% of responses. Inter-rater reliability agreement was greater than 85% for the presence of each type of reasoning (teleological, essentialist, and anthropocentric) and for each prompt.

After validation, the full data set consisting of 654 individual's written responses to 4 prompts each (2616 prompts in total) was completely coded for the presence of teleological, essentialist, and anthropocentric reasoning.

To determine significance, I did Pearson chi-squared tests with Bonferroni correction. To measure effect size, data was analyzed with Cramer's V.

Results:

My work has six main findings. To begin, I first establish what proportion of our participants (biology faculty and biology students) would vaccinate their children. Next, I produce evidence that regardless of expertise level, intuitive reasoning is prevalent in responses. Subsequently, I examine which types of intuitive reasoning the prompts elicit. Next, I explore how use of intuitive reasoning as well as endorsement of certain misconceptions correlate with vaccine refusal. Finally, we discuss whether there are demographic differences between vaccine acceptors and vaccine refusers.

There are biology students who would refuse vaccinations for their children

In order to better understand vaccine attitudes amongst our biology students, I examined what proportion of students responded "No" to "I would you vaccinate your children?". I also analyzed BF responses. Surprisingly, we found 9.8% of students would not vaccinate their

children. The proportion was not significantly different between non-biology majors: (10%, 29/291) and entering bio majors (9.6%, 22/230). This suggests we should not assume that EBM has more positive or science-based attitudes towards vaccines than NBM (Fig. 1). In contrast, all faculty (24/24) responded that they would or already have vaccinated their children.

Finding no significant difference between the percent respondents of NBMs and EBMs, and due to the similarity in the proportion of vaccine refusers in each student category, refusers from student groups were collapsed together for following analyses.

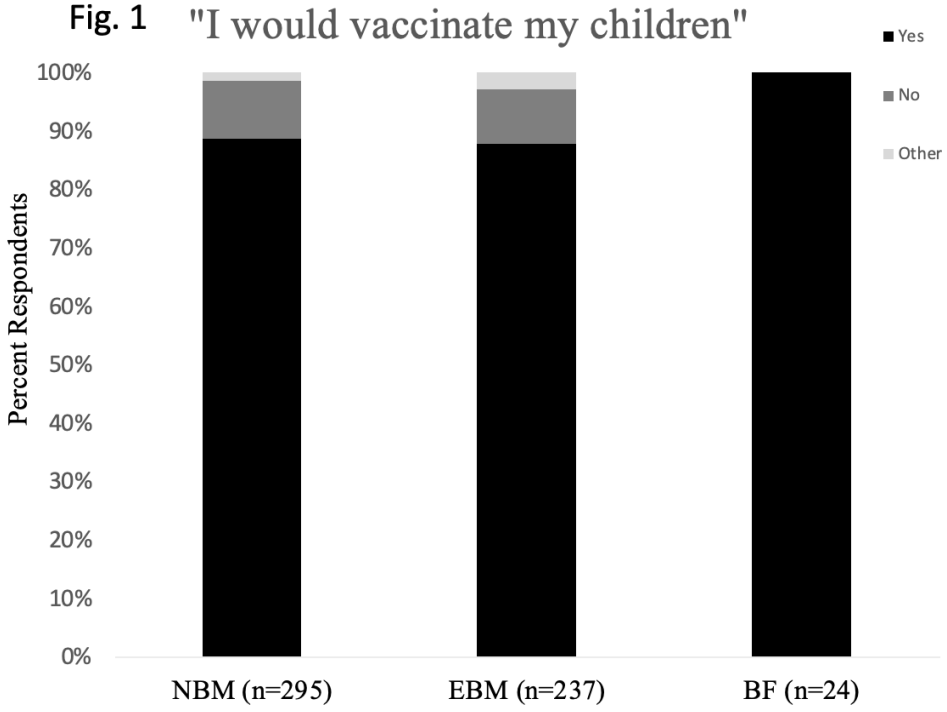

FIGURE 1: Analysis of expertise level and respective responses to "I would vaccinate my children".

Intuitive reasoning is prevalent across all levels of expertise

How might intuitive reasoning play a role in student thinking about vaccines? Previous literature has shown that biology students spontaneously use intuitive reasoning when thinking about other biological misconceptions (Coley & Tanner, 2012). Therefore, we coded all participant

responses for the presence of three types of intuitive reasoning. Table 4 depicts examples of quotes from all four prompts by type of reasoning, with the part of the quote that demonstrates intuitive reasoning bolded.

TABLE 4: Sample quotes from data set demonstrating types of intuitive reasoning used by different expertise levels by misconception.

Type of Misconception	Statement	Expertise Level
Teleological	"**That's why we have vaccines.** With the vaccines, children get exposed to diseases in amounts that allow them to build immunity but not necessarily to get sick."	BF, Agree with Teleological misconception
Essentialist	"**We are not artificial beings, so why would we use synthetic/fake elements** to keep us healthy. That doesn't make sense."	NBM, Agree with Essentialist misconception
Anthropic	"If you give too many vaccines, **the immune system won't be able to focus on anything because it is overwhelmed**."	EBM, Agree with Anthropic misconception
Autism	"Vaccines do not cause DNA or chromosomal change. It elicits an immune response. Therefore, it cannot cause autism. **Autism is caused by mutation in DNA/chromosome**.	ABM, Disagree with Autism misconception

Overall, we found that intuitive reasoning was prevalent across all levels of expertise when thinking about vaccines. We looked across prompts to see whether individuals at different levels of expertise used intuitive reasoning. Roughly 90% of individuals at each expertise level used intuitive reasoning of some sort.

Our data demonstrated that Faculty were more likely to use teleological thinking than all student levels, but all students at all levels were more likely to use anthropic thinking (Fig. 2) ($p<0.001$ for all groups, Cramér's V of 0.57 and 0.23 for teleological thinking and anthropic thinking respectively. This may be important in understanding how intuitive-reasoning-based language affects classroom learning and aiding students in better understanding complex biological phenomena.

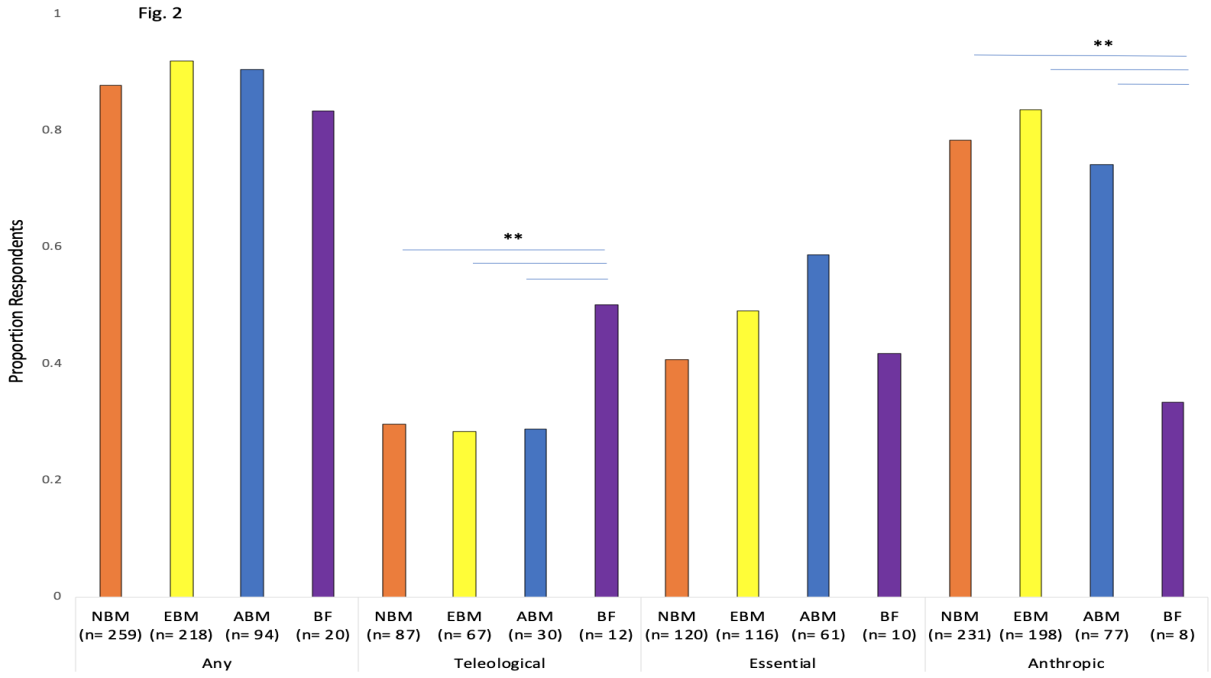

FIGURE 2: Prevalence of intuitive reasoning among expertise level. **p< 0.001.

Misconceptions elicited a variety of intuitive reasoning

I hypothesized that each of our misconceptions would elicit a specific type of intuitive reasoning. However, our data set suggests otherwise, as we found that our intuitive-reasoning-associated prompts did not always elicit the types of reasoning we hypothesized (Fig 3). For example, agreement with the essentialist prompt was associated with essentialist reasoning ($p<0.004$ for all groups, Cramér's V of 0.27 overall) but also with less teleological reasoning ($p<0.004$ for all groups, Cramér's V of 0.19 overall). Interestingly, agreement with the Autism misconception was associated with being *less* likely to use essentialist reasoning ($p<0.004$ for all groups, Cramér's V of 0.17 overall). Agreement with the anthropic prompt was associated with anthropic reasoning ($p<0.004$ for all groups, Cramér's V of 0.25 overall). Agreement with teleological misconception was associated with less essentialist reasoning $p<0.004$ for all groups, Cramér's V of 0.21 overall) but more anthropic reasoning. ($p<0.004$ for all groups, Cramér's V of 0.26 overall)

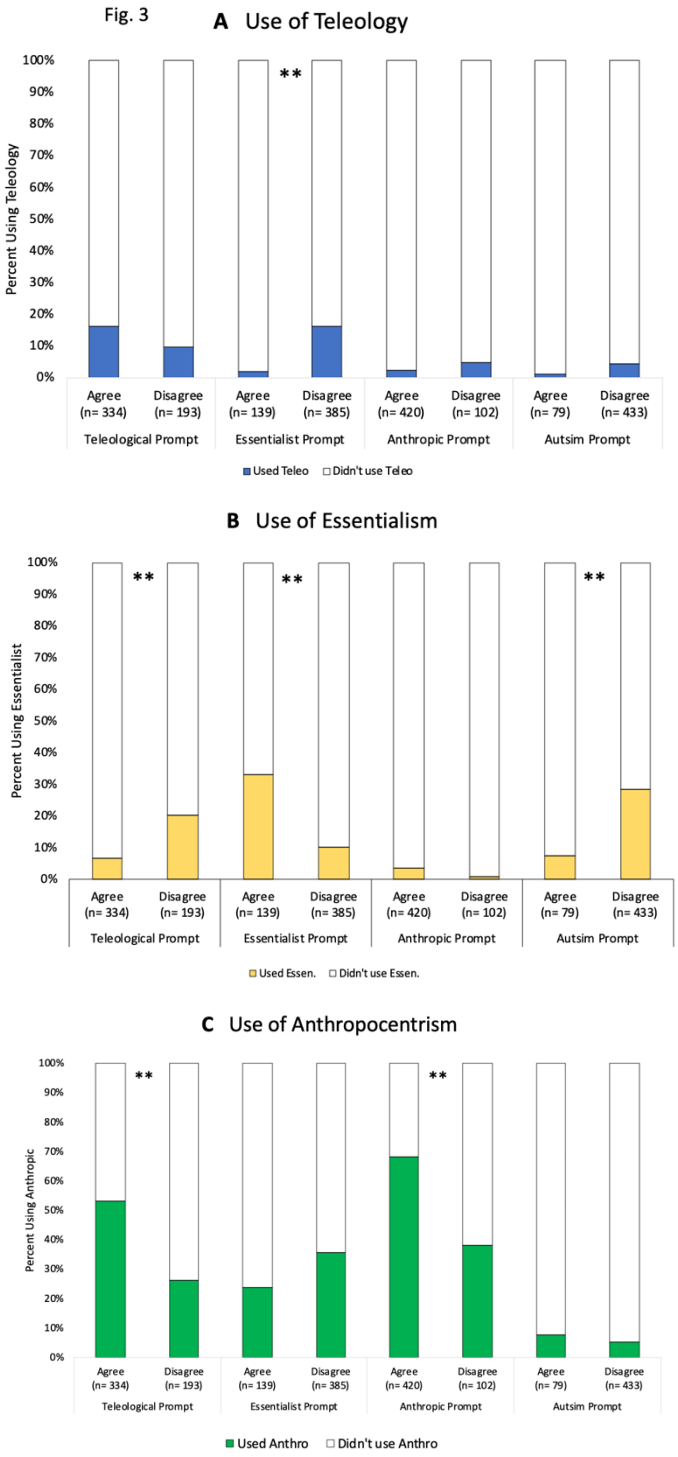

FIGURE 3: Relationship of Cognitive based thinking and Misconceptions in (A) the Teleological prompt, (B) the Essentialist prompt, and (C) the Anthropic prompt. ** $p<0.004$.

Intuitive-thinking-based thinking and endorsement of misconceptions correlate with vaccine refusal

We wanted to know what factors correlate with vaccine refusal. First, we examined the types of reasoning vaccine acceptors and vaccine refusers used. We found that vaccine *acceptors* were more likely to use teleological reasoning ($p<0.02$ for all groups, Cramér's V of 0.34 overall) but found no significant differences with the other types of reasoning (Fig. 4a). However, given that agreement with some of the prompts was associated with *less* use of certain types of intuitive reasoning, we wanted to examine the use of intuitive reasoning by refusers and acceptors by prompt. We did not find a significant association between whether someone was a refuser or an acceptor and their use of teleological or anthropic thinking for any prompt.

However, there was a significant association between use of essentialist reasoning and being a refuser for all prompts except the autism one (Figure 4b). ($p<0.004$ for all groups, Cramér's V of 0.15 for Teleological, 0.13 for Essentialist, and 0.27 for Anthropic). There was a trend between use of essentialist reasoning and being an acceptor for the autism prompt, but it did not reach significance ($p<0.01$). That may be because some forms of reasoning were used in both pro- and anti-vaccine ways. Essentialist reasoning, for example, was used by both many refusers to agree with the essentialist misconception and many acceptors to disagree with the autism misconception.

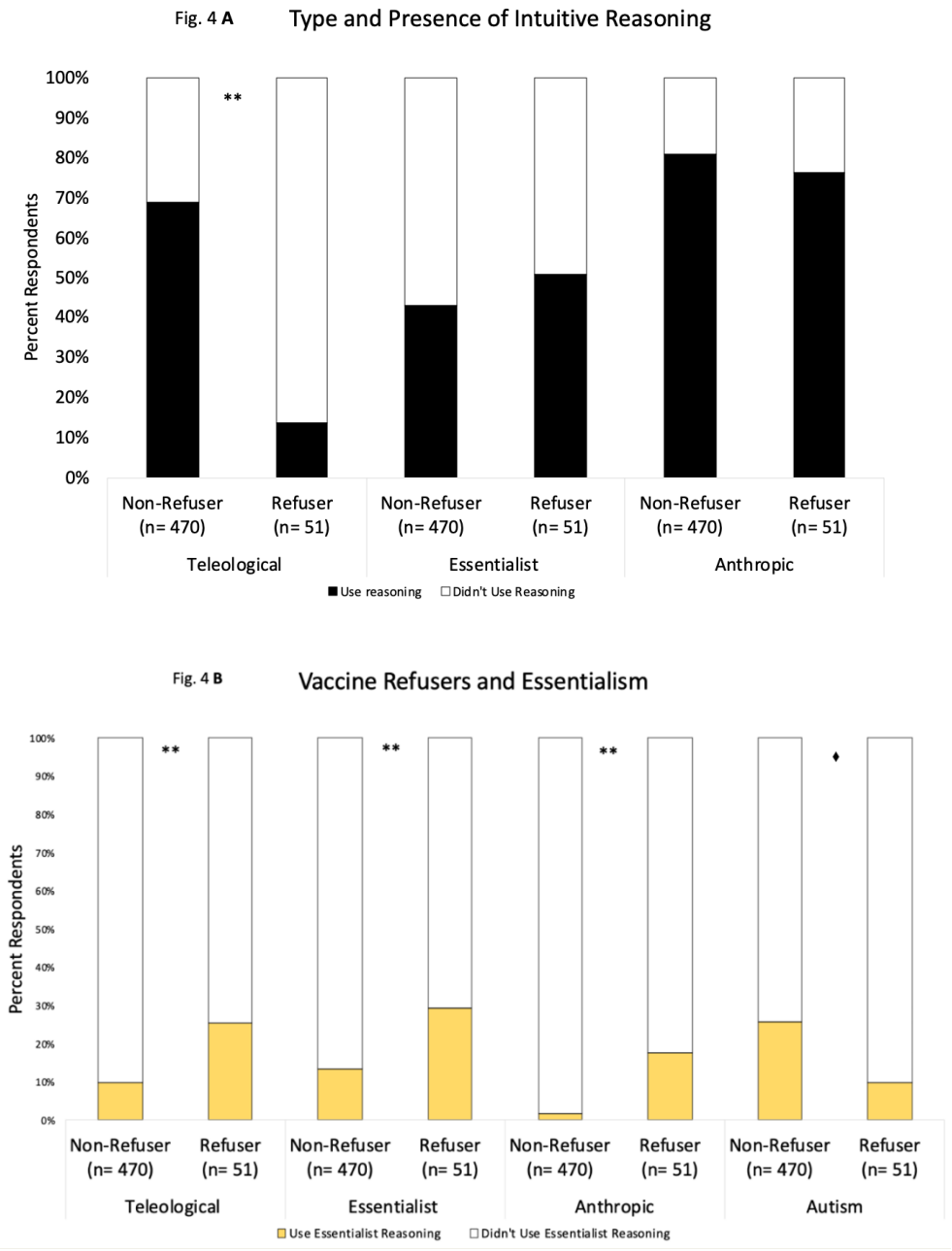

FIGURE 4: (A) Intuitive-thinking-based thinking use. (B) Endorsement of misconceptions correlate with vaccine refusal A** $p < 0.02$, B ** $p < 0.004$ and ♦ $p = 0.01$ trending significance.

We also wanted to know whether endorsement of particular misconceptions was associated with vaccine refusal. We found that endorsement of the essentialist, anthropic, and autism

misconceptions was significantly correlated with vaccine refusal (Fig 5). That suggests that these misconceptions, particularly the essentialist one with the biggest effect size, may be particularly associated with refusal ($p<0.01$ for all groups, Cramér's V of 0.40 for Essentialist, 0.14 for Anthropic, and 0.33 for Autism).

Fig. 5 Vaccine Refusal and Endorsement of Misconceptions

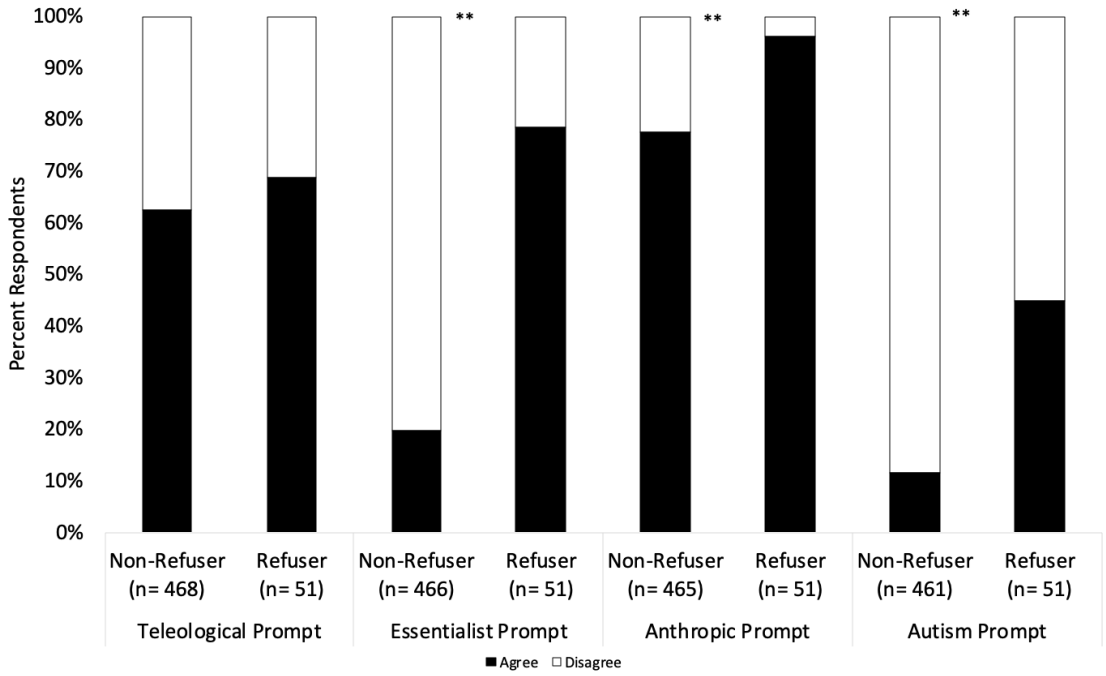

FIGURE 5: Vaccine Refusers endorse three out of the four misconceptions. ** $p<0.01$

No significant difference found in the demographics of vaccine refusers and acceptors

Previous studies have found that unvaccinated children were more likely to be white, with higher income, and with a mother with a college degree (Smith et al., 2004; Yang et al., 2016). However, in our data set, we did not find any differences in the proportion of vaccine refusers by class level (Fig. 6A), first-generation college student status (Fig. 6B), white vs. non-white race (Fig. 6C), or gender (Fig. 6D).

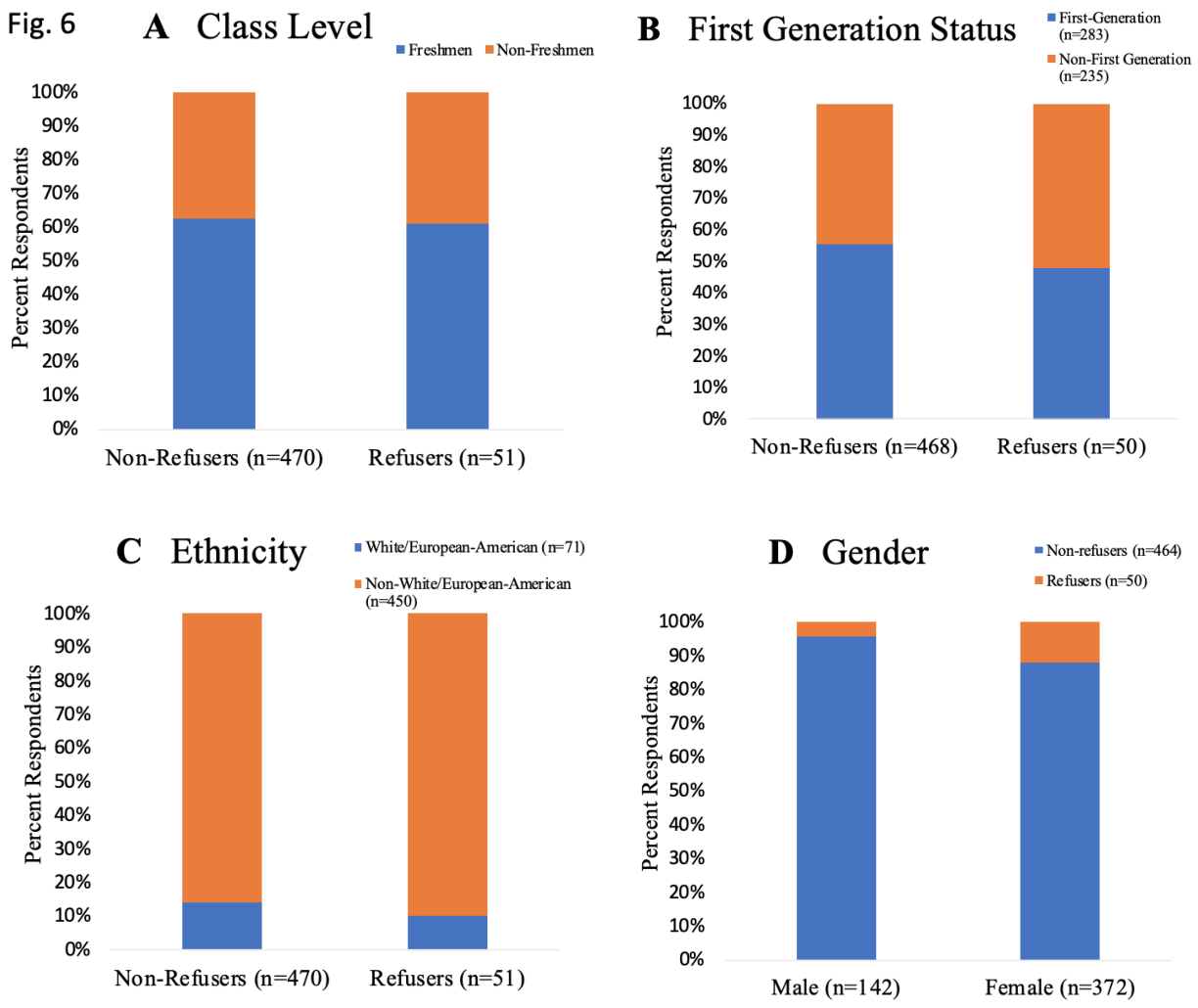

FIGURE 6: No demographic differences in our data set.

Discussion:

We know the relationship between vaccine hesitancy and misconceptions are not the only factors when it comes to an individual's choice to get vaccinations. Our goal is to explore another factor that might be influencing how students think about vaccines.

Sizable minority of students are Vaccine refusers

In our sample, we observe students who do refuse vaccines. Many may think that students

who are entering biology students would be less likely to be refusers compared to non-biology majors; however, that is not the case. From our analysis, we cannot assume that EBMs are more willing to vaccinate than NBMs simply because one group is biology majors.

Intuitive Reasoning Common in Participant Responses in all groups

I hypothesized that instructors would use very minimal to no intuitive reasoning in their responses. However, instructors do use cognitive construal language like students. According to previous literature, instructors heavily use anthropic language, especially in non-majors classes (Betz et al., 2019). In contrast, we see in our analysis that instructors were more likely to use Teleological language when compared to students. Students were more likely to use Anthropic language than instructors in our data set. This may be a difference between how instructors explain themselves on a survey compared to how they explain concepts to their students. Regardless, our results corroborate the Betz et al. 2019 that biology faculty use intuitive reasoning and raises the possibility that their use of it may influence student understanding of biology.

Intuitive-reasoning-associated prompts did not always elicit cognitive construal language

We aimed to evaluate the relationship between intuitive reasoning-based prompts and use of cognitive construal language. We observed that agreement with the essentialist prompt was associated with essentialist reasoning, as well as with less teleological reasoning. With agreement with the Autism misconception there was associated with being less likely to use essentialist reasoning. Agreement with the anthropic prompt was associated with anthropic reasoning. Lastly, agreement with teleological misconception was associated with more anthropic reasoning, but less essentialist reasoning. These associations are helpful in understanding that not all prompts evoke

the use of their hypothesized type of intuitive reasoning.

Construal-based thinking, and vaccine refusal

We wanted to know what factors correlate with vaccine refusal. So, we examined the types of reasoning vaccine acceptors and vaccine refusers used. We found that vaccine *acceptors* were more likely to use teleological reasoning but found no significant differences with the other types of reasoning. However, if we look at the prompts individually, we see that there was a significant association between use of essentialist reasoning and being a refuser for all prompts except the autism one. There was a trend between use of essentialist reasoning and being an acceptor for the autism prompt, but it did not reach significance, possibly because so few people believed in this misconception in the first place. Taken all together, these findings indicate that the relationship between use of intuitive reasoning and vaccine refusal is complex and raises the possibility that some forms of reasoning are used in both pro- and anti-vaccine ways. Essentialist reasoning, for example, was used by both refusers to agree with the essentialist misconception and acceptors to disagree with the autism misconception.

Endorsement of misconceptions and vaccine refusal

It is important to see if any misconceptions were more popular or more likely to be held amongst vaccine refusers so that instructors might know how to focus their teaching. We found that although the majority of students endorsed the teleological and anthropic misconceptions, it was the endorsement of the essentialist, anthropic, and autism misconceptions that was significantly correlated with vaccine refusal. It is interesting that very few people endorsed the autism misconception, despite its prominence in the media; this may be because many students

had heard that this idea was debunked. Of these three misconceptions, the effect size for the essentialist misconception was the largest. Combined with the results above that suggest essentialist reasoning is associated with vaccine refusal in all but one of the prompts, this finding raises the possibility that in this population of students, essentialist reasoning may be particularly associated with anti-vaccine thinking.

Demographic differences do not exist

In our analysis we observe no demographic differences in our sample. Although previous literature informs us that vaccine refusers tend to be white, college-educated mothers of higher income, this is not seen in our analysis. Many different kinds of individuals refuse vaccines, so there can be a variety of reasons leading to a person's belief. Our participants are diverse, and there were no correlations between the demographic factors of ethnicity, college education, or gender to vaccine refusal.

Caveats and Limitations

Our conclusions are limited to our sample, in a diverse, urban, politically liberal area. Different populations of students may well have yielded different results. We also did not collect other demographic information that may inform the vaccine views of our students, such as their parent's immunization views, immunization status, and income to further evaluate if any demographic difference exists among vaccine refusers and acceptors.

Also, we did not collect data from ABM students on whether or not they would vaccinate their children. It would be interesting to see how students change or do not change their views and reasoning about vaccines as they progress in their biology education.

Furthermore, we did not analyze participant explanations to why they answered yes or no to the prompt "Would you vaccinate your children?" If the participants were asked to provide detailed explanations, it could have provided insight to the use of construal-based language.

Potential implications for designing education interventions

It is improbable that any single intervention would change everybody's mind, especially considering the different factors and demographics that are contributors to vaccine hesitancy. Focusing on cognitive construals, our data analysis supports the claim that intuitive language, particularly essentialist language, might perpetuate vaccine misconceptions. We have shown that instructors do use intuitive reasoning in their own explanations, matching with other research on instructional language (Betz et al., 2019). We also know students learn optimally when their instructors know their prior knowledge and background (Sadler et al., 2013). Awareness amongst instructors might be able to help control these false claims. Numerous vaccine refusers believed vaccines were artificial, so when talking about vaccines it might be crucial to point out or emphasize vaccines are actually not artificial and use elements of the natural immune response.

Conclusion and Future Directions:

In conclusion, we find that students almost ubiquitously use intuitive reasoning when thinking about vaccines but that the relationship between intuitive reasoning, endorsement of intuitive-reasoning-based misconceptions, and vaccine refusal is complex. Nearly all students agree with some intuitive-reasoning-based misconceptions, but only certain misconceptions are strongly associated with vaccine refusal. In addition, some forms of intuitive reasoning in some prompts were actually associated with disagreement with misconceptions. Lastly, there were no

significant demographic differences between vaccine acceptors and vaccine refusers.

These findings raise crucial questions for future research. We hope to explore this relationship in more depth with examples of intuitive reasoning that are pro- and anti-vaccine. Furthermore, we can also investigate the role of instructors. Do instructors use cognitive construal-based language purposefully as a tool or accidentally as a by-product of their own persistent conceptions? To what extent is the instructor's use of construal-consistent language impact student learning as beneficial or detrimental? Eventually, we would like to design educational interventions to combat misconceptions and vaccine hesitancy.

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.

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 generation 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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