Title

College Students' Knowledge about the Flu Vaccine and Its Relation to Intrinsic Motivation and Vaccination Intention

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Publication Date

2021

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA SAN DIEGO

College Students' Knowledge about the Flu Vaccine

and

Its Relation to Intrinsic Motivation and Vaccination Intention

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

in

Biology

by

Keying Deng

Committee in charge:

Professor Melinda Tsao-ying Owens, Chair
Professor Matthew Daugherty
Professor Claire Meaders

2021

The thesis of Keying Deng is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2021

EPIGRAPH

凡授书不在徒多，但贵精熟。

王阳明

(Translate)
Teaching is not about quantity but excellence and proficiency.

Wang Yangming

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ACKNOWLEDGEMENTS

My thesis would not have been possible without our lovely instructors, who welcomed us to recruit students from their classes, or without participating faculty, students, and interviewees. Thank you!

I am extremely grateful to Prof. Melinda T. Owens for supporting my work, caring for my personal growth, and encouraging me to pursue a teaching career. Also, special thanks to my amazing committee members, Prof. Matthew Daugherty and Prof. Claire Meaders, whose feedback was invaluable in bringing my work to a higher level.

I am also grateful to Ola Mostafa for her impressive work in advancing the coding guidelines. I would like to extend my sincere thanks to Prof. Wendy Huang, Prof. Lisa McDonnell, Geneva Walters, and the amazing scholars in the Chem/Bio Education Research Journal Club, whose expertise was tremendously helpful in improving my work.

Many thanks to my family, friends, and teachers for supporting my educational endeavors.

ABSTRACT OF THE THESIS

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Keying Deng

Master of Science in Biology

University of California San Diego, 2021

Professor Melinda Tsao-ying Owens, Chair

Flu vaccination coverage rates have been concerningly low on college campuses, but it is unclear what college students know about the vaccine or how their knowledge relates to their intrinsic motivation and vaccination intentions. To inform vaccine-related teaching, I explored students' knowledge using the *Actional* perspective of knowledge construction, which suggests that erroneous conceptions are deviations from or precursors of accurate knowledge; I examined students' intrinsic motivation using the 3 components of Self-Determination Theory (*Autonomy*, *Competence*, and *Relatedness*); and I measured a spectrum of students' vaccination intentions.

From an urban public university, we recruited 369 students from three levels of biology courses and 25 immunology faculty as expert controls. We used Likert-type questions to capture students' flu-vaccine-related intrinsic motivation and vaccination intentions. I assessed knowledge about how the flu vaccine works with three open-ended questions, and responses were analyzed with a rubric to quantify basic knowledge and alternative conceptions. I used logistic regression modeling to identify correlations between knowledge and vaccination intentions. Unfortunately, factor analysis revealed that my study cannot distinguish the 3 components of intrinsic motivation.

I found that the presence of certain alternative conceptions is correlated with the absence of basic knowledge about how the flu vaccine works. Additionally, knowing about the vaccine's preventative power is related to intention to vaccinate, yet believing in the flu-causing effects of vaccination is related to intention to not vaccinate. My findings highlight common gaps in college students' vaccine-related knowledge and contribute to current understanding of how knowledge relates to vaccination intention.

Introduction

Although college campuses are prone to seasonal outbreaks of influenza, studies in 2010 and 2014 found that only 14%-30% of college students were vaccinated against flu, much lower than needed for herd immunity in shared living and learning spaces (Benjamin & Bahr, 2016; Poehling *et al.*, 2012). College students are in a transition to legally make medical decisions for themselves, including vaccine decisions (Diekema *et al.*, 2017). For this reason, college is a critical stage to educate young adults and imbue them with positive flu vaccine attitudes. Surprisingly, previous studies have found that vaccine-refusing parents were more likely to be college-educated than not college-educated (Smith *et al.*, 2004; Wang *et al.*, 2014), so it remains unclear how college education shapes students' vaccine knowledge and attitudes. Furthermore, it is not clear what college students know about how the flu vaccine works or how their knowledge relates to their vaccination decisions. To inform future interventions aimed at educating college students about vaccines, my goal is to investigate college students' knowledge about the flu vaccine and its possible correlations with vaccination intention.

Vaccine knowledge

Researchers have investigated the extent to which the general public has scientifically accurate knowledge about vaccines. Many parents knew that vaccines generally contain preservatives and adjuvants, and some were also aware of possible severe side effects of the Measles, Mumps and Rubella (MMR) vaccine (Brown *et al.*, 2012). A well-known erroneous paper claimed that the MMR vaccine could cause autism spectrum disorders (Evans *et al.*, 2001). However, a recent study in Sweden revealed that half of the participating parents knew about the disproved link between the MMR vaccine and autism (Jama *et al.*, 2018), indicating the success of communications that refuted the causal relationship at least in Sweden. In addition to parents' knowledge about vaccines, study found that healthcare workers knew about uncertain efficacies of seasonal flu vaccines (Qureshi *et al.*, 2004). Additionally, a recent study discovered that college students generally knew that receiving vaccines can prevent future onsets of vaccine-preventable diseases (Kahlon *et al.,* 2020). Other than the presence of scientifically accurate knowledge, the lack of knowledge was also identified. Reviewing perspective-related vaccine literature from 2009-2012, Yaqub *et al.* (2014) suggested that the general public lacked knowledge about transmissions and progressions of vaccine-preventable diseases, so the lack of scientifically accurate knowledge could serve as a potential target for vaccine interventions-related education.

In addition to the presence or absence of scientifically accurate knowledge, many studies have captured widespread erroneous information related to vaccines. A recent study surprisingly found 20% of U.S. adults believed that natural infections of vaccine-preventable diseases were safer than vaccine-induced immunity (Stecula *et al.*, 2020). Additionally, some parents believed that healthy children would not need vaccines (Brown *et al.,* 2012). Perceptions of low disease susceptibility or severity were also prevalent among unvaccinated individuals (Brewer *et al.,* 2007; Weinstein *et al.,* 2007). Despite vaccine-related misinformation being common, it remains critical to improve vaccination uptake because vaccination benefits not only the immunized individuals but also susceptible populations (CDC, 2020; Nowak *et al.*, 2015).

Understanding college students' knowledge about the flu vaccine is important to construct effective educational interventions (Sadler *et al.*, 2013). The philosophical *Action* theory provides an innovative perspective to knowledge construction (Gilbert & Watts, 1983). In the *Classical* perspective, knowledge is constructed and stored in a hierarchy, and misconceptions are treated as flaws in the hierarchy that need to be repaired or eliminated

(Brown & Vanlehn, 1980; Markova 1982). Challenging the oversimplification of the *Classical* perspective, the *Actional* perspective argues that knowledge acquisition involves actively re-constructing existing knowledge, where "errors" are recognized as conceptional alternatives to accurate knowledge (Freyberg & Osborne, 1981; Kelly, 1955). Since the *Actional* perspective emphasizes dynamic conceptual development, alternative conceptions are seen as natural and even desirable constructive precursors of accurate knowledge (Gilbert & Watts, 1983). With the ultimate goal to build on their pre-existing knowledge in future educational interventions, I applied the *Actional* perspective to understand students' knowledge about the flu vaccine, separating knowledge into two distinct categories: basic knowledge and alternative conceptions.

To connect students' knowledge to its practical use in teaching students about the flu vaccine, I explored cognitive reasons that could explain students' vaccine learning. The Self-Determination Theory (SDT), a cognitive psychology theory formulated by Ryan & Deci (2000), might explain what motivates students to learn about vaccines. Ryan & Deci (2000) reviewed empirical evidence that highlighted three basic psychological needs: 1. *Autonomy*, or the acknowledgment of one's feeling and the opportunity for self-direction (Deci & Ryan, 1985); 2. *Competence*, or positive feedback in self-efficacy and freedom from demeaning evaluations (Deci, 1975); and 3. *Relatedness*, or the feeling of belongingness and connectedness (Ryan *et al.*,1994). In fulfillment of the three psychological needs, intrinsic motivation would be enhanced and, in turn, stimulate curiosity, spark desires for challenges, and improve learning outcomes (Hsu *et al.*, 2019; Ryan & Deci, 2000).

<u>Disputed relationship between vaccine hesitancy and knowledge</u>

Despite various accurate and inaccurate knowledge people have about vaccines, how knowledge contributes to vaccine hesitancy is hotly debated. In this study, we adopted

MacDonald's definition of vaccine hesitancy (2015) - delay, refusal, or uncertain intent to receive some or all available vaccines.

One model of vaccine hesitancy, the knowledge deficit model, directly connects knowledge to health behaviors by positing that public skepticism towards science stems from the lack of scientific knowledge, suggesting that supplying the general public with the information could reverse the skepticism (Irwin & Wynne, 1996). However, it remains unclear whether providing scientifically accurate information could reverse vaccine hesitancy. One example of this lack of clarity was shown in an educational intervention for vaccines. By displaying myths and facts about vaccines to the participants, Pluviano *et al.* (2017) demonstrated that the educational intervention was ineffective or even backfired to cause unintended opposite effects on the participants' vaccine attitudes. Also, a survey experiment on a nationally representative sample of U.S. parents showed that presenting scientifically accurate information about the threats of measles (preventable by childhood vaccines) might be counterproductive and could end up reducing vaccination intentions for some parents (Nyhan *et al.*, 2014). Further demonstrating the unclear link between knowledge and vaccination intentions, Kahlon *et al.* (2020) found no significant correlation between vaccine hesitancy and the lack of scientifically accurate knowledge about general vaccines among college students, revealing the puzzling nature of effective interventions to bring about positive vaccine attitudes.

In contrast, the Health Belief Model depicts a more sophisticated picture of health behaviors that downplays the role of knowledge. Developed by social psychologists, the Health Belief Model suggests six evidence-based factors as predictors of health-related actions: perceived disease susceptibility, perceived disease severity, perceived action's benefits, perceived action's barriers, self-efficacy, and cues to action (Myers, 2016; Rosenstock, 1974).

The model has been widely applied to frame studies of health decisions, such as sexual health, nutrition, and vaccination (Glanz, 2001; McKellar & Sillence, 2020; Fall *et al.*, 2018). In this model, knowledge indirectly influences health behaviors through perceived threats and perceived benefits (Rosenstock, 1974).

Examining the relationship between knowledge, learning motivation, and vaccination behaviors, a longitudinal study put together the Health Belief Model and the autonomous motivation of Self-Determination Theory to investigate French college students' beliefs and decisions about the seasonal flu vaccine. The study found that autonomous motivation positively correlated with flu vaccination intentions, which in turn predicted the participants' vaccination behaviors in the following flu season (Fall *et al*., 2018). Unexpectedly, knowledge was not found to be correlated with flu vaccination behaviors (Fall *et al*., 2018), and the result aligned with Kahlon's finding (2020) that the lack of scientifically accurate knowledge did not predict vaccine hesitancy. However, these findings may be limited by the study design. Fall *et al.* (2018) measured students' knowledge with 6 Likert-point questions about pathogen transmissions, disease onset, and vaccine safety. Studies on educational assessments have found that multiple-choice questions tend to overestimate respondents' knowledge, a characteristic that make them less desirable than open-ended questions (Frary, 1985; Newble *et al.*, 1979). For this reason, knowledge measured in the study might not be representative of participants' actual knowledge. Although Kahlon's study (2020) overcame this obstacle by measuring knowledge with open-ended questions, participants' vaccination intentions were collected with a yes-no question, dismissing the continuum of vaccine hesitancy in its definition (MacDonald, 2015; Rossen *et al.*, 2019).

No study has explored college students' knowledge about the flu vaccine deliberately with open-ended questions along with Likert-scaled vaccination intentions. For this reason, I put together the *Actional* perspective of knowledge and the three components of SDT to understand possible correlations between college students' knowledge about the flu vaccine, their intrinsic motivation for learning about vaccines, and their vaccination intentions on a Likert scale.

Research Design

With the positive association between learning outcomes and intrinsic motivation (Hsu *et al.*, 2019), I hypothesized that college students who were more intrinsically motivated would possess more accurate knowledge and fewer alternative conceptions about the flu vaccine when compared to less motivated students. I also hypothesized that college students with more accurate knowledge or fewer alternative conceptions about the flu vaccine would be more likely to intend to vaccinate. In our study, we developed a survey to assess college students' knowledge about how the flu vaccine works with three open-ended questions. The survey also measured students' intrinsic motivation about the flu vaccine on a 6-point Likert scale. Specifically, participants were presented with vaccine-supporting and -refusing statements in the framework of each of the three psychological needs for intrinsic motivation. Intentions to receive the flu vaccine were also measured on the 6-point Likert scale, where participants were asked whether they plan to vaccinate against flu in a hypothetical obstacle-free condition. Using a mixed-method approach, I analyzed the qualitative data about students' knowledge combined with quantitative survey data about intrinsic motivation and vaccination intentions to answer the following research questions:

1. To what extent do college students of different levels of formal biology expertise differ in their knowledge about how the flu vaccine works?

2. To what extent does intrinsic motivation correlate with college students' knowledge about how the flu vaccine works?
3. To what extent do vaccination intentions relate to knowledge about how the flu vaccine works?

Methods

Data Collection

The data were collected from a large urban R1 public university in the Fall Quarter of 2020. I recruited immunology faculty (FC, n=25) as expert controls and undergraduate students (n=369) from three levels of developing formal biology expertise: advanced-level biology students (ABS, n=90), entry-level biology students (EBS, n=153), and non-biology-major students (NBS, n=126). ABS was defined as biology-major students with more than 1 year of college-level biology education, recruited from an upper-division biology course. EBS was defined as biology-major students with less than 1 year of college-level biology education, recruited from five lower-division biology courses. NBS was defined as students whose majors were not any of the seven majors offered by the Division of Biological Sciences in the university, recruited from a non-biology-major biology course. In the non-biology-major biology course, participants with undeclared majors were also considered NBS. After they completed the survey, student participants were categorized based on the courses from which they were recruited and their self-reported majors.

To initiate the recruitment process for undergraduate students, I invited instructors of the courses of interest to send out a survey link to their students. Students who were interested to participate may access the online student survey through the survey link. Participation incentives were mostly provided as extra credits to all students in the course if a certain percentage of the class filled out the survey in time. The number of extra credits and the threshold percentage of the class to fill out the survey was determined by the instructors. In the survey, participants were asked to respond to the best of their knowledge without referring to online sources or seeking help from other people.

To recruit immunology faculty, I reached out via emails to professors and health professionals affiliated with the university, whose research disciplines were related to immunology. Compared to the student participants, the invited faculty filled out a version of the survey that contained different demographic questions but was otherwise identical to the student survey. All survey responses were collected anonymously. The online surveys were powered by Qualtrics XM (https://www.qualtrics.com/), a professional survey platform with the Federal Risk and Authorization Management Program (FedRAMP) certification of standard security services (Qualtrics, n.d.).

After collecting survey responses from immunology faculty and undergraduate students, I excluded some of the survey responses based on four guidelines: 1. Participants who disagreed to be included in the study (n=18); 2. Incomplete surveys (n=191); 3. Participants who did not qualify for any of the four levels of formal biology expertise as previously described (502); 4. Participants whose responses to the open-ended questions were found to be similar to online sources (n=11). To generate a similarity report for every survey response, I submitted the survey responses to Turnitin (https://www.turnitin.com/), a widely used similarity-check platform (Turnitin, n.d.). If a survey had one or more responses that were found over 60% similar to online sources, the entire survey was excluded from the analysis.

This study was approved by the Human Research Protections Program of the University of California San Diego (Project #201521XX).

Survey Design

To assessed conceptual knowledge of how the flu vaccine works, we asked three open-ended questions on the survey:

1. How does a flu vaccine work?

2. Some vaccines, like the measles vaccine, are only given in childhood. For the flu vaccine, why is it recommended that you get the flu vaccine every year?
3. To what extent does vaccinating people for flu influence the health of people in their community who don't get the vaccine? Please explain.

Open-ended data were analyzed with a rubric to quantify the presence of basic knowledge and corresponding alternative conceptions of how the flu vaccine works. The rubric development and validation will be discussed in detail in the next section.

To capture participants' vaccination intentions, we asked whether they would vaccinate themselves or their children against the flu if there were no obstacles. Participants answered the two questions on a 6-point Likert scale (1=strongly disagree, 2=disagree, 3=slightly disagree, 4=slightly agree, 5=agree, 6=strongly agree). The student's t test was performed to confirm that participants' responses to these two questions did not significantly differ ($p=0.37$). Based on their responses, I categorized participants into the *not intend to vaccinate* group if their average scores were not higher than 3.5. Otherwise, they were categorized into the *intend to vaccinate* group.

To assess participants' intrinsic motivation, we developed 26 challenge statements framed into the three components of the Self-Determination Theory (SDT): *Autonomy*, *Competence*, and *Relatedness*. The challenge statements in every component were further divided into either vaccine-supporting or -rejecting direction, generating a total of 3x2 types of challenge statements. For instance, an autonomy-framed, vaccine-supporting statement was: "Getting the vaccine is a way of being responsible to my own health." Another example of a competence-framed, vaccine-rejecting statement was: "Healthy people with a healthy diet and habits do not need the flu vaccine to stay healthy." Participants responded to the challenge statements on the same 6-point Likert scale. In the survey, all 26 statements of 3x2 types were displayed to participants in random order. Before analysis, all responses to the vaccine-rejecting statements were reversed ("strongly disagree" reversed to "strongly agree" and vice versa, etc.) as if participants were responding to the vaccine-supporting version of the statements.

Demographic data were collected at the end of the survey, including childhood vaccination history, flu vaccination history in the past 12 months, year in college, college transfer status, first-generation college student status, the number of children (if any), gender, race, and political orientation. Political orientations were surveyed on a 5-point Likert scale (1=consistently conservative, 2=mostly conservative, 3=mixed, 4=mostly liberal, 5=consistently liberal). FC participants were additionally asked to provide their highest degrees, the year they graduated with the highest degrees, and the disciplines of their degrees, but they were not asked about their years in college.

Investigating health decisions among minoritized groups, several studies have found that racial or gender minorities were more likely to be hesitant about vaccines (Bell *et al.,* 2017; Boakye *et al.,* 2017; Qureshi *et al.,* 2004). However, a meta-analysis revealed that racial minorities were more likely than Whites to initiate HPV vaccination but less likely to complete the vaccination series (Spencer *et al.*, 2019), so the complexity of racial and gender identities in relation to health beliefs awaits further investigations. Additionally, compared to continuing-generation college students, first-generation college students were more likely to rely on compulsive health decisions that might not be necessarily good for their health (Gallagher, 2019). For these reasons, gender, race, and first-generation college student status were processed into binary codes (1=male, 0=non-male; 1=White, 0=non-White; 1=first-generation, 0=continuing-generation college student) to categorize together the traditionally minoritized groups before analysis. Since students' formal biology expertise levels were also a demographic variable, I assigned ordinal values to represent student groups in the study (1=NBS, 2=EBS, 3=ABS). No personally-identifying information was collected in the demographics questions.

An attention check question was also included in the survey to ensure quality responses: "Please choose 'Strongly Agree' to indicate that you are paying attention to this instruction." Participants who did not select "Strongly Agree" in this question were prompted to continue in the survey normally, but their survey responses were excluded from analysis (n=43), as I cannot determine whether they paid full attention to the survey questions or whether they answered the survey questions truthfully. The full survey can be found in Appendix 1.

Survey Validation

The face validity of the survey was assessed by interviewing two participants from each of the four participant groups (FC, ABS, EBS, NBS) in July 2020. Eligible students were recruited from summer biology courses in the university, and two immunology experts were recruited via emails. To increase incentives to participate, we distributed gift cards of $15 to participants upon completion of the interviews. The interviews were individually conducted via Zoom. During the interviews, participants were presented with the survey questions one by one. For the challenge statements and questions for vaccination intentions, the participants were asked to provide their responses on the same 6-point Likert scale and give verbal explanations for their responses. If a question was interpreted differently from what it was intended for, we would reword the question and test again in the following interviews.

After the interviews, I assessed the internal consistency of the 3x2 types of challenge statements by testing the survey on a crowdsourcing platform called Amazon Mechanical Turk (https://www.mturk.com/). Research studies have found that pilot tests on crowdsourcing platforms can effectively model target educational populations due to the nature of a large and diverse sample (Sadler *et al.*, 2016). I recruited 50 adults in the United States with monetary incentives to complete the survey. Based on participants' responses to the challenge statements on the 6-point Likert scale, I measured internal consistency by calculating Cronbach's alpha for each of the 3x2 types of challenge statements. All 3x2 types of challenge statements had $\alpha>0.7$, which indicated moderate to strong internal consistencies (Taber, 2018).

Rubric Design

To analyze participants' responses to the three aforementioned open-ended questions, I developed a rubric to capture the presence of basic knowledge and alternative conceptions about how the flu vaccine works. To evaluate basic knowledge, I applied a rubric to look for 5 items related to how the flu vaccine works (Table 2a). The first three items of the rubric were adopted from a pre-design rubric on college students' knowledge about how general vaccines work (Kahlon *et al.,* 2020), and the rest of the rubric was created based on flu-vaccine related information disclosed to the general public by the Centers for Disease Control and Prevention (CDC, 2021). With the pre-structured rubric of basic knowledge, I applied deductive coding (Saldana, 2009) with a careful check against the expert controls (FC's responses) to consolidate the rubric items before applying them to evaluate students' responses. For every item that was present in a response, the participant would score 1 on the item. Otherwise, the participant would score 0 on that item.

As the 5 basic knowledge components captured scientifically accurate knowledge about how the flu vaccine works, the *Actional* perspective of conceptual knowledge development asserts the natural presence of diverse alternative conceptions (Gilbert & Watts, 1983; Kelly, 1955). To code alternative conceptions about how the flu vaccine works, I implemented inductive coding (Saldana, 2009) to derive common themes of erroneous ideas from survey responses. Alternative conceptions were excluded from further analysis if: 1. They were uncommon (n<9) among all participants; 2. They were irrelevant to how the vaccine works. At the end of the process, the rubric was consolidated into 7 erroneous ideas about how the flu vaccine works (Table 2b).

Rubric Validation

To validate the rubric for basic knowledge and alternative conceptions about how the flu vaccine works, I consulted two immunology experts to evaluate the rubric items. Both of them rated the 5 basic knowledge components as representative, essential, and clear in assessing participants' basic knowledge about the flu vaccine. One of the experts constructively suggested adding to the rubric the protective mechanisms of anti-influenza antibodies. However, we decided to not include this item because very few FC responses addressed this point.

The alternative conception codes went through two rounds of evaluation. In the first round, an immunology expert pointed out that some items were unclear or not erroneous, so we modified or excluded the items accordingly. In particular, Alternative Conception #5 (Table 2b) was presented to the expert as "The flu vaccine can give you some or all symptoms of the flu," and the expert appealed that the vaccine can cause flu-like symptoms. For this reason, we modified the item to "The flu vaccine can give you the flu." The revised rubric was then evaluated by the second immunology expert, who rated all of the items as clear and erroneous. After the expert evaluations, I calculated the Jaccard similarity indexes of the alternative conception items using the "jaccard" package in R (Chung *et al.*, 2018), and I found two items similar to each other (Jaccard=58%). For this reason, I merged the two codes into Alternative Conception #7 (Table 2b).

To ensure interrater reliability of the rubric, I trained an undergraduate student as an independent coder to use the rubric, who then independently coded 46 surveys that were randomly selected from the four participant groups (FC, ABS, EBS, and NBS) using stratified sampling. Interrater reliability of the rubric items was evidenced by Cohen's kappa higher than 0.8 and/or raw agreement higher than 90% (Table 2a-b). The full coding rubric can be found in Appendix 2.

Statistical Analysis

To compare the knowledge scores among the four participant groups (FC, ABS, EBS, and NBS), I first summed up the component scores for basic knowledge and alternative conception for every participant. The maximum total score of basic knowledge was 5, and that of alternative conception was 7. Statistical significance of knowledge differences among the participant groups was then calculated using the pairwise Wilcoxon rank-sum test with Bonferroni correction.

Correlational analyses in this study were performed using logistic regression on students' responses (ABS, EBS, and NBS) utilizing the "MuMIn" R package (Barton, 2020). Faculty's data were excluded because I was most interested in how students' knowledge, intrinsic motivation, and vaccination intentions relate in the context of the flu vaccine, with an eye towards future educational interventions. In all logistic regression analyses, demographic variables were included as fixed effects, 3 of which were processed into binary codes as described in the Survey Design section. The second-order Akaike Information Criterion (AICc) model selection was then performed in four steps to select independent variables that were more likely than others to correlate with the dependent variables. First, all independent variables, including the variables of interests and demographic variables, were loaded onto a logistic regression model. Second, I used the *dredge* function to list all possible combinations of independent variables in the order of descending AICc (Barton, 2020). Third, candidate models were selected based on AICc and degree of freedom. The model with the lowest AICc was always selected as a candidate model, and other models with near-identical AICc (defined as AICc±2) and lower degrees of freedom were selected as well (Theobald, 2018). Lastly, I ran a Chi-square test on these regression models. If a model was significantly different ($p<0.05$) from the model with the lowest AICc, I used this model as the final logistic regression model; otherwise, I chose the model with the lowest AICc as the final model (Theobald, 2018).

Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used to explore the underlying factors of the 3x2 types of challenge statements. The R packages "lavaan", "psych", and "GPArotation" were used to carry out the calculations (Bernaards & Jennrich, 2005; Revelle, 2020; Rosseel, 2012). Student responses were randomly assigned to either the EFA (n=185) or CFA group (n=184) to ensure no overlapping response. The EFA was performed in four steps. First, I plotted the Scree Plot and identified possible numbers of factors, including the right-hand point of the steepest slope (Knekta *et al.*, 2019) and the theoretical 3-factor model that the challenge statements intended to construct (*Autonomy*, *Competence*, and *Relatedness*). Next, I performed the factor analysis with oblimin rotation on the 26 challenge statements with a selected number of factors (Brown, 2009). I then examined the factor correlation to confirm the oblimin rotation type (Brown, 2009). The last step of the EFA was assigning the 26 challenge statements to mutually exclusive factors based on their highest standardized loadings (Knekta *et al.*, 2019). Using the factor structures determined in EFA, I performed CFA's on the CFA group of responses and compared the factor structures based on comparative fit index (CFI), Bayesian information criterion (BIC), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR).

Results

To what extent do college students of different levels of formal biology expertise differ in their knowledge about how the flu vaccine works?

Table 1 includes a glimpse into the participant group along with participant distributions in the three binary-coded demographic variables.

Table 1. Participant population demographics.

Participant Group	Number Invited	Sample Size	Participation Rate	Number Qualified	Participants Identified as Non-Male (% in the group)	Participants Identified as Non-White (% in the group)	Participants Identified as First-Generation College Student (% in the group)
FC	143	29	20%	25	8 (32%)	4 (16%)	4 (16%)
ABS	210	157	75%	90	71 (79%)	61 (68%)	35 (39%)
EBS	1103	663	60%	153	104 (68%)	109 (71%)	48 (31%)
NBS	232	163	70%	126	75 (60%)	106 (84%)	46 (37%)

Content validity of the rubric items, which served to assess participants' basic knowledge and alternative conceptions about how the flu vaccine works, was confirmed by the two immunology experts. Additionally, excellent interrater reliability of most rubric items was confirmed by Cohen's kappas greater than 0.8 (McHugh, 2012). Alternative Conceptions #4, 5, and 7 had Cohen's kappas below the threshold, but their interrater reliability was confirmed by the rater's raw agreement of 98% (Table 2). The discrepancy between the substantial Cohen's kappa and the near-perfect raw agreement may be explained by the item's low occurrence in the stratified sample of 46 participants. Cohen's kappa is quite sensitive to outliers in substantially low occurrence (McHugh, 2012), whereas raw agreement is not. For this reason, the interrater reliability of all rubric items was confirmed despite some items having Cohen's kappas below the threshold.

Table 2. Outline of (a) basic knowledge items or (b) alternative conception items, with Cohen's kappa and raw agreement (%).

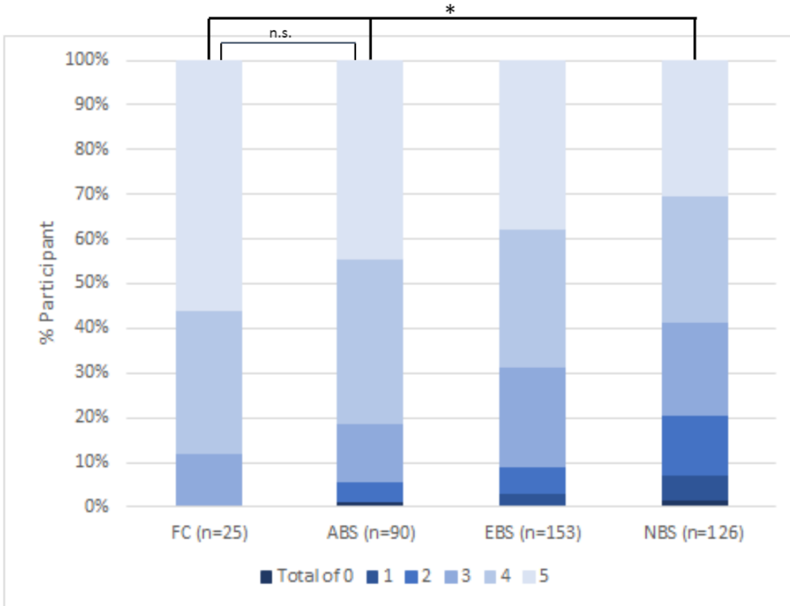
a)

Item #	Item Description	Cohen's Kappa	Raw Agreement
1	The flu vaccine resembles the influenza virus.	1.00	100%
2	The flu vaccine stimulates a specific immune response.	0.82	93%
3	The immune memory prevents subsequent infection.	0.83	96%
4	The influenza virus mutates frequently.	0.91	98%
5	Vaccinating may reduce the spread of the influenza virus in the community.	0.79	91%

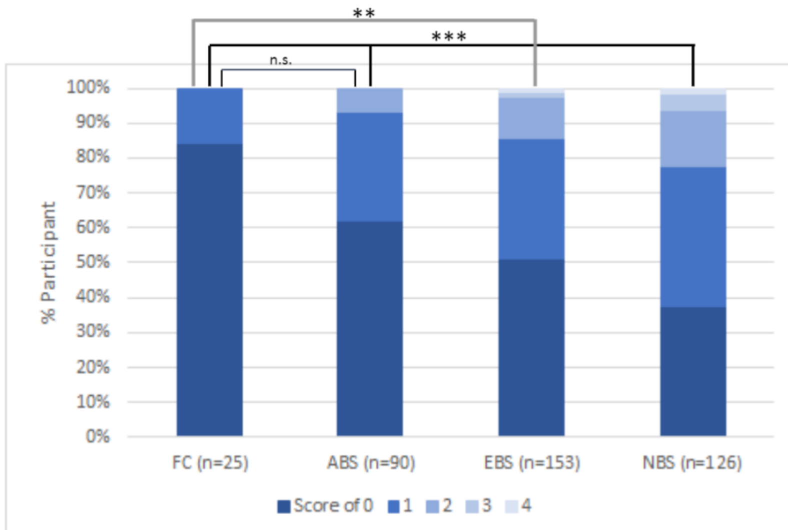
b)

Item #	Item Description	Cohen's Kappa	Raw Agreement
1	The vaccine contains the unmodified pathogen.	0.82	94%
2	The vaccine contains antibodies.	0.85	98%
3	The vaccine contains the flu bacterium.	1.00	100%
4	The vaccine directly fights the infection in the body.	0.79	98%
5	The vaccine can give you the flu.	0.66	98%
6	The vaccine provides no community effects other than benefits on individual levels.	0.90	98%
7	Annual flu shots are booster vaccines.	0.79	98%

Assessing participants' basic knowledge about the flu vaccine, I found 83% of students knew that the vaccine prevents future onsets of flu symptoms, but far fewer (70%) knew that the vaccine induces an active immune response. Comparing the total basic knowledge scores among the four participant groups, I found that NBS scored significantly lower compared to either ABS or FC, but there was no significant difference found among FC, ABS, and EBS (Fig. 1a).



a)



b)

Figure 1. Participants of different levels of formal biology expertise had somewhat different levels of basic knowledge and alternative conceptions about the biology of the flu vaccine. The binary scores of each of (a) the 5 basic knowledge components or (b) the 7 alternative conceptions were summed up for every participant. The bar graphs represent the distribution of participants' total scores in the four participant groups (FC, ABS, EBS, NBS). Statistical significance was calculated using the pairwise Wilcoxon rank-sum test with Bonferroni correction. *$p<0.05$, **$p<0.01$, ***$p<0.001$, n.s. = not significant.

Assessing participants' alternative conceptions about the flu vaccine, I found the most prevalent alternative conception among students (24%) was that the flu vaccine contains the unmodified form of the pathogen. Comparing the total alternative conception scores among the four participant groups, I found that EBS scored significantly higher than FC and that NBS scored higher than the ABS and FC (Fig. 1b). However, no significant difference was found between the FC and the ABS or between the EBS and the NBS (Fig. 1b).

Since the *Actional* perspective of knowledge suggests that alternative conceptions naturally flourish alongside conceptual knowledge development, I was interested in how the presence of certain alternative conceptions correlates with the presence or absence of basic knowledge about the flu vaccine using logistic regression analysis. In each of the 5 logistic regressions, I set each of the 5 basic knowledge components as the dependent variable, and the independent variables included all 7 alternative conceptions and 7 demographic variables (as described in Methods). I then ran the logistic regression with AICc model selection. Four out of five logistic regression models had significant correlations between alternative conceptions and the corresponding basic knowledge component.

Assessing students' alternative conceptions in relation to their basic knowledge about how the flu vaccine works, I found interesting statistical significance in the logistic regressions. Students who believed that the flu vaccine contains antibodies or directly fights the infection were 9 times and 25 times less likely to know that the vaccine resembles the pathogen (Table 3a). Additionally, students who believed that the flu vaccine contains antibodies, contains "the flu bacterium", or directly fights the infection were 8 times, 3 times, and 9 times less likely to know that the vaccine induces immune responses in the body (Table 3b). Students who believed that receiving the flu vaccine provides no community benefits or that seasonal flu vaccines are booster vaccines were 5 times and 7 times less likely to know that the influenza virus is prone to frequent mutations (Table 3c). Besides, students who believed that the vaccine can cause the flu were 6 times less likely to know that sufficient vaccine coverage can provide herd immunity to the community (Table 3d).

Students' formal biology expertise and racial identities were also found to be significantly correlated with the endorsement of certain basic knowledge. For every level of increase in formal biology expertise, students are 2 times more likely to know about the pathogen-like nature of the vaccine and frequent mutations of the virus (Table 3a, c).

Table 3. Logistic regression on the 7 alternative conceptions and the 7 demographic variables (binary gender, binary racial identity, binary first-generation college student status, binary transfer college student status, number of children, year in college, political orientation, and formal biology expertise) of (a) Basic Knowledge #1, (b) Basic Knowledge #2, (c) Basic Knowledge #4, or (d) Basic Knowledge #5 with AICc model selection. Four binary and two numeric demographic variables were included in the final logistic regression models. S.E. standard error. *p<0.05, **p<0.01, ***p<0.001. Bolded font indicates statistical significance.

a)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	-0.01	0.39	-0.03	0.98	0.99
Unmodified Pathogen (#1)	**4.67**	**1.36**	**3.44**	**0.001****	**106.63**
Antibody (#2)	**-2.23**	**0.56**	**-3.97**	**<0.001*****	**0.11**
Fight Infection (#4)	**-3.30**	**1.15**	**-2.87**	**0.004****	**0.04**
No Community Benefits (#6)	-0.70	0.40	-1.73	0.08	0.50
Formal Biology Expertise	**0.70**	**0.20**	**3.46**	**0.001****	**2.01**

b)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	**1.24**	**0.14**	**8.82**	**<0.001*****	**3.47**
Antibody (#2)	**-2.03**	**0.50**	**-4.03**	**<0.001*****	**0.13**
Bacterium (#3)	**-1.25**	**0.54**	**-2.31**	**0.02***	**0.29**
Fight Infection (#4)	**-2.19**	**0.82**	**-2.66**	**0.008****	**0.11**
No Community Benefits (#6)	-0.58	0.35	-1.68	0.09	0.56

Table 3. Logistic regression on the 7 alternative conceptions and the 7 demographic variables, continued.

c)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	0.84	0.43	1.95	0.05	2.31
Antibody (#2)	-0.84	0.52	-1.61	0.11	0.43
No Community Benefits (#6)	**-1.50**	**0.40**	**-3.76**	**<0.001*** **	**0.22**
Booster Vaccine (#7)	**-1.93**	**0.37**	**-5.27**	**<0.001*** **	**0.14**
White	**1.20**	**0.47**	**2.56**	**0.01***	**3.34**
Transfer	16.86	979.43	0.02	0.99	<0.001
Formal Biology Expertise	**0.58**	**0.23**	**2.53**	**0.01***	**1.78**

d)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	**3.33**	**0.62**	**5.39**	**<0.001*** **	**28.05**
Antibody (#2)	1.74	1.20	1.45	0.15	5.71
Cause Flu (#5)	**-1.84**	**0.59**	**-3.13**	**0.002** **	**0.16**
No Community Benefits (#6)	**-6.87**	**1.24**	**-5.55**	**<0.001*** **	**0.001**
Male	-0.78	0.38	-2.02	0.04	0.46
White	**1.23**	**0.53**	**2.31**	**0.02***	**3.42**
First-Gen	-0.67	0.35	-1.91	0.06	0.51
Formal Biology Expertise	-0.48	0.25	-1.96	0.05	0.62

<u>To what extent does intrinsic motivation correlate with college students' knowledge about how the flu vaccine works?</u>

To reveal the underlying factors in students' responses to the 26 challenge statements, I performed an exploratory factor analysis (EFA) on randomly selected student participants (n=185, no stratified sampling). As the Scree Plot shows (Fig. 2), the challenge statements likely consisted of 2 factors, which was the right-hand point of the steepest slope, or 3 factors, which was the theoretical model derived from SDT (Knekta *et al.*, 2019). For these reasons, I performed EFA with oblimin rotation on 2 and 3 factors separately.

With the EFA suggested statement grouping in each factor based on standardized factor loadings, I performed confirmatory factor analyses (CFA) on the other half of student participants (n=184). Compared with the target statistics of a good model, which include CFI, BIC, RMSEA, and SRMR in desirable ranges (Brussow *et al.*, 2020; Knekta *et al.*, 2019), I found that both models failed to reach all criteria except for SRMR (Table 4). However, the statistics of the 2-factor model were closer to the thresholds compared to those of the 3-factor model, so I decided to implement the 2-factor model to summarize participants' responses to the 26 challenge statements. Factor 2 was defined as the three challenge statements that emphasized the side-effects of the flu vaccine, whereas Factor 1 was defined as the rest of the challenge statements. To make pattern interpretations straightforward, responses to vaccine-rejecting statements were reversed, including all three statements in Factor 2.

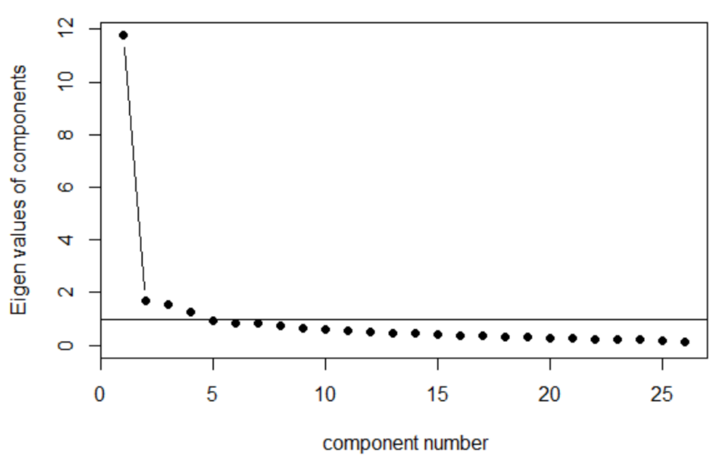


Figure 2. Scree Plot of the 26 challenge statements. Students' responses (ABS, EBS, and NBS) to the vaccine-rejecting challenge statements were reversed (1 changed to 6, "Strongly Disagree" changed to "Strongly Agree", etc.) as if students were responding to the vaccine-supporting version of the statements. All 26 challenge statements were then plotted by eigenvalues.

Table 4. CFA statistics of the EFA models.

	Aim	2-Factor	3-Factor
CFI	≥0.90	0.856	0.834
BIC	Smaller statistics is preferred	11954	12027
RMSEA	<0.06	0.088	0.095
SRMR	<0.08	0.071	0.070

To analyze the correlation between the two factors and each of the basic knowledge components, I ran 5 logistic regressions with AICc model selection on students' responses. For each logistic regression, a basic knowledge component was assigned as the dependent variables, whereas the 2 factors and the 7 demographic variables were assigned as independent variables. I found that every unit of increase in Factor 1 made students 1.8 times more likely ($p<0.001$) to know about the preventative power of the flu vaccine (Table 5a). For every unit of increase in Factor 2, students were 3 times and 2 times more likely ($p=0.01$, $p<0.001$, respectively) to know about flu virus mutation and herd immunity, respectively (Table 5b-c).

In addition to the factors' effects, 2 demographic variables were found to correlate with basic knowledge. For every level of increase in formal biology expertise, students were 2 times more likely ($p=0.001$) to know about flu virus mutation (Table 5b). Students who identified as White were also 3 times more likely ($p=0.03$) to possess this basic knowledge. However, first-generation college students were 3 times less likely ($p=0.004$) to know about herd immunity upon a sufficient vaccination rate (Table 5c).

To analyze the correlation between the two factors and the alternative conceptions, I ran 7 logistic regressions with AICc model selection on students' responses. For each of the logistic regression, an alternative conception was assigned as the dependent variable, and the 2 factors and the 7 demographic variables were treated as independent variables. I found that every unit of

Table 5. Logistic regression of the 2 factors and the 7 demographic variables on (a) Basic Knowledge #3, (b) Basic Knowledge #4, or (c) Basic Knowledge #5 with AICc model selection. Four binary and two numeric demographic variables were included in the final logistic regression models. S.E. standard error. *p<0.05, **p<0.01, ***p<0.001. Bolded font indicates statistical significance.

a)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	-1.30	0.89	-1.46	0.15	0.27
Factor 1	**0.59**	**0.18**	**3.19**	**0.001****	**1.80**
Male	-0.49	0.29	-1.70	0.09	0.61
First-Gen	0.56	0.32	1.77	0.08	1.75
Transfer	1.13	0.75	1.50	0.13	3.10

b)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	0.11	0.87	0.13	0.90	1.12
Factor 2	**0.35**	**0.14**	**2.59**	**0.01***	**1.42**
White	**0.94**	**0.44**	**2.14**	**0.03***	**2.56**
Transfer	16.70	1001.06	0.02	0.99	<0.001
Political Orientation	-0.34	0.12	-2.71	0.007	0.71
Formal Biology Expertise	**0.74**	**0.22**	**3.40**	**0.001****	**2.09**

c)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	-0.14	0.47	-0.30	0.77	0.87
Factor 2	**0.44**	**0.12**	**3.67**	**<0.001*****	**1.56**
First-Gen	**-0.74**	**0.26**	**-2.86**	**0.004****	**0.48**

increase in Factor 2 made students 3 times less likely (p<0.001) to hold the incorrect belief that the flu vaccine can cause the flu (Table 6a). Every unit of increase in Factor 2 also made students 1.4 less likely (p=0.01) to incorrectly believe that the vaccine provides no community benefits (Table 6b). Only one demographic variable was found to significantly correlate with the endorsement of an alternative conception. First-generation college students were 2 times more likely (p=0.03) to think that the flu vaccine has no community benefits (Table 6b).

Table 6. Logistic regression on the 2 factors of (a) Alternative Conception #5 or (b) Alternative Conception #6 with AICc model selection, controlled for demographic variables. One binary and one numeric demographic variables were included in the final logistic regression models. First-Gen: 1=first-generation college student, 0=not first-generation college student. Category: 1=NBS, 2=EBS, 3=ABS. *p<0.05, **p<0.01, ***p<0.001.

a)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	0.77	0.71	1.08	0.28	2.16
Factor 2	**-1.10**	**0.24**	**-4.58**	**<0.001*** **	**0.33**

b)

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	-0.22	0.69	-0.31	0.75	0.81
Factor 2	**-0.36**	**0.15**	**-2.47**	**0.01***	**0.70**
First-Gen	**0.68**	**0.32**	**2.13**	**0.03***	**1.98**
Formal Biology Expertise	-0.37	0.22	-1.70	0.09	0.69

<u>To what extent do vaccination intentions relate to knowledge about how the flu vaccine works?</u>

The four participant groups did not differ in their vaccination intentions, having about 15% of the group who did not intend to vaccinate against the flu (Fig. 3).

To gather participants' self-reported childhood vaccination history, we included a question in the survey: "Were you vaccinated with childhood vaccines?" Most participants reported having received childhood vaccines regardless of their flu vaccination intentions. In each group, participants who did or did not intend to vaccinate did not differ in their childhood vaccination history (Fig. 4a).

To compare participants' flu vaccination intentions and flu vaccination history, we asked this question in the survey: "Did you receive the flu vaccine in the past 12 months?" In NBS and EBS, statistically significant differences were found between participants who did or did not intend to vaccinate, indicating differences in vaccination behaviors. No significant difference was found in FC and ABS (Fig. 4b).

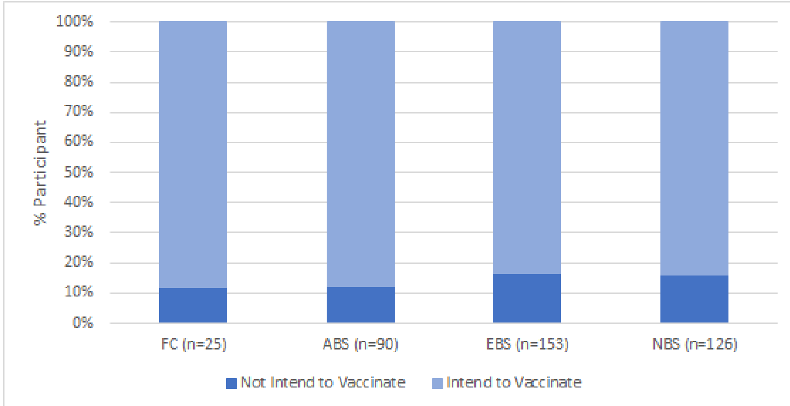
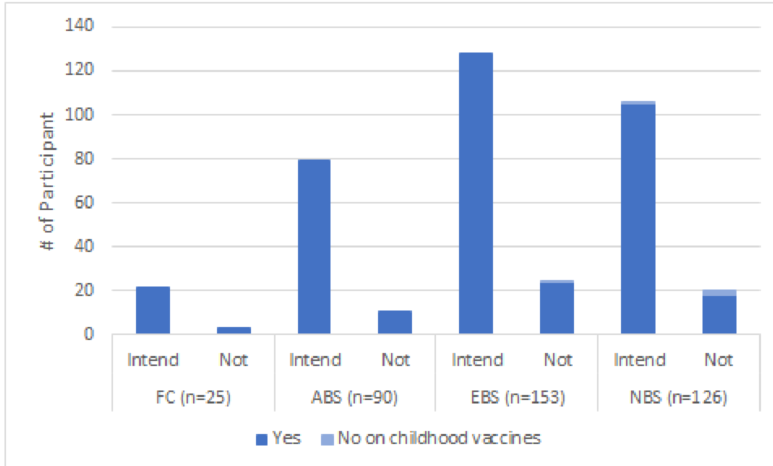


Figure 3. Vaccination intention did not differ among the four participant groups. Vaccination intentions were calculated based on participants' responses to 2 survey statements: "If there were no obstacles to being vaccinated, such as cost, time, or availability, I would get the flu vaccine (or vaccinate my children) every year." Participants responded to the questions on a 6-point Likert scale, as described in Methods (1=Strongly Disagree, 6=Strongly Agree). The average Likert score of the 2 responses was used to categorize participants into either the *not intend to vaccinate* (Likert score ≤ 3.5) or the *intend to vaccinate* (Likert score > 3.5) group. A Chi-square test was performed ($p=0.80$) with the null hypothesis that there is no difference in vaccination intentions among participants of different formal biology expertise levels. No statistical significance was found.

To find the correlation between vaccination intentions and vaccine-related knowledge, I performed two logistic regressions. I set vaccination intentions as the dependent variable (1=intend to vaccinate, 0=not intend to vaccinate), and I used the 5 basic knowledge components (or the 7 alternative conceptions) and 7 demographic variables as independent variables. The AICc model selection was then performed to eliminate variables that were not likely to correlate with the dependent variable. Intention to vaccinate was found to be positively correlated with the basic knowledge that the vaccine prevents flu infection, but it was negatively correlated with the alternative conceptions that the flu vaccine can cause the flu (Tables 7&8).

a)



b)

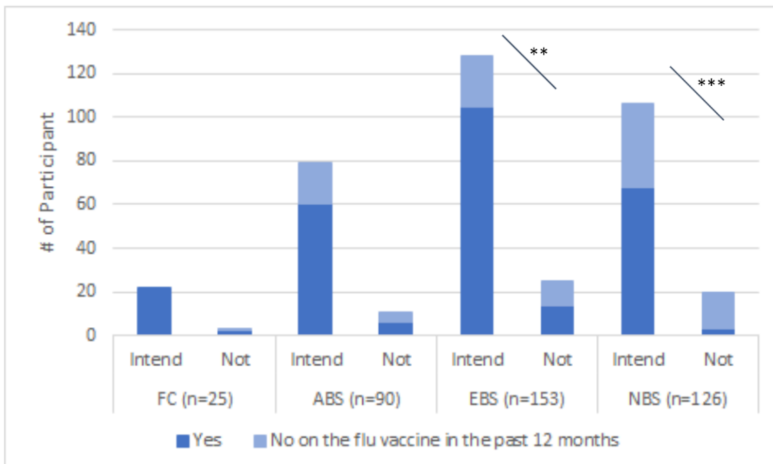


Figure 4. Childhood vaccination history did not differ among participants who did or did not intend to vaccinate, but EBS and NBS who did or did not intend to vaccinate differed in their flu vaccination status. The four participant groups (FC, ABS, EBS, and NBS) were further categorized into either the *intend to vaccinate* group or the *not intend to vaccinate* group as described in Methods and Fig. 3. Significance level calculated with the Fisher's exact test within each participant group. The colors of the bar diagram represented the number of participants who responded "yes" or "no" to the questions: (a) "Were you vaccinated with childhood vaccines?" or (b) "Did you receive the flu vaccine in the past 12 months?". **$p<0.01$, ***$p<0.001$.

Table 7. Logistic regression of vaccination intentions on the basic knowledge components with AICc model selection. Basic Knowledge item # in parenthesis (Table 2a). **$p<0.01$. Bolded font indicates statistical significance.

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	**0.94**	**0.28**	**3.38**	**0.001****	**2.56**
Prevention (#3)	**1.01**	**0.33**	**3.09**	**0.002****	**2.75**

Table 8. Logistic regression of vaccination intentions on the alternative conceptions with AICc model selection. Alternative Conception item # in parenthesis (Table 2b). ***p<0.001. Bolded font indicates statistical significance.

Variable	Estimate (β)	S.E.	z-value	p-value	Odds Ratio
Intercept	**1.86**	**0.16**	**11.84**	**<0.001*** **	**6.40**
Cause Flu (#5)	**-1.57**	**0.47**	**-3.35**	**<0.001*** **	**0.21**

Discussion

To what extent do college students of different levels of formal biology expertise differ in their knowledge about how the flu vaccine works?

Assessing participants' knowledge about how the flu vaccine works, I applied the *Actional* perspective of knowledge construction and developed a rubric for knowledge of how the flu vaccine works that contains 5 basic knowledge components and 7 alternative conceptions. The validity of the rubric items was confirmed by two immunology expert evaluations, and the interrater reliability was confirmed by Cohen's kappas and high raw agreements (Table 2).

Applying the rubric, I used the 5 basic knowledge components to assess participants' scientifically accurate knowledge about how the flu vaccine works. I hypothesized that higher levels of formal biology expertise would correlate with more knowledge. Specifically, I expected NBS to score lower than EBS and EBS to score lower than ABS on average. This hypothesis was partially supported by the result that ABS scored higher in basic knowledge compared to NBS (Fig. 1a). However, ABS and EBS did not differ in their basic knowledge scores, suggesting that the basic conceptual knowledge about the flu vaccine can be developed early in the development of formal biology expertise. Surprisingly, EBS scored no higher than NBS (Fig. 1a). This finding aligned with the results of Sundberg & Dini's study (1993), where they found no significant difference in biology knowledge between entering biology majors and non-majors. However, the comparison's puzzling nature was revealed when conflicting results emerged in a similar study on a different cohort. Sundberg *et al.* (1994) have found that, before introductory biology courses, entering biology majors slightly but significantly outperformed non-biology majors in a comprehensive exam. The ambiguous difference of biology knowledge between EBS and NBS suggests that students' previous biology knowledge may vary in different cohorts, implying that to teaching, it is important to know the level of knowledge of one's own students.

Even if most of the participants possess some basic knowledge about how the vaccine works, their knowledge might not be free of alternative conceptions. I hypothesized that students of higher levels of formal biology expertise might have had more biology-learning time to revise naturally occurring alternative conceptions and, thus, that higher formal biology expertise would correlate with endorsing fewer alternative conceptions of the flu vaccine. My hypothesis was partially supported by the finding that alternative conceptions were more prevalent in NBS than ABS and were also more prevalent in EBS than in FC (Fig. 1b). However, no significant difference was found between EBS and NBS, suggesting that educational interventions may want to target alternative conceptions early in the biology-learning process.

After comparing vaccine-related knowledge among the participant groups, I extracted the most common basic knowledge and alternative conceptions students had about how the flu vaccine works. Students commonly know that the vaccine has protective power, but they might not know how it works in the body or have alternative conceptions about what it contains, which highlights gaps that instructors could target.

Exploring the correlation between alternative conceptions and basic knowledge about the biology of flu has practical value in teaching students about the flu vaccine. As the *Actional* perspective suggests, alternative conceptions are naturally generated in the process of knowledge construction, which builds upon previous knowledge that might or might not be erroneous (Gilbert & Watts, 1983). This might mean that alternative conceptions could serve as precursors of accurate knowledge, and thus they might correlate with the absence of accurate knowledge. On the other hand, alternative conceptions might also be naturally generated during knowledge construction, and thus they might correlate with the presence of accurate knowledge. For this reason, I expected to find correlations between the presence of some alternative conceptions and the presence or absence of basic knowledge components. The results revealed that, when students believe the flu vaccine contains agents that can directly respond to an infection, it correlates with the absence of basic knowledge that the vaccine resembles the pathogen and induces immune response upon vaccination (Tables 3a-b). Therefore, clarifying the vaccine's composition might be an important instructional objective when teaching about vaccines. Moreover, believing that seasonal flu vaccines are identical correlates with the absence of basic knowledge that the influenza virus is prone to frequent mutations (Table 3c). Furthermore, thinking that the vaccine can cause the flu correlates with the absence of basic knowledge about herd immunity upon sufficient coverage rate (Table 3d). Together, these results suggest that future teaching about vaccine biology may want to construct scientifically accurate knowledge while clarifying existing related alternative conceptions.

Most of the correlations were found between the presence of alternative conceptions and the absence of basic knowledge, but one correlation revealed that the presence of an alternative conception is related to the presence of basic knowledge. Students who erroneously believed that the vaccine contains the unmodified pathogen also by definition possessed the knowledge that the vaccine resembles the pathogen (Table 3a). Based on the *Actional* perspective, I may infer that the knowledge construction about the vaccine's composition sometimes leads to the formation of this alternative conception. For this reason, future vaccine-related teaching might want to carefully address this alternative conception while explaining the vaccine's contents.

To what extent does intrinsic motivation correlate with college students' knowledge about how the flu vaccine works?

Uncovering the factors in the 26 challenge statements, I unexpectedly found that the responses to the challenge statements could be best explained by only 2 factors, which did not reflect the intended 3x2 structure to measure intrinsic motivation. Compared to the intended theoretical model of three SDT components, the 2-factor model led to more desirable outcomes of higher CFI, lower BIC, lower RMSEA, and lower SRMR (Brussow *et al.,* 2020; Knekta *et al.*, 2019). Plus, it outperformed the 3-factor model in parsimony. EFA and CFA then revealed the grouping of the 2 factors. Factor 2 related to beliefs about side effects of the flu vaccine, and Factor 1 consisted of all other challenge statements, which related to common vaccine-supporting and -rejecting beliefs about the flu vaccine. Although the factors did not measure the three intended SDT components, I were interested in exploring correlations between these two factors and students' knowledge, considering that the 2 factors were meaningful representations of students' responses to common vaccine-supporting or -rejecting messages.

Students who disagreed that the flu vaccine typically has severe side effects were more likely to know about the influenza virus's frequent mutation and potential herd immunity. Furthermore, they were less likely to erroneously believe that the vaccine causes flu or provides no community benefits. Since no study has examined the direct correlation between knowledge and perception of vaccine side effects, uncovering mechanisms that mediate these correlations would be an interesting future direction.

To what extent do vaccination intentions relate to knowledge about how the flu vaccine works?

In evaluating participants' vaccination intentions, I found that the four participant groups did not differ in their vaccination intentions despite varying knowledge about how the flu vaccine works (Fig. 3), suggesting that intention to not vaccinate remains an issue regardless of levels of formal biology expertise, yet the reason was not clear. As EBS and ABS develop scientifically accurate knowledge about vaccines, they might acquire a more precise perception of vaccine safety and disease susceptibility, but at the same time, they could also develop perceptions of shortcomings of vaccines or science. Also, reasons for being vaccine-hesitant might be different for different participant groups. Previous research has suggested college students were hesitant about the flu vaccine mainly because of concerns about severe side effects or distorted perception of low disease susceptibility (Benjamin & Bahr, 2016). However, healthcare workers were concerned about the flu vaccine mainly because of its short testing period and the uncertain vaccine efficacy (Blasi *et al.*, 2011; Qureshi *et al.*, 2004). Overall, these findings suggest that addressing vaccine hesitancy cannot be simply accomplished through supplying the audience with scientifically accurate information, and more studies are needed to carefully construct interventions targeting audiences with different biology backgrounds.

Comparing participants' vaccination intentions with their vaccination histories, I expected to find flu vaccination intentions a strong predictor of flu vaccination behaviors (Fall *et al.*, 2016). My hypothesis was partially supported as significant correlations were found in participants' flu vaccination status in the past 12 months and their flu vaccination intentions for EBS and NBS, but the correlation was not found among ABS or FC (Fig. 4b). A work-related requirement might explain this result. Hospitals are required by law to offer the seasonal flu vaccine to their staff and volunteers, who are strongly recommended to vaccinate to protect themselves and patients (CDC, 2014). In this R1 university, it is possible that a good number of ABS had taken initial steps towards healthcare-related careers and followed clinical guidelines to vaccinate against flu. Plus, some FC were healthcare professionals, so these two groups might have vaccinated for work regardless of their vaccination intentions. In other words, although many healthcare workers have been vaccinated against flu, some of them might still dispute the necessity of vaccination, and their opinions could have an amplifying influence on their patients and patients' families and friends. This finding calls for action to carefully address vaccine hesitancy among healthcare workers.

My study did find a few correlations between knowledge and vaccine intention. Knowing about the vaccine's preventative power was associated with vaccination intention. . One possible explanation is the preventative power of the vaccine was recognized as a key feature that convinced many participants to receive the vaccine. However, further investigations are needed to explore possible causal relationships. Believing that the vaccine can cause flu was associated with reduced vaccination intention, suggesting that inaccurate perceptions of the vaccine's side effects may negatively impact vaccination intentions. This finding aligns with previous research of risk-benefit analysis on vaccination behaviors, which suggested that fear of side effects can outweigh perceptions of vaccination benefits (Karafillakis & Larson, 2017). Highlighting alternative conceptions and accurate knowledge in relation to vaccination intentions, my findings suggest that future educational interventions might want to teach students about the vaccine's preventative measures while refuting the causal link between vaccination and disease onset.

Limitations & Future Directions

In the recruitment process, volunteer bias was inevitable as students volunteered to participate in the study. Incentives to participate were provided as community extra credits in the courses from which students were recruited, so it was likely that participants would ask their friends in the same course to fill out the survey. This means that students might have influenced other students' decisions to participate in the study, and they might have shared some of their answers with each other. Although I strongly advised against seeking outside resources and excluded plagiarized responses, the online survey did not allow us to strictly enforce this rule.

My rubric development could have omitted valuable but uncommon ideas. My selection criteria excluded codes that were not common (n<9) among all participants, but those excluded codes included many striking ideas that might correlate with motivation or vaccination intention. For example, some students had very in-depth knowledge, including knowing about the quadrivalent design of the flu vaccine. One striking example of excluded alternative conceptions was that the flu vaccine can infect vaccinated individuals, who then can transmit the disease to unvaccinated individuals. Although the *Actional* perspective of knowledge construction proposed diverse alternative conceptions based on different personal experiences, the scope of my study was limited and did not analyze all alternative conceptions and all the in-depth knowledge the participants had.

In my analysis of basic knowledge and alternative conceptions, I cannot infer causal relationships. This means that, for the alternative conceptions that correlated with the absence of basic knowledge, I cannot confirm that addressing these alternative conceptions will lead to the construction of these basic knowledge components. Considering that presenting scientifically accurate information could cause back-fire effects, future studies are needed to design effective ways to carefully address these alternative conceptions and construct the basic knowledge.

My statistical analysis of expertise compared to knowledge also has an inherent assumption that is not necessarily satisfied. In all logistic regression models, formal biology expertise was included as a continuous variable. Given that NBS=1, EBS=2, and ABS=3, I inherently assumed that the distance between each level of formal biology expertise was equal. However, this assumption is unlikely. In fact, I found that NBS and EBS did not differ in their basic knowledge and alternative conceptions about how the flu vaccine works. My results suggested that NBS might be similar to EBS in terms of biology knowledge, yet ABS possessed much basic knowledge and fewer alternative conceptions compared to them. For this reason, one must be aware of this caveat when interpreting the significant correlations that the formal biology expertise appeared to have with knowledge.

For measuring motivation, a major caveat of the study was that I failed to distinguish the 3 components of intrinsic motivation with the Likert-scale challenge statements. It is unclear whether these three components are actually not distinguishable when it comes to learning about vaccines, but our challenge statements failed to capture any distinction. Possible correlations between intrinsic motivation and knowledge about how the flu vaccine works remains an interesting and unexplored question that awaits future studies.

When analyzing vaccination intentions and behavior, there are two caveats. First, dichotomized vaccination intentions might have lost valuable insights. I dichotomized their responses on the 6-point Likert scale to categorize participants into either the vaccine-accepting or -hesitant group. Although I simplified the analyses in this way to produce straightforward results, I acknowledged this simplification as a limitation because it might have collapsed meaningful findings based on varying degrees of vaccine acceptance (MacDonald, 2015; Rossen *et al.*, 2019). Additionally, participants' vaccination history was self-reported, so it is unclear how reliable this information is. First, many years have passed since participants received childhood vaccines, so their memories about their vaccination records might not be reliable. Second, I cannot assume that all participants clearly know what childhood vaccines were recommended. Some of them might have been undervaccinated for some of the recommended childhood vaccines, but the yes-no question did not capture this possibility. In future studies, this limitation may be overcome by asking participants to use their vaccination records to report their vaccination status on each of the recommended childhood vaccines to receive more complete and reliable information.

Conclusion

My findings have contributed to the current understanding of what college students know about the flu vaccine and how their knowledge relates to vaccination intentions, but unfortunately, my study failed to capture students' intrinsic motivation in relation to the vaccine. I developed a rubric to assess college students' basic knowledge and alternative conceptions about how the flu vaccine works. EBS and NBS did not differ in their total knowledge scores. Also, students usually know that receiving the vaccine would prevent future onset of flu, but they might not know how the vaccine works in the body or they might hold alternative conceptions about what the vaccine contains. My findings highlighted knowledge gaps that future vaccine-related lessons might want to target and suggests that future vaccine-related lessons might want to first examine students' prior knowledge relevant to the biology of vaccines.

I also identified alternative conceptions that related to particular components of basic knowledge. Students who erroneously believed that the vaccine directly responds to infections tend to not know what the vaccine contains or how it induces immune response. Students who thought that seasonal flu vaccines were identical tend to not know about influenza virus mutation. Furthermore, students who believed that the vaccine can cause the flu tend to not know about vaccine-induced herd immunity. These correlations suggest it may be fruitful while teaching to address the basic knowledge and relevant alternative conceptions together.

In addition to correlations among students' different types of knowledge, I also found correlations between students' knowledge and vaccination intentions. Students who knew that the vaccine helps prevent flu were more likely to intend to vaccinate against the flu, yet students who erroneously believed that the vaccine could cause flu were more less likely to intend to vaccinate. Therefore, future educational interventions for changing student attitudes about vaccines might want to teach students about the vaccine's preventative powers and refute a causal relationship between the vaccine and flu symptoms.

APPENDIX 1

<u>Survey shown to Students:</u>

[introduction]

In this survey, we want to understand more about **what students think and believe about the flu vaccine.** In this survey, you will be asked roughly 40 questions, and it will take approximately 20 minutes. Most of these questions will ask whether you agree or disagree with some common opinions people have about vaccines. **We expect that you will agree with some of these statements and disagree with others.** We will also ask you for a little bit of information about yourself to better understand our study population.

Your responses will be kept anonymous as no personally identifying information is collected on this survey. All virtual data will be kept and stored on Team Google Drive, owned and protected by UC San Diego and accessible only to the research team. Additionally, your responses are collected through Qualtrics, a professional survey platform with FedRamp authorization, which certifies standard security services provided by Qualtrics. Protecting your privacy is the priority of the research team.

This survey is part of a research study. **If a certain percentage of students in your course complete this survey, everyone will receive extra credit. However, you do not have to agree to have your responses be analyzed as part of the research study.** If you do not agree to be part of the study, it will still be counted towards the number of students participating.

Please read the consent form below.

[the consent form will display here]

I agree to have my survey responses analyzed as part of this research study. I understand that if I do not agree, my response will count towards the number of people responding in my course, but my responses will not be analyzed for research.
By agreeing, I also affirm that I am over 18 years of age and have read the consent form.

- I agree to have my survey responses analyzed as part of this research study.
- I do not agree to have my survey responses analyzed as part of this research study.

[questions regarding vaccine knowledge and beliefs]

Please read the statement below and choose a response on the scale.
"The flu vaccine is a way to keep myself healthy."

- Strongly disagree
- Disagree
- Slightly disagree
- Slightly agree
- Agree
- Strongly agree

Please read the statement below and choose a response on the scale.

"My community is generally in favor of the flu vaccine, so I will receive the flu vaccine."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The government should not pressure people to get the flu vaccine."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu vaccine works effectively to protect me."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"By getting the flu vaccine, I am making a good decision about my health."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Among my friends and family, receiving the flu vaccine is controversial."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu is a severe disease."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu vaccine can cause symptoms of the flu."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu vaccine can work safely to protect me from the flu."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"My parents are against the flu vaccine, so I will not get the flu vaccine."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Getting the flu vaccine contributes to protecting other members of the community."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Getting myself vaccinated against flu is a way of keeping my family healthy."
Strongly disagree

Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Getting the flu vaccine is an irresponsible decision for my own health."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Keeping my space clean will keep me away from infections, so I do not need the flu vaccine to stay healthy."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu vaccine can cause the flu."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Members of my community generally do not want to receive the flu vaccine."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The pharmaceutical industry cannot be trusted to care about the wellbeing of patients who are given the flu vaccine."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Medical experts should not pressure anyone to receive the flu vaccine."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Members of my community generally do not get the flu vaccine, so I will not."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Getting the flu vaccine reassures me that I am helping protect myself from the flu."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Getting the flu vaccine is important for being as healthy as possible."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu vaccine helps me build my immune system."
Strongly disagree

Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"I decide to get the flu vaccine because I understand the outcomes of doing so."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Healthy people with a healthy diet and habits do not need the flu vaccine to stay healthy."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"The flu vaccine usually has side-effects that cause severe symptoms of sickness."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"My parents vaccinated me against flu in the past, so I will get the flu vaccine."
Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Choosing to get the flu vaccine is a way of being responsible for my own health."
Strongly disagree
Disagree

Slightly disagree
Slightly agree
Agree
Strongly agree

Please read the statement below and choose a response on the scale.
"Vaccination conflicts with my own spiritual or religious beliefs."

- Strongly disagree
- Disagree
- Slightly disagree
- Slightly agree
- Agree
- Strongly agree

Please read the statement below and choose a response on the scale.
"If there were no obstacles to being vaccinated, such as cost, time, or availability, I would get the flu vaccine every year."

- Strongly disagree
- Disagree
- Slightly disagree
- Slightly agree
- Agree
- Strongly agree

How does a flu vaccine work?

Some vaccines, like the measles vaccine, are only given in childhood. For the flu vaccine, why is it recommended that you get the flu vaccine every year?

To what extent does vaccinating people for flu influence the health of people in their community who don't get the vaccine? Please explain.

Were you vaccinated with childhood vaccines?

- Yes
- No
- I don't know

Did you receive the flu vaccine in the past 12 months?

- Yes
- No
- I don't know

[attention check][1]

[1] The attention check question serves to identify quality responses to this survey. If a participant did not pay full attention to the instruction and select "Strongly Agree" before proceeding to the next page, the responses will still be collected but not analyzed.

"Please choose "Strongly Agree" to indicate that you are paying attention to this instruction."

Strongly disagree
Disagree
Slightly disagree
Slightly agree
Agree
Strongly agree

[demographic questions]

What is your year in college?

Freshman
Sophomore
Junior
Senior
Other _______

Did you transfer to UCSD from a community college?

Yes
No

What is/are your majors here at UCSD?

What college-level biology classes have you taken as of now, if any? Please include AP Biology if you received 4 or above on the AP Exam. Please include classes in progress.

Are you a member of the first generation in your family to go to college?

Yes
No

How many children do you have?

0
1
2
More than 2

What is your age?

18 – 24 years
25 – 44 years
45 – 64 years
Over 64 years

What gender do you identify as?

Which of the following categories best describes your race or ethnicity? You may select more than one option.

White
Latinx or Hispanic
Black or African American
Asian
Native American
Native Hawaiian or Pacific Islander
Other (please specify) _____
Prefer not to answer

What is your political orientation?
Consistently conservative
Mostly conservative
Mixed
Mostly liberal
Consistently liberal
Prefer not to answer

[end note]
Thank you for completing this survey. Your responses are very valuable to us.
If you have any follow-up questions, please contact Dr. Melinda Owens at mtowens@ucsd.edu or Keying Deng at k3deng@ucsd.edu.

<u>Survey shown to Faculty:</u>

[introduction]

In this survey, we want to understand more about **what students think and believe about the flu vaccine.** We are asking you as experts in a related discipline. In this survey, you will be asked roughly 40 questions, and it will take approximately 20 minutes. Most of these questions will ask whether you agree or disagree with some common opinions people have about vaccines. **We expect that you will agree with some of these statements and disagree with others.** We will also ask you for a little bit of information about yourself to better understand our study population.

Your responses will be kept anonymous as no personally identifying information is collected on this survey. All virtual data will be kept and stored on Team Google Drive, owned and protected by UC San Diego and accessible only to the research team. Additionally, your responses are collected through Qualtrics, a professional survey platform with FedRamp authorization, which certifies standard security services provided by Qualtrics. Protecting your privacy is the priority of the research team.

This survey is part of a research study. Please read the consent form below.

[the consent form will display here]

[questions regarding vaccine knowledge and beliefs]
[attention check]
(These sections are the same as in the Student Survey)

[demographic questions]

What was your highest degree? You may select more than one option.

MD
PhD
MPH
Other _______

What discipline did you receive your highest degree in?

When did you receive your highest degree?

Before 1980
1980-1989
1990-1999
2000-2009
2010 or later

Are you a member of the first generation in your family to go to college?

Yes

No

How many children do you have?
0
1
2
More than 2

What is your age?
18 – 24 years
25 – 44 years
45 – 64 years
Over 64 years

What gender do you identify as?

Which of the following categories best describes your race or ethnicity? You may select more than one option.
White
Latinx or Hispanic
Black or African American
Asian
Native American
Native Hawaiian or Pacific Islander
Other (please specify) ______
Prefer not to answer

What is your political orientation?
Consistently conservative
Mostly conservative
Mixed
Mostly liberal
Consistently liberal
Prefer not to answer

[end note]
(same as in the Student Survey)

APPENDIX 2

Coding Guidelines

Responses to the following survey questions were coded

I. How does a flu vaccine work?

II. Why do you need a flu shot every year?

III. To what extent does vaccinating people for flu influence the health of people in their community who don't get the vaccine?

Overarching Rules of Coding

I. Although some questions elicit the knowledge about particular knowledge components, the codes of the response to every question will not be restricted to those knowledge components.

II. When a response may be interpreted multiple ways, interpret it in the best possible way (highest Knowledge score, lowest Misconception score).
   a. Refer to responses from the same participant to fill in the context when the message is unclear.

III. For Knowledge Coding, focus on the general concept rather than specific language.
   a. Only give a 0 if all ideas within the response are misconceptive or insufficient.

IV. For Knowledge Coding, response can be coded even if the response isn't exhaustive in the knowledge components.

V. Things in quotes will be taken literally/directly, unless it is obvious the students do not mean the term that way.

VI. Parenthesis and statements of uncertainty will be ignored.

VII. For Misconception Coding, don't code unless it is clearly a misconception.

VIII. For most misconceptions, a single mention of the misconception is enough to code it. Exceptions will be noted in the coding guide.

IX. Double coding under the same completeness component is encouraged.

Section 1: Basic Knowledge Coding

[Pathogen Likeness] The flu vaccine contains elements that resembles parts or all of the influenza virus.

1. Score 1 if
    a. [contains antigens] Antigens
    b. [inactive/dead form] Inactive or dead form of the pathogen (“not harmful”, “not active”, etc.)
    c. [weaken] Weaken form of the pathogen (“less harmful”, “less active”, etc.)
    d. [bacteria] Bacteria (referring to the influenza virus) (should also be coded as the misconception [flu bacterium])
    e. [mimics the virus] Mimics the influenza virus
    f. [contains multiple strains] Multiple strains of the flu virus
    g. [genetic content] Genetic content of a flu virus
2. Score 0 if
    a. Artificial chemicals
    b. Antibodies / antibiotics
    c. “Covers for” or “work against” the influenza virus
    d. If it is unclear whether the pathogen refers to the pathogen in the flu vaccine

[Immune Response] The flu vaccine stimulates a specific, active immune response in the body.

3. Score 1 if
    a. [active immune defense] Active immune defense (“the immune system is activated/stimulated/induced”)
        i. Shortest statements that would earn a 1 for [immune response] and a 1
    b. [create immune components] The immune system creates immune components such as antibodies, T cells, B cells, memory cells, etc.
        i. Do code if the response mentions immune components without suggesting where the immune components come from
        ii. The vaccine “create”, “produce”, “give rise to” antibodies are not coded
4. Score 0 if
    a. The immune system is strengthened (only if there is no reference to a specific immune response being activated)
    b. The vaccine directly fights the infection
    c. The “body” is being activated/stimulated/induced
    d. The vaccine causes something else that’s not specifically the person’s immune system to provide the protection

[Prevention] Immune memory (prevention is key) will quickly eliminate the infection of the specific strains at subsequent encounters.

5. Score 1 if
    a. [learn to fight the virus] Learned/remembered/memory to fight the influenza virus
    b. [protection] Protection, resistance, or tolerance against the influenza virus (quickly recognize/eliminate future infection)
    c. [not infected] Won’t be infected by the influenza virus
    d. [reduced symptoms] Reduced symptoms in future infection
6. Score 0 if
    a. Non-specific immunological memories
    b. It makes you immune or provides immunity (vague description)

    c. The vaccine directly provides the protection

[Mutation] The influenza virus mutates quickly, so the immune memory for the past circulating strains may not protect the person from the current circulating strains.

7. Score 1 if
    a. [different circulating strains] The circulating strains every year might be different
    b. [different circulating strains] Mentioning of mutation/evolution in a general way (antigenic shift, genetic drift, virus mutates, virus evolves, virus develops)
8. Score 0 if
    a. The body changes
    b. The vaccine/immunological memory loses effectiveness
    c. The vaccine is not 100% effective
    d. Updated/more advanced flu vaccine
    e. The epidemic is seasonal

[Herd Immunity] Getting the flu vaccine can reduce the chance of contracting the virus and spreading the infection among your community.

9. Score 1 if
    a. [reduced transmission] Reduced chance of transmission
        i. The language may be as vague as "reducing the points of contact for the unvaccinated"
    b. [herd immunity] Herd immunity
    c. [more sick if not vaccinated] More people would get sick if others are unvaccinated
    d. [protect the unvaccinated] It protects or provides a safe place for the unvaccinated people
10. Score 0 if
    a. Creates mutual trust in vaccine
    b. Peer pressure / herd behavior
    c. No community benefits
    d. Benefits the public health (only if the response is extremely vague)
    e. Prevents the evolution of the flu virus
    f. Boost everyone's immunity to the flu
    g. Vaccinated people are protected

Section 2: Alternative Conception Coding

1. **[Unmodified Virus]** The flu vaccine contains the unmodified pathogen.
    a. If it is unclear if the pathogen refers to the circulating pathogen, don't code
    b. Do code if it clearly refers to a pathogen in the vaccine, but no modifiers are used
    c. Do not code if [contains antigens], [inactive/dead form], or [weaken] is coded unless the participant explicitly states the misconception as a possibility
2. **[Vaccine Is Antibodies]** The flu vaccine contains or provide antibodies.
    a. If it is unclear whether the antibodies come from the body or the, don't code
    b. The vaccine "create", "produce", "give rise to" antibodies are not coded; responses should also not be coded for [create immune components]
    c. Do not code if the participant correctly identifies the source of antibodies, unless the participant explicitly states the misconception as a possibility
3. **[Flu Bacterium]** The flu vaccine contains the flu bacterium.
4. **[Fights the Infection]** The flu vaccine directly fights or treats the infection in the body.
    a. Indirect implication or unclear explanation like "it gets into your body so you have it from getting infected" or "updated to combat the virus at the current level" would not be coded
5. **[Cause Flu]** The flu vaccine can give you the flu.
6. **[No Community Effect]** The flu vaccine provides no community effect other than benefits on individual levels.
    a. Code if the participant suggests that getting the flu vaccine does not reduce the recipient's chance/ability of transmission
    b. Do not code if [increase the transmission] or [mild symptoms]
    c. Do not code for non-biological community effects like "getting the vaccine encourages/discourages other people from getting the vaccine."
7. **[Booster Vaccine]** Annual shots are booster vaccines.
    a. Implication that the shots contain highly similar/identical contents would be coded

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