

Supplemental Material

*CBE—Life Sciences Education*

Kahlon *et al.*

Table S1. Immunology expert’s suggestions for additional rubric items, in order of how commonly they were present in the BF responses.

<b>Suggested concept or term</b>	<b>% BF responses containing item</b>
A vaccine causes a <i>better or stronger immune response</i> when the antigen is encountered again	58% (14 of 24)
Memory cells	46% (11 of 24)
Antigen	42% (10 of 24)
B cells	38% (9 of 24)
T cells	29% (7 of 24)
Macromolecular identity of antigens	25% (6 of 24)
Recognizing non-self or foreign material	25% (6 of 24)
Antigen-presenting cells (APCs)	8% (2 of 24)
Clonal selection	8% (2 of 24)
Intersection of innate and adaptive immunity	4% (1 of 24)
Timeframe of innate vs. adaptive immune response	4% (1 of 24)

Table S2. Summary of initial linear regression model for combined knowledge score. n = 511. Bolded values are significantly different from 0 (p<0.05). The model contains “Coursework” (whether the student self-reported taking coursework addressing vaccines), “Confidence” (whether the student reported being confident in their vaccine knowledge), Gender (reference level is female), First-Generation (college-going status) (reference level is continuing-generation), “Race/Ethnicity” (reference level is white race), Expertise Level (NPH, PH, or EBM status) (reference level is NPH), and Years in College.

Variable	Estimate ( $\beta$ )	S.E.	t-value	p-value
<b>Intercept</b>	<b>1.826</b>	<b>0.188</b>	<b>9.682</b>	<b>&lt;0.001</b>
Expertise- PH	0.037	0.154	0.240	0.810
Expertise- EBM	-0.022	0.126	-0.176	0.861
<b>Coursework</b>	<b>0.631</b>	<b>0.115</b>	<b>5.483</b>	<b>&lt;0.001</b>
<b>Confidence</b>	<b>0.479</b>	<b>0.118</b>	<b>4.047</b>	<b>&lt;0.001</b>
Male Gender	0.026	0.125	0.209	0.835
First-generation	-0.001	0.123	-0.014	0.989
<b>Race- Asian</b>	<b>-0.390</b>	<b>0.180</b>	<b>-2.169</b>	<b>0.031</b>
<b>Race- Black</b>	<b>-0.666</b>	<b>0.260</b>	<b>-2.560</b>	<b>0.011</b>
Race- Latinx	-0.290	0.187	1.554	0.121
Race- Multiracial	-0.303	0.211	-1.439	0.151
Years in College	0.096	0.057	1.680	0.094

Table S3. Summary of initial logistic regression model for accuracy. n = 511. Bolded values are significantly different from 0 ( $p < 0.05$ ). The model contains “Coursework” (whether the student self-reported taking coursework addressing vaccines), “Confidence” (whether the student reported being confident in their vaccine knowledge, Gender (reference level is female), First-Generation (college-going status) (reference level is continuing-generation), “Race/Ethnicity” (reference level is white race), Expertise Level (NPH, PH, or EBM status) (reference level is NPH), and Years in College.

Variable	Estimate ( $\beta$ )	S.E.	z-value	p-value	Odds ratio
<b>Intercept</b>	<b>-0.931</b>	0.324	-2.869	<b>0.004</b>	<b>0.39</b>
Expertise- PH	-0.120	0.261	-0.458	0.647	0.89
Expertise- EBM	-0.348	0.219	-1.594	0.111	0.71
<b>Coursework</b>	<b>0.617</b>	<b>0.201</b>	<b>3.063</b>	<b>0.002</b>	<b>1.85</b>
Confidence	0.153	0.202	0.758	0.448	1.17
Male Gender	0.182	0.213	0.852	0.394	1.20
First-generation	-0.173	0.214	-0.811	0.417	0.84
Race- Asian	0.089	0.306	0.291	0.771	1.09
Race- Black	-0.365	0.474	-0.772	0.440	0.69
Race- Latinx	0.120	0.320	0.376	0.707	1.13
Race- Multiracial	-0.116	0.364	-0.318	0.751	0.89
Years in College	0.169	0.096	1.756	0.079	1.18

Table S4. Initial list of possible inaccurate ideas, number of experts who agreed it was inaccurate, and final form of the inaccurate ideas

<b>Initial Possible Inaccurate Idea</b>	<b># experts who agreed it was inaccurate</b>	<b>Final Inaccurate Idea</b>
Vaccines contain the unmodified pathogen.	4/5	A vaccine contains the pathogen in an unmodified form.
Vaccines work through administering a small or non-harmful dose of the pathogen.	3/5	<i>Discarded</i>
A vaccine is a treatment or cure.	3/5	Vaccines are primarily a treatment or cure.
Vaccines directly harm or fight the pathogen.	4/5	A vaccine directly harms or fights the pathogen, not through the immune system.
A vaccine provides immunity to all pathogens or diseases.	4/5	A single vaccine provides immunity to all pathogens or diseases.
Vaccines are injected directly into the skin or bloodstream (as opposed to into a muscle).	4/5	Vaccines are injected directly into the blood.

Table S5: Summary of initial linear regression model for basic knowledge score by common inaccurate ideas. n = 635. Bolded values are significantly different from 0 ( $p < 0.05$ ). The model contains variables representing the presence or absence of the five most common inaccurate ideas (listed in Table 6).

Variable	Estimate ( $\beta$ )	S.E.	t-value	p-value
<b>Intercept</b>	<b>1.914</b>	<b>0.049</b>	<b>38.98</b>	<b>&lt;0.001</b>
<b>Unmodified pathogen</b>	<b>0.547</b>	<b>0.082</b>	<b>6.65</b>	<b>&lt;0.001</b>
<b>Vaccine is treatment</b>	<b>-0.992</b>	<b>0.130</b>	<b>-7.65</b>	<b>&lt;0.001</b>
<b>Vaccine directly harms pathogen</b>	<b>-0.930</b>	<b>0.154</b>	<b>-6.03</b>	<b>&lt;0.001</b>
Vaccine injected into blood	-0.050	0.145	-0.35	0.73
<b>Single vaccine for all diseases</b>	<b>-0.726</b>	<b>0.143</b>	<b>-5.07</b>	<b>&lt;0.001</b>

Table S6. Summary of initial logistic regression model for the three components of total basic knowledge by inaccurate ideas. n = 635. Bolded values are significantly different from 0 (p<0.05). The model contains variables representing the presence or absence of the five most common inaccurate ideas (listed in Table 6).

<b>Knowledge Component</b>	<b>Variable</b>	<b>Estimate (β)</b>	<b>S.E.</b>	<b>z-value</b>	<b>p-value</b>	<b>Odds ratio</b>
Pathogen-Likeness	<b>Intercept</b>	<b>0.690</b>	<b>0.117</b>	<b>5.875</b>	<b>&lt;0.001</b>	<b>1.99</b>
	<b>Unmodified pathogen</b>	3.114	0.473	6.588	<b>&lt;0.001</b>	<b>22.51</b>
	<b>Vaccine is treatment</b>	-2.240	0.426	-5.260	<b>&lt;0.001</b>	<b>0.11</b>
	<b>Vaccine directly harms pathogen</b>	-2.363	0.597	-3.956	<b>&lt;0.001</b>	<b>0.09</b>
	Vaccine injected into blood	-0.315	0.399	-0.789	0.43	0.73
	<b>Single vaccine for all diseases</b>	-1.912	0.419	-4.564	<b>&lt;0.001</b>	<b>0.15</b>
Immune Activation	Intercept	0.026	0.111	0.238	0.81	1.03
	<b>Unmodified pathogen</b>	<b>0.504</b>	<b>0.189</b>	<b>2.666</b>	<b>0.008</b>	<b>1.65</b>
	<b>Vaccine is treatment</b>	<b>-2.685</b>	<b>0.613</b>	<b>-4.381</b>	<b>&lt;0.001</b>	<b>0.07</b>
	<b>Vaccine directly harms pathogen</b>	<b>-3.002</b>	<b>1.030</b>	<b>-2.916</b>	<b>0.003</b>	<b>0.05</b>
	Vaccine injected into blood	0.337	0.374	0.902	0.37	1.40
	<b>Single vaccine for all diseases</b>	<b>-2.166</b>	<b>0.540</b>	<b>-4.012</b>	<b>&lt;0.001</b>	<b>0.11</b>
Prevention	<b>Intercept</b>	<b>1.202</b>	<b>0.128</b>	<b>9.425</b>	<b>&lt;0.001</b>	<b>3.33</b>
	<b>Unmodified pathogen</b>	<b>0.516</b>	<b>0.237</b>	<b>2.180</b>	<b>0.03</b>	<b>1.68</b>
	<b>Vaccine is treatment</b>	<b>-1.227</b>	<b>0.300</b>	<b>-4.093</b>	<b>&lt;0.001</b>	<b>0.29</b>
	<b>Vaccine directly harms pathogen</b>	<b>-1.503</b>	<b>0.372</b>	<b>-4.039</b>	<b>&lt;0.001</b>	<b>0.22</b>
	Vaccine injected into blood	-0.371	0.353	-1.049	0.29	0.69
	Single vaccine for all diseases	-0.078	0.361	-0.217	0.83	0.92

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

---

## **What risks are associated with vaccines?**

---

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



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

---

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

Strongly Disagree  
1

Disagree  
2

Agree  
3

Strongly Agree  
4

---

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

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

---

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

Strongly Disagree

1

Disagree

2

Agree

3

Strongly Agree

4

---

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

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

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

---

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

Strongly Disagree  
1

Disagree  
2

Agree  
3

Strongly Agree  
4

---

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

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

---

**“Vaccines can cause autism in children.”**

Strongly Disagree  
**1**

Disagree  
**2**

Agree  
**3**

Strongly Agree  
**4**

---

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

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

---

## How does a vaccine work?

---

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

Please circle YES or NO in response to the following...

---

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

**Yes**

**No**

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

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

**Yes**

**No**

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

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

**Yes**

**No**

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

**I would vaccinate my children.**

**Yes**

**No**

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

Secret Code: \_\_\_\_\_

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

## **Demographics Form-UNIVERSITY STUDENT**

*Please circle an answer for each question*

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

- a) Undergraduate student
- b) Graduate student
- c) Other (please describe) \_\_\_\_\_

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

- a) Freshman (0-29 units)
- b) Sophomore (30-59 units)
- c) Junior (60-89 units)
- d) Senior (90 or more)
- e) Other (please describe) \_\_\_\_\_

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

Yes                      No

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

**BIOLOGY**

- a) BS Botany
- b) BS Ecology
- c) BS Microbiology
- d) BS Zoology
- e) BS Cell & Molecular Biology
- f) BS Marine Biology
- g) BS Physiology
- h) BA General Biology

**OTHER MAJOR(S)**

Please describe \_\_\_\_\_

**5. Anticipated Semester and Year of graduation: \_\_\_\_\_ semester \_\_\_\_\_ year**

**6. What year were you born? \_\_\_\_\_**

**7. How many children do you have? \_\_\_\_\_**

**8. The gender I identify as is \_\_\_\_\_**

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

Yes                      No

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

- a) African American
- b) Filipino/a
- c) Latino/a
- d) White
- e) Asian
- f) Native Hawaiian/Pacific Islander
- g) Native American
- h) Decline to state
- i) \_\_\_\_\_ (please describe)

SEPAL Data Collection

<course>

<term>

If asked by a professional colleague,  
how would you respond to the following question...

---

## **What risks are associated with vaccines?**

---

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



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

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

---

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

Strongly Disagree  
1

Disagree  
2

Agree  
3

Strongly Agree  
4

---

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

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

---

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

Strongly Disagree

1

Disagree

2

Agree

3

Strongly Agree

4

---

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

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

---

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

Strongly Disagree  
1

Disagree  
2

Agree  
3

Strongly Agree  
4

---

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

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

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

---

**“Vaccines can cause autism in children.”**

Strongly Disagree  
**1**

Disagree  
**2**

Agree  
**3**

Strongly Agree  
**4**

---

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

If asked by a professional colleague,  
how would you respond to the following question...

---

## How does a vaccine work?

---

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

Please circle YES or NO in response to the following...

---

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

**Yes**

**No**

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

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

**Yes**

**No**

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

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

**Yes**

**No**

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

**I would vaccinate my children.**

**Yes**

**No**

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

Secret Code: \_\_\_\_\_

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

**Demographics Form-UNIVERSITY FACULTY**

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

1. Which of the following best describes your **general research area**?

*Please circle all that apply and write any concentrations in the provided blank:*

- |                                   |                                  |
|-----------------------------------|----------------------------------|
| a) Botany _____                   | f) Physiology _____              |
| b) Cell & Molecular Biology _____ | g) Zoology _____                 |
| c) Ecology _____                  | h) Clinical Science _____        |
| d) Marine Biology _____           | i) Other (please describe) _____ |
| e) Microbiology _____             | _____                            |

2. What was your field of study as an *undergraduate student*? \_\_\_\_\_

3. What was your field of study as a *graduate student*? \_\_\_\_\_

4. Highest graduate degree obtained (Masters / Ph.D) \_\_\_\_\_ Year Received \_\_\_\_\_

5. How many years have you been teaching undergraduate students as an instructor of record at SFSU?  
\_\_\_\_\_

6. How many years total have you been teaching undergraduate students as an instructor of record? (*total across all institutions where you have taught*) \_\_\_\_\_

7. Which of the following describes the type of biology courses you have taught? (*circle all that apply*):

- a) Introductory Biology for Majors
- b) Biology for Non-Majors
- c) Upper Division Biology course(s)
- d) Other (describe) \_\_\_\_\_

8. What year were you born? \_\_\_\_\_

9. How many children do you have? \_\_\_\_\_

10. The gender that you most closely identify as is \_\_\_\_\_

11. Are you a member of the first **generation** in your family to attend college? (please circle)

Yes                      No

12. Which of the following do you most closely identify as (*circle all that apply*)....

- |                     |                                     |
|---------------------|-------------------------------------|
| a) African American | f) Native Hawaiian/Pacific Islander |
| b) Filipino/a       | g) Native American                  |
| c) Latino/a         | h) Decline to state                 |
| d) White            | i) _____ (please describe)          |
| e) Asian            |                                     |

## **“HOW DOES A VACCINE WORK?” CODING GUIDE:**

*Note: this coding guide contains detailed guidelines on what sorts of student responses were or were not given credit for the basic knowledge components and inaccurate ideas.*

### **Overall rules:**

- Code **everything**, including words with quotes, parentheses, or ending in question marks, **unless** a word is crossed out.
  - This also includes coding things that say “I am not sure but...”, “I am guessing ...”, “I am not a science major but...” and similar
- Focus on whether general concept is present
  - Anthropomorphic or metaphorical language is OK
- If there is an inaccurate idea **and** a basic knowledge component, mark for both independently

### **Basic knowledge components (3)**

1. ***Pathogen-likeness: a vaccine contains something that is part of or is shaped like the pathogen, including the pathogen itself or a weakened or modified version of it. (1)***

- **Score (0) if they ONLY say:**
  - ❖ “Antibodies” instead of “antigens”
  - ❖ “Artificial virus/sickness” **only if** there is no other reference to it being similar to the pathogen.
- **Score (1) if they say:**
  - ❖ “Smaller dose” of pathogen
  - ❖ “Disease, illness, sickness” being in the vaccine
  - ❖ A vaccine is an antigen
  - ❖ “Artificial strain” or “artificial form” of a specific disease (falls under the realm of mimics or is shaped like the pathogen)

2. ***Immune activation: A vaccine stimulates an active immune response. (1)***

- **Score (0) if they ONLY say:**
  - ❖ “The body” is fighting/being stimulated (because they are not referring to the immune system)
  - ❖ Vaccines builds immunity in some non-specific way, such as “strengthening” or “building” the immune system
  - ❖ “Immunity” is enhanced (we don’t know if they know what this means or if it’s active or passive)



- **Score (1) if they say:**
  - ❖ The “immune system” is reacting, being stimulated, fighting it off
  - ❖ Antibodies being made
  - ❖ Immune/white blood cells being made or activated in some way

**3. Prevention: Vaccines can prevent disease caused by a pathogen or lessen the disease’s severity in the future. (1)**

- **Score (0) if the ONLY say:**
  - ❖ Building or strengthening immunity in general
  - ❖ A vaccine protects you from all diseases in general
  - ❖ Vaccine will **directly** fight off that pathogen (implying it is a treatment or a cure instead of prevention)
- **Score (1) if they say:**
  - ❖ In the future/next time, the body will respond more effectively
  - ❖ Some reference to “memory/remember”
  - ❖ When the body encounters the actual pathogen, the body will be **prepared**
  - ❖ Strengthens immune system for **that particular pathogen** (not in general)
  - ❖ Won’t “catch” the same pathogen **again**, or **in the future**.
  - ❖ **Next time** you catch the real pathogen you are immune (even if they reference vaccine being cure/treatment)
  - ❖ Prevent/prevention
  - ❖ Encounter **again**
  - ❖ Vaccine will protect you from a disease **in the future**
  - ❖ You will not get the same virus **again**

**Accuracy(1):**

**1. Are there false claims?**

- **Score (0) if YES - there are inaccurate ideas present, for example (list is not exhaustive):**
  - ❖ One of the 5 most common inaccurate ideas below
  - ❖ A vaccine prevents virus/diseases/sickness from **entering** body
  - ❖ Vaccines contain artificial virus, sickness, or pathogen, but **only if** there is no reference to pathogen likeness
  - ❖ A vaccine can give or make you sick with the disease
  - ❖ Vaccines are or have antibodies

- ❖ Vaccine becomes a part of or alters the immune system, DNA, RNA, or protein
- ❖ Vaccines change body composition
- ❖ Vaccine has a high concentration of virus
- ❖ Vaccine contain pathogen but other substances that protect the body against the pathogen in the vaccine (hence why a person does not get sick)
- ❖ Vaccines attack cells to build immunity
- ❖ Vaccines don't work for most people or are ineffective
- ❖ Vaccines are a supplement
- ❖ Vaccine builds your tolerance towards the disease (or get used to, get accustomed to it)
- ❖ Vaccines are or have white blood cells
- ❖ Vaccines creates or allow the immune system to create a wall, shield, barrier of some sort
- ❖ Vaccines are made of “chemicals”
- ❖ The disease is typically isolated to a specific region of the body
- **The following items are NOT automatically scored (0)**, unless there are other inaccurate claims linked to them:
  - ❖ A vaccine is an inactive or weakened dose, sample, or concentration of a disease or pathogen
  - ❖ All plausible claims about personal experiences (i.e. got scar on arm after vaccination, “my mom got sick after the flu vaccine”)
  - ❖ “Vaccine combats pathogen” (unless response implies the vaccine **directly** combats pathogen)
  - ❖ Vaccine **helps** fights off or works to help fight off disease (unless response implies the vaccine **directly** fights pathogen)
  - ❖ Vaccines build or strengthen immune system
  - ❖ Vaccines build resistance
  - ❖ Vaccines are “artificial” form of pathogen
  - ❖ Vaccines are a “strain” of the pathogen

**Coding for particular inaccurate ideas:**

1. **A vaccine contains the pathogen in an *unmodified* form:** Code if they say vaccine has the original disease/pathogen or just says disease/pathogen without mentioning modifications (weakened/killed/partial/artificial/version etc.)
2. **Vaccines are primarily a treatment or a cure:** Code if they suggest that vaccine is a treatment, cure, or medicine or is given to patient that is already ill

with pathogen and the vaccine is administered to fight (or help fight) the disease off.

- 3. A vaccine directly harms or fights the pathogen, not through the immune system:** Code if they suggest that vaccine directly fights or harms the pathogen or disease or that the vaccine remains in body until “real” pathogen enters and this is when the vaccine fights it off.
- 4. Vaccines are mainly injected directly into the bloodstream:** Code if they say the vaccine is injected *directly* into blood or a blood vessel
- 5. A single vaccine provides immunity to all pathogens or diseases:** Code if they suggest that vaccines help prevent all diseases and aren't pathogen-specific