Uncovering alternative conceptions in student thinking

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What is something that you thought/believed for a long time that turned out not to be true (or only partially true)?

- Individual think (30s)
- Table share (30s per person)

What do we mean by “misconception”?

Broadest meaning:
“scientifically inaccurate idea”

Warning: Some people use the word “misconception” to mean an idea that is wrong, coherent, and deeply-seated

In this presentation, I’ll be using the terms “**alternative conception**” or “**scientifically inaccurate idea**”

Alternative conceptions are inevitable

- Students may have been exposed to this topic in some limited and incomplete way from other sources
- Students have overall ideas about how the world works, which may or may not be accurate when applied to your topic
- Students construct new knowledge **out of their existing prior knowledge.**
  - Knowledge is not replaced but instead built upon or transformed.
  - Often that transformation is not smooth.

Alternative conceptions must be addressed

- It is not enough to ensure that students give accurate responses: students can simultaneously hold accurate and inaccurate ideas. (*knowledge-in-pieces* concept, Harlow & Biachini, 2020)
- Some alternative conceptions hinder the acquisition of accurate knowledge (Coley & Tanner, 2015)
  - But! Some alternative conceptions can be a *waypoint* to developing more accurate ideas (Maskiewicz & Lineback, 2017)
- Students learn more when their teachers understand what alternative conceptions their students hold (Chen et al, 2020)

Uncovering and understanding alternative conceptions about how vaccines work

- Research where I uncovered alternative conceptions
- Research on whether these conceptions impede acquiring accurate knowledge
- Discussion of how you can find alternative conceptions in your students

(Kahlon et al., 2022)

Context for my study

Public, West Coast, master's granting institution in a politically liberal area

- Racially **diverse** (32% Asian, 6% Black, 34% Latinx, 15% white, 12% multiracial)
- **72%** women / non-men
- **55%** first-gen

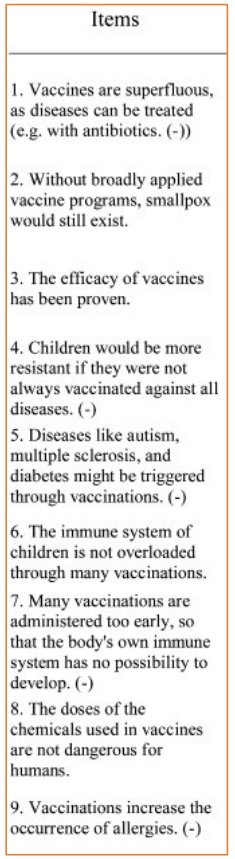
Data collected 2017-2018

Participant group	n
Non-bio major, non-pre-health (NPH)	183
Non-bio major, pre-health (PH)	111
Intro bio major (EBM)	237
Advanced bio major (ABM)	104
Bio faculty (control) (BF)	24

Uncovering alternative conceptions in my student population: previous literature

- There has been research on alternative conceptions that students hold, but it's concentrated on certain topics
  - For some topics, there hasn't been much previous research
  - For other topics, like vaccines, there's almost been *too much* previous research
- Will a checklist developed in a different context be appropriate for measuring what my biology students think?

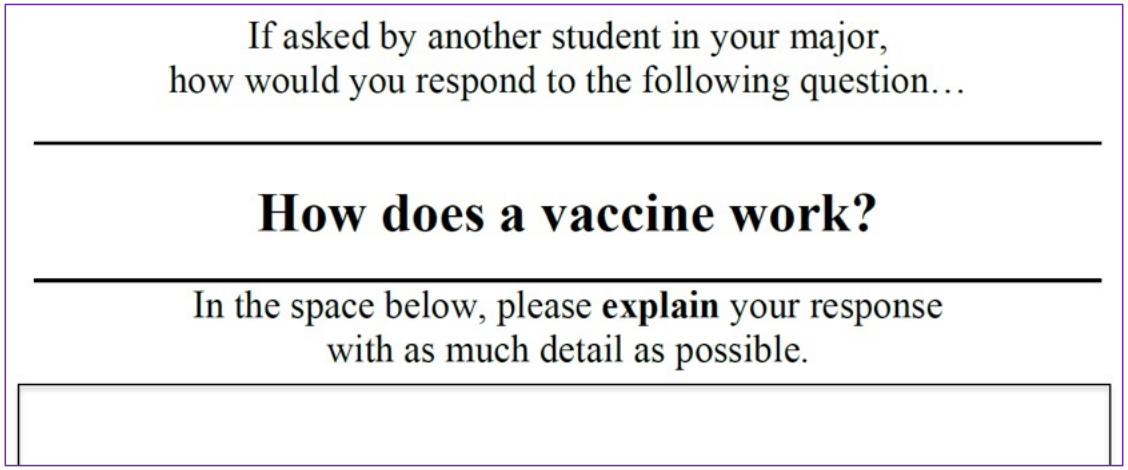
Scale for measuring vaccine knowledge (Zingg & Siegrist, 2012)



Items
1. Vaccines are superfluous, as diseases can be treated (e.g. with antibiotics. (-))
2. Without broadly applied vaccine programs, smallpox would still exist.
3. The efficacy of vaccines has been proven.
4. Children would be more resistant if they were not always vaccinated against all diseases. (-)
5. Diseases like autism, multiple sclerosis, and diabetes might be triggered through vaccinations. (-)
6. The immune system of children is not overloaded through many vaccinations.
7. Many vaccinations are administered too early, so that the body's own immune system has no possibility to develop. (-)
8. The doses of the chemicals used in vaccines are not dangerous for humans.
9. Vaccinations increase the occurrence of allergies. (-)

Uncovering alternative conceptions in my student population: open-ended questions

- **Students asked to explain things in their own words**
  - No-stakes (not for points)
  - Assured students that whatever they put down is okay, even if they don't feel like they know



Analyzing written responses for alternative conceptions

- My research student and I **read a small number of responses and came up with a list of tentative alternative conceptions.**
- She trained another research student to recognize these ideas, and they read new responses until they were both reliably able to recognize the alternative conceptions.
- We validated the inaccuracy of these ideas by:
  - Making sure none or nearly none of the bio faculty had these ideas
  - Asking immunologists whether these ideas were clearly inaccurate

Instructions for next slide

- The next page has student quotes.
- Please read the quotes and think about **what student ideas you notice.**
- **Go to menti.com and use the code: 7443 0623**
  - Or: use this QR code
  - Or: use this link: https://www.menti.com/alkbuyrqssve
- Type in the ideas you see!

Sample responses: What ideas do you notice?

- “A vaccine is a concentrated virus injected into your body to better prepare your immune system. When the vaccine is injected, your white blood cells and T-cells are learning how to identify and fight that virus. This information is used in the future when the same/similar diseases are detected.”
- “Vaccines could be injected, the doctor usually clears the area of skin with alcohol swab and then injects the shot with vaccine fluid that is inside the shot.”
- “A vaccine is an artificial or GMO version for a disease or virus that is introduced to one’s body in a controlled manner so that the body learns to recognize the disease & is able to fight it of instead of allowing you to catch the illness naturally which could possible be more threatening.”

Word cloud on Menti.com

Key insight: students could have both inaccurate and accurate ideas!

- "A vaccine is a **concentrated virus** injected into your body to better prepare your immune system. When the vaccine is injected, your **white blood cells and T-cells are learning how to identify and fight that virus**. This information **is used in the future** when the same/similar diseases are detected."
  - This response has a lot of accurate knowledge and detail, but it has the inaccurate idea about the "**concentrated virus**"
- "Vaccines could be injected, the doctor usually clears the area of skin with alcohol swab and then injects the shot with vaccine fluid that is inside the shot."
  - This response lacks both inaccurate ideas and accurate knowledge about how vaccines work.

Rubric for accurate knowledge

- Created rubric for accurate knowledge from expert sources
- Calculated a "basic knowledge score" by counting how many of these items a student wrote

Item of basic knowledge / "Student quote"	% student responses
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. "**A certain vaccine contains a small dosage of the pathogen**…"	60%
Immune activation: A vaccine *stimulates an immune response*. "**The immune system detects [the vaccines] and starts making white blood cells and antibodies** to combat it."	45%
Prevention: Vaccines function mostly to *prevent* disease or lessen its severity *in the future.* "I guess the body familiarizes itself with it **so if you face it again it won't affect you**."	70%

Most common alternative conceptions

Alternative conception / "Student quote"	% student responses
A vaccine contains the pathogen in an unmodified form. "It's a cocktail of different things, **including whatever virus its meant to protect you from**…"	28%
Vaccines are primarily a treatment or a cure. "It even helps to **clean out an infection you might already have**."	11%
A vaccine directly harms or fights the pathogen, not through the immune system. "**The fluid is the actual injection that fights off diseases**."	6.9%
Vaccines are mainly injected directly into the bloodstream. "A vaccine is **injected through a vein** which would mean that it goes through the inferior vena cava of the heart and eventually distributes from the aorta to the systemic circulation."	6.9%
A single vaccine provides immunity to all pathogens or diseases. "the vaccine… is used to help take over the body so **no other known disease** can take over the body."	6.8%

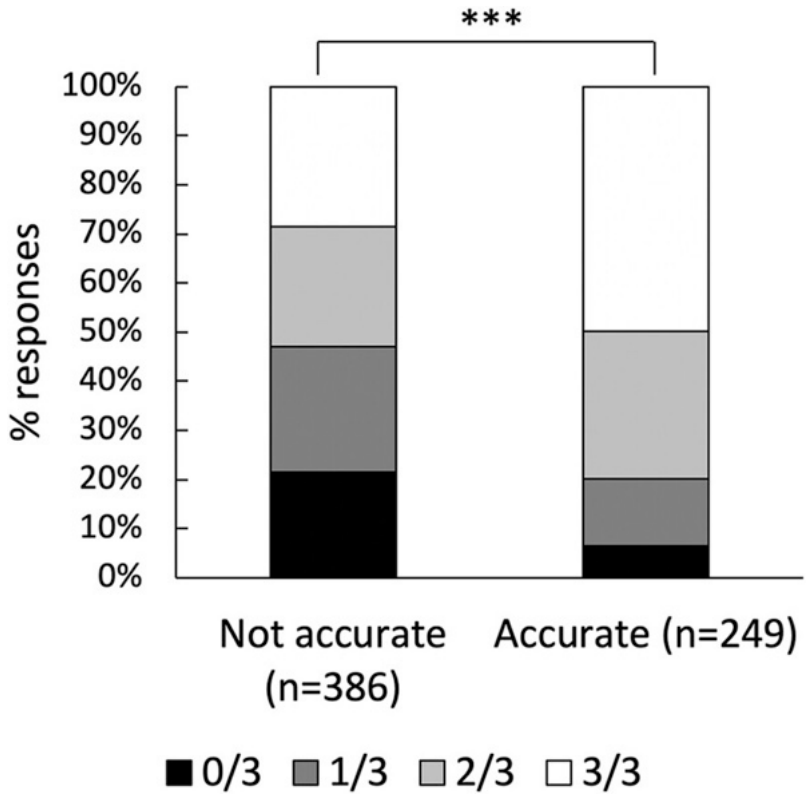
Do students with inaccurate ideas have worse basic knowledge scores?

Share your prediction with the Menti poll!

Menti poll – 3 min

Do students with inaccurate ideas have worse basic knowledge scores?

- On average, yes.



Are **all** the alternative conceptions associated with lower basic knowledge scores?

Share your prediction with the Menti poll!

Menti poll – 3 min

Are all the alternative conceptions associated with lower basic knowledge scores?

- Performed regression analysis with model selection to find the effect of having each inaccurate idea on basic knowledge scores

Inaccurate idea	Summary of effect	p-value
Unmodified pathogen	**Significantly higher; 0.55 ± 0.08**	**<0.001**
Vaccine is treatment/cure	**Significantly lower; -1.00 ± 0.13**	**<0.001**
Vaccine directly fights	**Significantly lower; -0.93 ± 0.15**	**<0.001**
Injected into bloodstream	No effect	n/a
Single vaccine for all	**Significantly lower; -0.73 ± 0.14**	**<0.001**

Summary of these results

- When given an open-ended question, students revealed both accurate and inaccurate ideas
- Most of these inaccurate ideas were negatively associated with accurate knowledge, but some had no effect, and one had a positive association
- This information lets us **focus on which alternative ideas to address and how**

Your turn:
Find student misconceptions with the Question Formulation Technique (QFT)

You may already have misconceptions you address or that come to mind (i.e. mitosis/meiosis; everything is on google, etc.)

For the next short while, consider how to uncover (a productive or additional) student misconceptions

We'll work on generating **questions** for your students to answer

Set-up

The QFT, on one slide…

1) Question Focus
2) Produce Your Questions
   - ✓ Follow the rules
   - ✓ Number your questions
3) Improve Your Questions
   - ✓ Categorize questions as Closed or Open-ended
   - ✓ Change questions from one type to another
4) Prioritize Your Questions
5) Share & Discuss Next Steps
6) Reflect

1. Ask as many questions as you can
2. Do not stop to discuss, judge or answer
3. Change statements into questions

Closed-Ended: Answered with "yes," "no" or one word

Open-Ended: Require longer explanation

Rules for Producing Questions

1. Ask as many questions as you can
2. Do not stop to answer, judge, or discuss
3. Change any statements into questions

Step 1: Question Focus

Probing student ideas while learning UNIT NAME

→Please write this Qfocus at the top of your paper.

→Remember: Number the questions. Follow the rules.

Use handout
consider your own ideas – 3 min
Discuss ideas – 10 min

CAMPBELL BIOLOGY

Brief Contents

For the sample QPrompt

Step 3: Categorizing Questions: Closed/ Open

Definitions:

- **Closed-ended** questions can be answered with a "yes" or "no" or with a **one-word** answer.
- **Open-ended** questions require more **explanation**.

Directions: Identify your questions as closed-ended or open-ended by **marking them** with a **"C"** or an **"O."**

As a table – 3 min

Summary: Use of closed- and open-ended questions

- Open-ended questions:
  - Eliciting novel or unexpected ideas
  - Uncovering a range of ideas
- Close-ended questions:
  - Determining the prevalence of particular ideas or misconceptions

Prioritizing

- Most **important** for students to know at the end of the unit
- **Most misunderstood** from the unit
- Choose your top 2 questions

Refining

- Change from closed-ended to open-ended
- Reduce use of jargon
- Clarify the question
- Is there an image, figure, equation that you could add?

Seating Configuration C

#2024BLC

Jigsaw: Testing prompts for eliciting alternative conceptions

- Move yourself to another table using your nametag instructions for **Configuration C**.
- Person with the longest hair: Ask the other people at the table **one** of your top two questions and see what responses you get!
  - No judgement! There are many different areas of biology represented here
  - Move to person with next longest hair
- After everyone has shared their questions, if there's extra time, you can workshop your questions.

Move tables – 3 min
Table discussion – 15 min

Reflection questions

- What am I assuming about the student's knowledge that might be wrong?
- What do I understand differently now about uncovering misconceptions?

think– 1 min
Table share

Share the top 2 questions you generated on Menti!

- We will collate and share with the entire group!

Menti poll to share

Thank you!

- **Gavina Kahlon, MS**
- Fareshta Waheed
- Instructors who let me give the prompts to their classes
- Faculty controls and immunologists who reviewed the rubrics
- SFSU SEPAL and UCSD Biology Education community

SEPAL
The Science Education Partnership & Assessment Laboratory
San Francisco State University

UC San Diego
BIOLOGICAL SCIENCES

Thank you for choosing to spend your time with us today.

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Singer Science Librarian, University of Oregon

References

- Kahlon, G., Waheed, F., & Owens, M. T. (2022). What college biology students know about how vaccines work. *CBE—Life Sciences Education*, *21*(4), ar75. https://doi.org/10.1187/cbe.20-12-0294
- Chen, C., Sonnert, G., Sadler, P. M., & Sunbury, S. (2020). The impact of high school life science teachers' subject matter knowledge and knowledge of student misconceptions on students' learning. *CBE—Life Sciences Education, 19*(1), ar9. https://doi.org/10.1187/cbe.19-08-0164
- Coley, J. D., & Tanner, K. (2015). Relations between intuitive biological thinking and biological misconceptions in biology majors and nonmajors. *CBE—Life Sciences Education, 14*(1), ar8. https://doi.org/10.1187/cbe.14-06-0094
- Harlow, D. B., & Bianchini, J. A. (2020). Knowledge-in-Pieces—Andrea A. diSessa, David Hammer. In Akpan B.Kennedy T. J. (Eds.), Science education in theory and practice: An introductory guide to learning theory (pp. 389–401). Cham, Switzerland: Springer International Publishing.
- Maskiewicz, A. C., & Lineback, J. E. (2017). Misconceptions are "so yesterday!" *CBE—Life Sciences Education, 12*(3), 352–356. https://doi.org/10.1187/CBE.13-01-0014
- Rothstein, D., Santana, L., & Puriefoy, W. D. (2011). *Make just one change: Teach students to ask their own questions*. Harvard Education Press. https://bookshop.org/p/books/make-just-one-change-teach-students-to-ask-their-own-questions-dan-rothstein/8193010
- Walsh, J., & Sattes, B. D. (2004). Quality Questioning: Research-Based Practice to Engage Every Learner. *Undefined*. https://www.semanticscholar.org/paper/Questioning-As-a-Pedagogical-Tool-for-Eliciting-the-Okanlawon/bc057847b6fc3a42dc26b754eadd184695877233
- Zingg, A., & Siegrist, M. (2012). Measuring people's knowledge about vaccination: Developing a one-dimensional scale. *Vaccine, 30*(25), 3771–3777. https://doi.org/10.1016/J.VACCINE.2012.03.014