Writing practical pre- and post-tests for concepts in introductory courses

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Overview

- We are developing an assessment of introductory statistics concepts
- Think-aloud interviews with students helped us uncover new misconceptions and improve assessment questions
- Pre- and post-tests can help you improve your courses by measuring student learning
- Interviews and assessments revealed new misconceptions about correlation and causation

Assessing Learning in Intro Stats

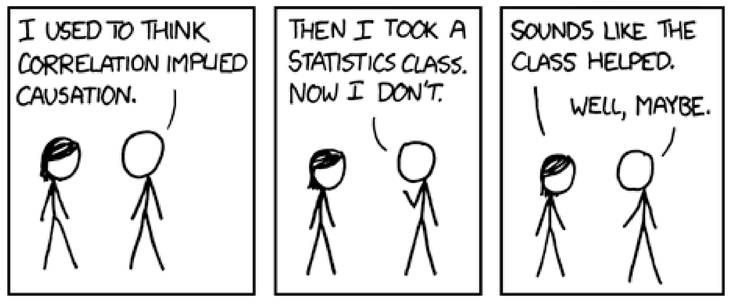
- To improve teaching, need to assess what the students are learning
- Used think-alouds: students think aloud while answering draft assessment questions (Adams and Wieman 2011, Burckhardt et al. 2017)
- Think-alouds elicit misconceptions and misreadings, and help us revise and write new questions
- Think-alouds allow us to make effective pre- and post-tests of complex misconceptions, guiding our teaching

Think-Aloud Results

- Conducted 42 interviews, each ≈ 1 hour long, in rounds timed to topics introduced in 36-200 (from Spring 2018 through Summer 2019)
- Tested roughly 50 draft questions in the interviews
- Used student feedback to revise questions, then re-tested in later think-aloud rounds

Data Collection

- After think-alouds, built revised assessment and gave it to students in 36-200 "Reasoning with Data" as a pre- and post-test
- Expanded the assessment to include students in "Introduction to Statistics and Data Science" at Colby College, starting Spring 2019
- Used ISLE, an online statistics learning platform, to administer the assessment to 379 students and extract the question-level answer data



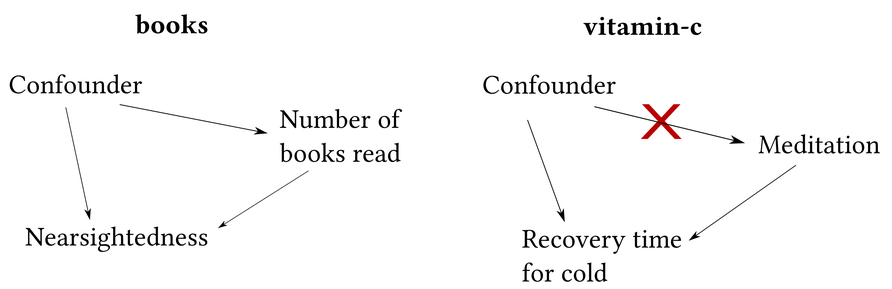
xkcd comic discussing correlation and causation. If Cueball only learned that correlation does not imply causation, but not when it *can* imply causation, he is right—the class may not have helped. Accessed 8/15/19, `https://xkcd.com/552/`

Asking about Correlation and Causation

We asked students several questions about when correlation does or does not imply causation:

- **books**: A survey of Californians found a statistically significant positive correlation between number of books read and nearsightedness. Which of the following can we conclude about Californians?
- **vitamin-c**: A clinical trial randomly assigned subjects to either practice mindfulness meditation or a placebo relaxation exercise as a treatment for a cold. The trial found that subjects who practiced mindfulness meditation had a shorter time to recovery than students assigned to the relaxation exercise, and the result was statistically significant. Which conclusion does this support?

Causal Diagrams of the Questions



Causal diagrams for the `books` and `vitamin-c` questions. The diagram for books is consistent with how students think about the question, but for vitamin-c the students do not realize the arrow from any confounder to "meditation" has been deleted by randomization. While students don't learn causal diagrams in 36-200, their understanding of causality from think-aloud interviews appears consistent with a causal diagram that includes arrows for confounding variables, regardless of the scenario.

Overheard in Think-Aloud Interviews

During the think-aloud interviews, some students gave reasoning suggesting that they are unwilling to ever infer causation:

- "Correlation does not imply causation is a universal rule" (`books`)
- "When can we ever say something causes something else?" (`candy-test`)
- "I think the word 'causes' is too strong... my friend who's a stats major always tells me you can't say this causes that—there's always other factors" (`vitamin-c`)
- "Usually [you] can't assume causation" (`vitamin-c`)

Combining Results

In post-test, most students correctly answered when correlation **doesn't** imply causation, but not when correlation **does** imply causation:

	books wrong	books right
vitamin-c wrong	5	**51**
vitamin-c right	5	**28**

Possible reasons to explore:

- Belief that correlation does not imply causation even when causal conclusions can be drawn
- Know the phrase "correlation does not imply causation," but can't recognize causal language that *doesn't* use keywords like "causation"
- Incomplete understanding of why randomization is useful (or of distinction between random sampling and assignment)

Next Steps

- Currently writing and testing new questions on correlation and causation
- Exploring other frequently misunderstood concepts in introductory statistics
- Expanding interviews to more undergraduate institutions
- Hope to experimentally test new ways to teach these concepts
- These same methods could work for your class too! Understanding student learning could lead you to new teaching strategies

References

Adams and Wieman (2011), *Int. J. Sci. Educ.* **33** 1289–1312.

Burckhardt et al. (2017), *Teaching & Learning Summit.*

ISLE: `http://www.stat.cmu.edu/isle/`

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