Teaching introductory statistics with randomization and bootstrapping
Blaine, Jan 16, 2021 https://github.com/bblaine6/ASARoch_2YCworkshop

"... despite broad acceptance and rapid growth in enrollments, the consensus curriculum is still an unwitting prisoner of history. What we teach is largely the technical machinery of numerical approximations based on the normal distribution and its many subsidiary cogs. This machinery was once necessary, because the conceptually simpler alternative based on permutations was computationally beyond our reach. Before computers statisticians had no choice. These days we have no excuse. Randomization-based inference makes a direct connection between data production and the logic of inference that deserves to be at the core of every introductory course." Cobb, G. 2007

Why teach Intro Stat with randomization methods?

Broader cultural reasons:

- Fisher would have wanted it, Tukey would have wanted it (see also Pittman, Mahalanobis, Quenouille, Efron, Cobb, etc) → it's in the DNA of our field.
- It helps us address the "AP Statistics problem" for our intro courses and stat curricula.
- Connect to a statistics/data science community of scholars strewn across disciplines and programs at your school.

Immediate pedagogical reasons:

1. Basic concepts like *sampling distribution*, *standard error*, and *p-value* are more intuitive when presented and learned via resampling methods. Plus, you can teach this material in maybe half the time it takes to set up parametric normal-theory inference.

2. Resampling methods encourage the use of Fisherian hypothesis testing concepts, which are intuitive and non-mathematical (and good for science), and allow us to avoid the Neyman-Pearson framework, which is: a) mechanistic, non-intuitive, and confusing for students, and b) doesn't deliver any better inferences for all the time it takes to teach.

3. Resampling methods allow the intro course to break free of the Ptolemaic system of concepts and procedures that are required to learn and use normal-theory inference (see Cobb, 2007). It is no small irony that the conventional intro stat course (i.e., the "consensus curriculum") is statistically impoverished. To learn and use normal-theory inference, all you *really* need to know is the mean, variance, and z-score—the rest is Cobb's "technical machinery of numerical approximations." The Ptolemaic system also constrains the intro course to 2 statistical models (and sometimes only 1!), which limits the kinds of questions students can ask, and the kind of data and variables they can work with.

4. Resampling methods help students learn algorithmic problem solving (which, though not *required* to learn intro stat material, bears all sorts of fruit in later statistics and data science courses). Granted, you can get a bootstrapped CI from a Minitab menu, or hide resampling algorithms in easy-to-use functions (i.e., mosaic, coin, boot packages in R). But resampling

methods are inherently algorithmic, so helping students to see how an inferential problem is addressed by a repeating loop of ordered steps is (for me at least) part of the teaching task.

Challenges:

1. Textbook options are few (but each very good in their own way)
2. Computing issues
3. Student support issues
4. Client program issues
5. Intra-departmental issues

Next:

- Look at some randomization tests for hypothesis testing using R
- Look at some examples of bootstrapping for effect size estimation using R
- Questions/thoughts/discussion

Resources:

General

Cobb, G. 2007. The Introductory Statistics Course: A Ptolemaic Curriculum? *Technology Innovations in Statistical Education, 1*. https://escholarship.org/uc/item/6hb3k0nz

This is so good.

Hesterberg, T. 2015. What Teachers Should Know about the Bootstrap: Resampling in the Undergraduate Statistics Curriculum. *American Statistician, 69*, 371-386. https://arxiv.org/abs/1411.5279

Kind of a must-read. Indeed, the entire *American Statistician: Special Issue on Statistics and the Undergraduate Curriculum* (Vol 69, Issue 4) is worth reading. https://www.tandfonline.com/toc/utas20/69/4

Texts and Guides

Pruim, R & Park. L. 2015. *Introduction to Statistical Inference with R: An R Companion to Introduction to Statistical Investigations* (Preliminary Edition). www.github.com/rpruim/ISIwithR

Pruim, R & Park. L. 2014. *Lock5 with R: A companion to Unlocking the Power of Data*. https://www.lock5stat.com/other/Lock5withR.pdf

R companions to the Tintle et al and Lock5 books respectively.

Diez, D., Barr, C., Centinkaya-Rundell, M. 2020. *Introductory Statistics with Randomization and Simulation* https://leanpub.com/ims

Kaplan, D., Horton, N., & Pruim, R. 2016. Randomization-based inference using the `mosaic` package. https://www.researchgate.net/publication/265027427_Randomization-based_inference_in_R_using_the_mosaic_package.

Also, earlier versions of the above:
Kaplan, Horton, & Pruim's *Simulation-based inference with* `mosaic`
https://cran.r-project.org/web/packages/mosaic/vignettes/Resampling.html
Pruim, Horton & Kaplan's *Start Teaching with R*.
http://www.stat.columbia.edu/~gelman/communication/PruimHortonKaplan2014.pdf

Blaine, B. 2020. *Applied Statistics with Resampling Methods and R*. https://leanpub.com/ASRR

My entry into the textbook field for the intro stat course that uses resampling methods for inference and teaches in/with R. If I offer anything new in this book to the excellent resources above, it's in teaching introductory concepts within the framework of 4 common statistical models.

Howell, D. 2015. Resampling Statistics: Randomization and the Bootstrap. University of Vermont. https://www.uvm.edu/~statdhtx/StatPages/ResamplingWithR/ResamplingR.html

Howell's a now-retired psychology professor who had a first-rate Intro Stat text, and whose html pages, R code, and lessons were excellent resources for me.