# Students' conceptual understanding of the distinction between random sampling and random assignment

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# Background and Motivation

According to statistics education recommendations (e.g., GAISE, 2016), students should understand:

- **Random sampling** tends to produce representative samples, allowing for **generalization** to a population.
- **Random assignment** tends to balance out confounding variables between groups, helping to enable **cause-and-effect** conclusions.

But students often have difficulty distinguishing between these two concepts (e.g., Derry et al., 2000).

# Study Design Unit

| Day | Topic | Activity name | Reading prior to activity |
|---|---|---|---|
| 1 | Sampling methods and unbiased estimation | *Sampling Countries* | None |
| 2 | Assignment to experimental groups and establishing causation | *Strength Shoe* | *Establishing Causation* |
| 3 | Observational studies | *Murderous Nurse* | *Scope of Inferences* |
| 4 | Study design and scope of inference | Group quiz | None |
| 5 | Distinguishing between random sampling/generalization and random assignment/causation | *Survey Incentives* | None |

# Course and Audience

- Undergraduate, 3-credit introductory statistics course that fills general education mathematical thinking requirement (using CATALST curriculum; Garfield et al., 2012; Zieffler et al., 2015)
- Taught by advanced graduate students in statistics education
- Engaged students in active learning and discovery, minimal lecture

# Pretest/posttest

*Inferences from Design Assessment* (IDEA)

- 22-item, forced-choice assessment, completed by $n = 125$ students
- Most items taken or modified from previous assessments (e.g., CAOS, delMas et al., 2007; ARTIST, Garfield et al., 2002)

# A look at the two IDEA items with the most improvement

| Item | Measured learning outcome |
|---|---|
| 16 | Ability to understand that correlation does not imply causation. |
| 18 | Ability to understand the purpose of random assignment in an experiment: To make groups comparable with respect to all other confounding variables. |

# Item #16

Researchers conducted a survey of 1,000 randomly selected adults in the United States and found a strong, positive, statistically significant correlation between income and the number of containers the adults reported recycling in a typical week.

Can the researchers conclude that higher income causes more recycling among U.S. adults? Select the best answer from the following options.

a) No, the sample size is too small to allow causation to be inferred.

b) **No, the lack of random assignment does not allow causation to be inferred.**

c) Yes, the statistically significant result allows causation to be inferred.

d) Yes, the sample was randomly selected, so causation can be inferred.

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d) Yes, the sample was randomly selected, so causation can be inferred.

**Answer option:**
**% of *n* = 125**

| a | b | c | d | Condition |
|---|---|---|---|---|
| 35.2 | **28.0** | 12.0 | 24.8 | Pretest |
| 7.2 | **77.6** | 3.2 | 12.0 | Posttest |

B: correct answer

D: incorrect answer confusing R.S. with R.A.

# Item #18

A research study randomly assigned participants into two groups. One group was given Vitamin E to take daily. The other group received only a placebo pill. The research study followed the participants for eight years. After the eight years, the proportion of each group that developed a particular type of cancer was compared.

What is the primary reason that the study used random assignment?

a) **To ensure that the groups are likely to be similar in all respects except for the level of Vitamin E.**

b) To ensure that a person is not likely to know whether or not they are getting the placebo.

c) To ensure that the study participants are likely to be representative of the larger population.

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| **Answer option: % of *n* = 125** | | | |
|---|---|---|---|
| **a** | b | c | Condition |
| **32.0** | 28.0 | 40.0 | Pretest |
| **77.6** | 8.0 | 14.4 | Posttest |

A: correct answer

C: incorrect answer confusing R.S. with R.A.

# Summary: Confusing Random Sampling with Random Assignment

| | | Percent (*n = 125*) | |
|---|---|---|---|
| **Item** | **Misconception or Misunderstanding** | **Pretest** | **Posttest** |
| 16 | The sample was randomly *selected*, so causation can be inferred | 24.8 | 12.0 |
| 18 | Purpose of random assignment: To ensure participants are likely to be representative of the larger population | 40.0 | 14.4 |

However, on posttest: Less than 5% of students chose BOTH of these incorrect answer options

# What about a shorter unit?

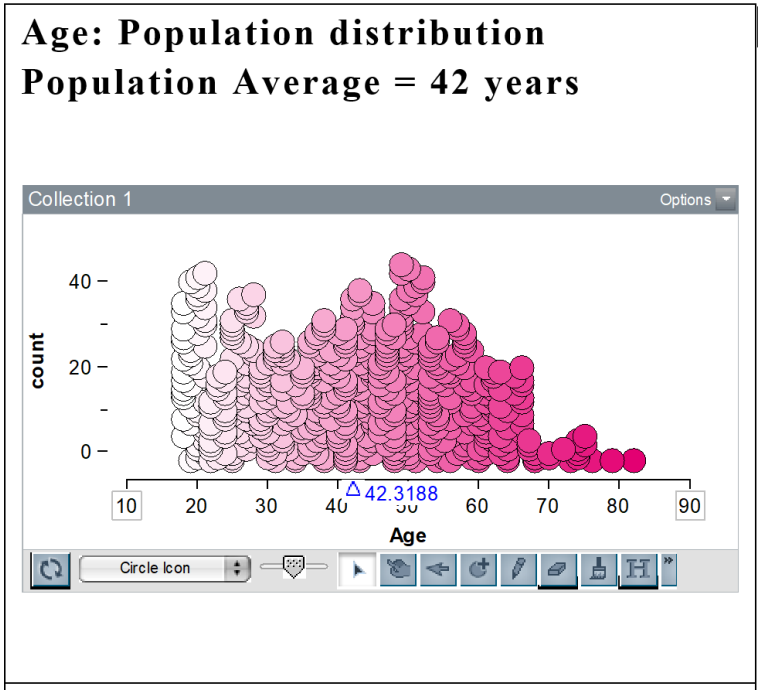
- You're probably thinking… but what if I don't have two and a half weeks?
- Survey Incentives activity (wrap-up activity) could be used or modified to use as a single activity to teach about both random sampling and random assignment

# Survey incentives: context

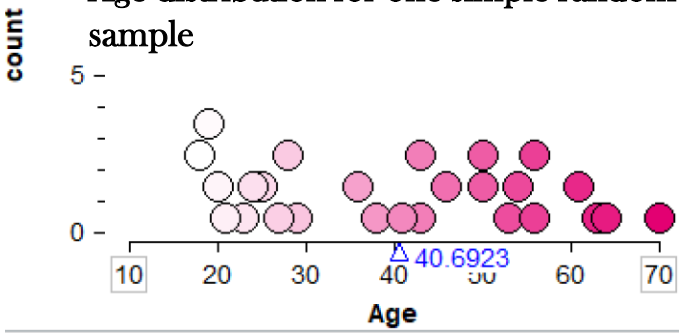
- Mayor of a town wants to conduct a pilot study to see if giving a $20 incentive to complete a survey will increase response rates.
- Students asked to play "statistical consultant" – they conduct both random sampling and random assignment. At the end, they have to explain to the mayor the difference between random sampling and random assignment.

# Survey Incentives: Part 1

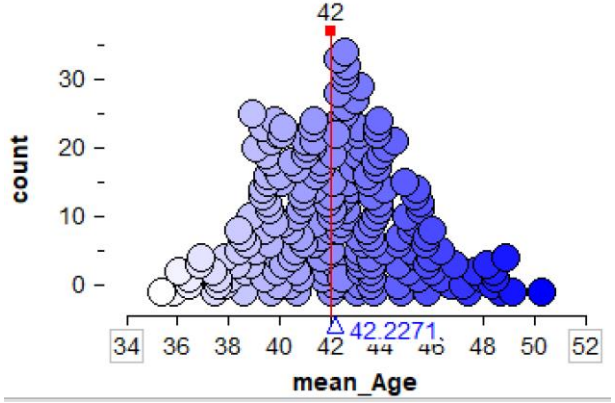
- Comparing random samples to population
- Observing that when many samples are taken, sample means centered at population mean




Age distribution for one simple random sample

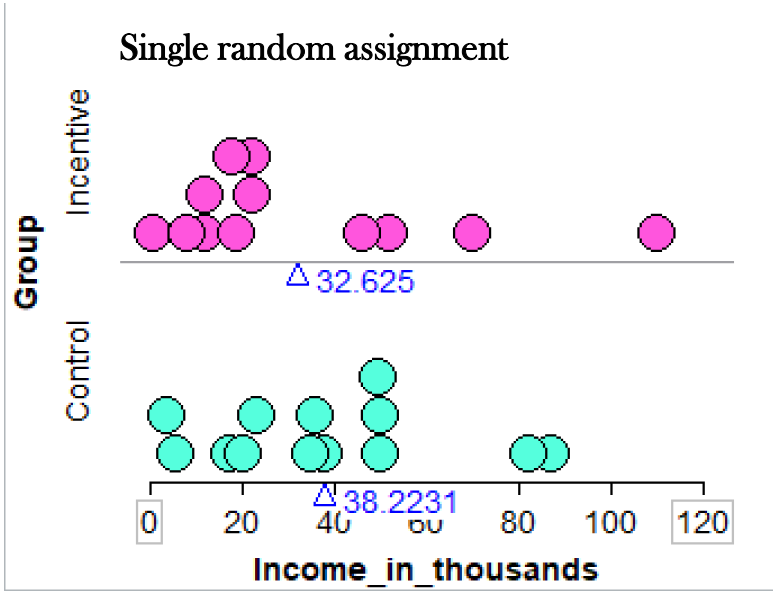


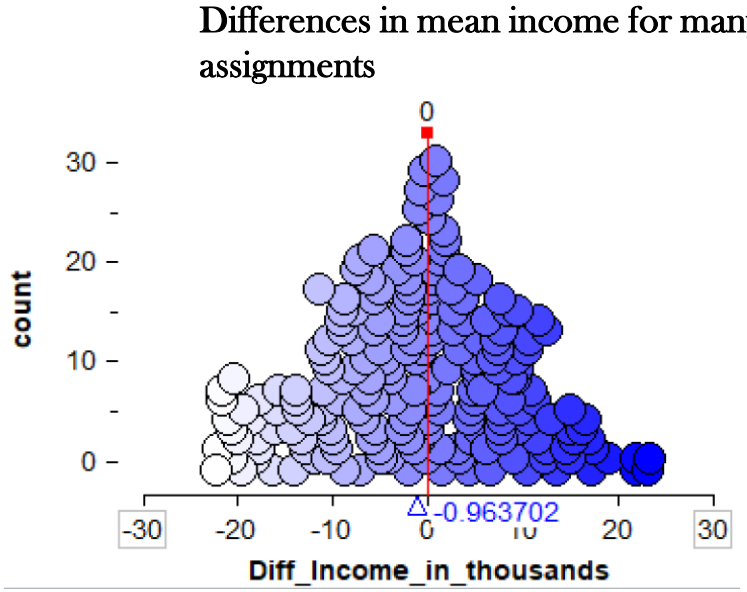

Sample mean age for 200 simple random samples



# Survey Incentives: Part 2

- Comparing groups in random assignment
- Observing that groups are *similar* (not always identical) in a single random assignment, but there is a long-run tendency to balance out group means across many random assignments.



# THANK YOU!

Materials available at http://z.umn.edu/studydesign

- All 4 activities and lesson plans are available, along with TinkerPlots™ files
- Survey Incentives_StatKey.docx is the Survey Incentives activity modified to use StatKey (Lock et al., www.lock5stat.com/statkey)

For more details on the research, see my dissertation posted at:

http://iase-web.org/Publications.php?p=Dissertations

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# References


- Derry, S. J., Levin, J. R., Osana, H. P., Jones, M. S., & Peterson, M. (2000). Fostering Students' Statistical and Scientific Thinking: Lessons Learned from an Innovative College Course. *American Educational Research Journal*, *37*(3), 747–773. doi:10.3102/00028312037003747
- GAISE College Report ASA Revision Committee, "Guidelines for Assessment and Instruction in Statistics Education College Report 2016," http://www.amstat.org/education/gaise.
- Garfield, J., delMas, R., & Zieffler, A. (2012). Developing statistical modelers and thinkers in an introductory, tertiary-level statistics course. *ZDM*, *44*(7), 883–898.
- Zieffler, A., & Catalysts for Change. (2015*). Statistical Thinking: A simulation approach to uncertainty* (3rd ed.). Minneapolis, MN: Catalyst Press.