Guidelines for Assessment and Instruction in Statistics Education (GAISE)

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Wisdom from George Cobb
“Almost any course in statistics can be improved by more emphasis on data and concepts, at the expense of less theory and fewer recipes.”

Intro Stat Reform
1. Content: more data analysis, less probability
2. Pedagogy: fewer lectures, more active learning
3. Technology: for data analysis and simulations

GAISE Recommendations
1. Emphasize statistical literacy and develop statistical thinking
2. Use real data
3. Stress conceptual understanding, rather than mere knowledge of procedures
4. Foster active learning in the classroom
5. Use technology for developing conceptual understanding and analyzing data
6. Use assessments to improve and evaluate student learning

1. Emphasize statistical literacy and statistical thinking
   • Statistical literacy: understanding the basic language of statistics and fundamental ideas
   • Statistical thinking: the type of thinking statisticians use when approaching or solving problems
   • These are way more important to convey than math skills or memorization

1. Emphasize statistical literacy and statistical thinking
   • Confidence interval:
     – Option 1: Give students data, make them choose the correct formula, calculate summary statistics, and plug numbers into the formula to get a CI
     – Option 2: Give students data with context. Discuss how the data was collected, and whether it makes sense to create a confidence interval. Have them create a confidence interval using technology, then discuss how to interpret that interval in context.
2. Use real data

- Real data: real data (or summary statistics) given to students with context
- Choose data from a variety of different areas likely to be of interest to students
- Sources for data:
  - Textbook
  - Class data
  - Online
    - [http://it.stlawu.edu/~rlock/maa51/data.html](http://it.stlawu.edu/~rlock/maa51/data.html) gives a nice summary of sources of data on the web

3. Stress conceptual understanding, rather than mere knowledge of procedures

- Your #1 goal should be students who leave your class fully understanding the important concepts
- NOT teaching students a long list of methods and procedures that they barely understand
- Covering less material **deeply** is better than covering lots of material shallowly
- Consider cutting some procedures from your syllabus, in order to spend more time on concepts

3. Stress conceptual understanding, rather than mere knowledge of procedures

- Example: hypothesis testing
  - Spend lots of time on hypotheses, the meaning of a p-value, and the fundamental idea of “are these results more extreme than would be observed just by random chance?”
  - Spend less time on a long list of different formulas for different situations
  - Computers can easily calculate a p-value... it’s fine if students forget how to do that. Students need to know how to interpret a p-value

3. Stress conceptual understanding, rather than mere knowledge of procedures

- Don’t waste time teaching anything that won’t help reinforce or deepen conceptual understanding
- Examples:
  - “shortcut” formula for variance
  - outliers as points 1.5 IQRs beyond quartiles?
  - distributional tables
    (better alternative: [http://www.lock5stat.com/statkey/index.html](http://www.lock5stat.com/statkey/index.html))

4. Foster active learning in the classroom

- Clickers
- Discussions in pairs or small groups
- Problem solving (individually or together)
- Class activities
- Handouts
- Ask them to come up with examples
- Collect data from students
4. Foster active learning in the classroom
• Class activities
  – Activity-Based Statistics (Scheaffer, Watkins, Witmer, Gnanadesikan)
  – Teaching Statistics: A Bag of Tricks (Gelman and Nolan)
  – Anything that gets everyone doing something, for example, they each take their own random sample and calculate their own statistic
  – Collaborate! Talk to other people who have taught intro stat, ask them to share their favorite activities

5. Use technology for developing concepts and analyzing data
• Do not waste time having students do by hand things that are easily done with technology
• Calculation of standard deviation, correlation, sums of squares, or any other tedious calculations should be done with technology
• p-values should be found with technology, NOT paper tables

5. Use technology for developing concepts and analyzing data
• Embrace technology and what it can provide for helping students learn
  – Simulations are a powerful way to convey difficult concepts (sampling distributions, CLT, confidence intervals, etc.)
  – Technology enables analysis of large, real, interesting data. We are no longer limited to toy examples easy to compute on a calculator
  – With EDA and technology, students can make pretty interesting discoveries from data early in the course

5. Use technology for developing concepts and analyzing data
• What technology?
  – Ease of use?
  – Ease of data input?
  – Future accessibility? (out of the lab, after Penn State)
  – Future use?
  – How well does it do what your course focuses on?

6. Use assessments to improve and evaluate student learning
• Homework
• Quizzes and Exams
• Projects
• Activities
• Oral presentations
• Written reports
• Minute papers
• Article critiques
• Lab reports
• Daily “mini review quiz” with clicker
6. Use assessments to improve and evaluate student learning

- Assessments should align with learning goals
- If your #1 goal is conceptual understanding, find a way to assess that
- It’s easy to assess whether students can plug numbers into a formula and plug this into a calculator and get the right answer... but is that really what you want to assess?
- Good assessment items in the appendix of GAISE

Example 1

- We have data from a random sample of size 10 with mean 5 and standard deviation 1. Calculate the p-value for testing $H_0: \mu = 4$ versus $H_1: \mu > 4$.

The Question

Can exposure to light at night make you fatter?

- Why is this important?
- How might you collect data to answer this question?

The Data

- We have data from an experiment in which 28 mice were randomly assigned to one of three conditions:
- Darkness at night
- Dim light at night (equivalent to a TV on)
- Bright light at night
- Initial body mass was recorded
- Over the course of the 8 week study, the following variables were measured:
  - Daily caloric consumption
  - Percent of calories eaten during the day as opposed to night
  - Measure of daily physical activity
  - Corticosterone (a measure of stress)
- At the end of the 8 week study, researchers measured:
  - Body mass
  - Glucose tolerance


Scope of Inference

- Does the data collection method allow us to make conclusions about causality?
  a) Yes
  b) No
- To what population can we generalize the results?
- How might results on mice differ from results on humans?
Exploratory Data Analysis

• What is our primary response variable?
• What is our treatment variable?

• What types of statistics and visualizations would be most appropriate to explore the relationship?

Inference: Hypothesis Test

• Let’s first compare bright light to darkness. What are the appropriate hypotheses?

• Calculate the p-value (randomization test?)
  – www.lock5stat.com/statkey

Inference

• P-value = 0.021

• Interpret the p-value in context. What does this tell us about exposure to light at night and body mass of mice?

Diabetes

• The p-value testing for an association between light at night and the glucose tolerance test values is 0.0023.

• What does this tell you about exposure to light at night and diabetes for mice?
**Time of Day?**

- The paper is titled “Light at night increases body mass by shifting the time of food intake.”
- Explore whether the data supports this claim.
- \( p \)-value of percentage of calories consumed during the day and light: 0.03
- \( p \)-value of percentage of calories consumed during the day and body mass gain:

**Time of Day?**

- \( p \)-value: 0.000

**Time of Day and Body Mass Change**

- \( p \)-value: 0.005

**Conclusions?**

- Can we conclude that exposure to light at night causes mice to consume more of their calories during the day?
- Can we conclude that exposure to light at night causes mice to gain weight?
- Can we conclude the consuming more of their calories during the day leads to weight gain for mice?

**Further Exploration**

- The paper claims “Mice housed in either bright or dim light at night have significantly increased body mass and reduced glucose tolerance compared with mice in a standard light/dark cycle, despite equivalent levels of caloric intake and total daily activity output.”
- Explore the second part of the claim.

**Consumption and Activity**

- Can we conclude that exposure to light at night causes mice to consume more of their calories during the day?
- Can we conclude that exposure to light at night causes mice to gain weight?
- Can we conclude the consuming more of their calories during the day leads to weight gain for mice?
Other Tips

- **Statistics is not math.** Stress the difference to your students, and teach it as a different subject. Avoid mathematical notation when possible.

- **Concrete examples** always make things more clear. Everything you teach should come with an example (or multiple examples!)

- **Visuals** are often much more powerful than words

- Intro stat should focus on collecting and analyzing **data**, which may or may not include probability

- Don’t be afraid to **steal**: experienced pros are usually happy to share their materials