Statistical Literacy: Developing a Purposeful Curriculum Across the Grades

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Consider the map of counties shown below. The number in each county is last month’s incidence rate for a disease in cases per 100,000 population. What do you think is going on?

(Dick Schaeffer, 2005)
Statistical Thinking Versus Mathematical Thinking

Mathematical Thinking
- Explain patterns
- Often a deterministic way of thinking
- Focus is on deductive reasoning
- Mathematical model: \( y = f(x) \)

Statistical Thinking
- Search for patterns in the presence of variability
- Acknowledge role of chance variation
- Focus is on inductive reasoning
- Statistical model: \( y = f(x) + e \)

“Statistical thinkers” ask:
Could this have happened by chance?
Statistical Thinking

Statistical thinking is critical to making informed decisions based on empirical evidence.

But...

Statistical thinking is HARD!

Needs to be developed and nurtured over time, much like mathematical thinking.

This is the opportunity provided by the Common Core State Standards, NCTM’s Principles and Standards for School Mathematics, and state standards with similar intent.
Developing Statistical Thinking Across the Grades

- CCSS/NCTM PSSM Challenges:
  - Achieving coherence across the grades. (Avoiding the “another year, another graph” curriculum)
  - Long time gaps—For example, in CCSS, many necessary connections skip years!
  - New content for most teachers.
Example of Two Year Gaps in CCSS Sampling Variability

- Grade 7
  - Recognizing sampling variability
- Grade 9
  - Describing sampling variability and sampling distributions
- Grade 11
  - Drawing conclusions in a way that takes sampling variability into account
Example: Topics New to Many (Most?) Teachers

Grade 7 (the foundation for statistical thinking!)
- Random sampling and concept of sampling variability
- Informal inference and comparative inferences

Grade 11
- Margin of error in the context of estimating a population proportion.
- Statistical significance in the context of randomized experiments
Standards versus Curriculum

- There is a difference!
- It is possible to “teach the standards” with a focus on the procedural fluency aspects of the standards. This is done in some curricula and the standards boxes are checked, but this approach does little to develop statistical thinking and statistical literacy, which is the ultimate goal.
- So how do we develop curricula that achieve the goals of developing statistical thinking and statistical literacy in the context of standards?
- It is all about the focus! Some curricula are PROCEDURAL FLUENCY concepts and others are procedural fluency concepts, but maybe we should work for CONCEPTS procedural fluency.
And What About Rigor?

Rigor in the context of statistics

- **Work worth doing**
- Requires engaging in a meaningful way with the context (statistics is ALL about context)
- Working with real data (or at least realistic data)
  - No silly data!

- There is a misconception that you have to sacrifice these things for pedagogical reasons, but this amounts to saying I won’t teach what is important because it might be easier to have students do work that “isn’t worth doing” or that doesn’t contribute to overall goals of developing statistical thinking and statistical literacy.
Some Thoughts on Curriculum and Lesson Design

- Hallmarks of a great statistics curriculum
  - Models good practice!
    Some think this isn’t important because it is just school… I respectfully disagree!
  - Focuses on concepts over mechanics
  - Incorporates real (or at least realistic) data
  - Asks student to engage with context in a meaningful way and to do work worth doing
Key to Coherence Across the Grades

- Keep our eyes on the end goals: Developing statistical thinking and statistical literacy.
- Design and implement lessons around the standards with these goals in mind.
- This will mean that while procedural fluency will still be a part of the curriculum, it won’t be the focus (or the desired end result).
- Procedural fluency provides tools to support learning from data, which requires most of all conceptual understanding.
Examples and Implications

Statistical Literacy

(our best defense against “fake news!”)
When I think of fake news, this is what I worry about!
Woman’s World
April 23, 2018
At newsstands now!
Statistical Literacy

- We all hope that when students complete the K-12 statistics curriculum that they are “statistically literate”. But are they??

- What are the important things that students ought to know? (This is a long list…)

- But when I think about what are the things we should be MOST embarrassed by if a graduating student didn’t know/remember/understand, almost all of them are related to statistical literacy.
Question to Consider…

Would you be more embarrassed if a graduating student couldn’t express a difference in centers as a multiple of a measure of variability or didn’t understand what it means for two groups to be “significantly different”

Draw informal comparative inferences about two populations.

3. Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. For example, the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable.
Question to Consider…

- Would you be more embarrassed if a graduating student couldn’t express a difference in centers as a multiple of a measure of variability or didn’t understand what it means for two groups to be “significantly different”

- Just because they can do the first, doesn’t mean that the second automatically follows!

- OK, probably want both, but I would be REALLY embarrassed by the second one, and if we look at how we allocate instructional time, I think we don’t really spend very much time on the things that are most important!
Implications for Curriculum

- “Express the difference in means as a multiple of a measure of variability” can be taught as a procedure. Do this, then do this, then divide and that is the answer...

- But developing an understanding of the meaning of significantly different as “not likely to be the result of sample-to-sample variability alone” suggest teaching this differently. Exploring what this difference looks like for samples from the same population, what it looks like for samples from very different populations, and talking about why it is tricky to draw a conclusion when samples are from populations that are different, but not very different.

- This is why it is important to keep one eye on the standard, but BOTH eyes on the end goal of developing statistical thinking and statistical literacy. In my opinion, this is what leads to coherence across the curriculum.
Another Example

Use random sampling to draw inferences about a population.
1. Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

Make inferences and justify conclusions from sample surveys, experiments, and observational studies
3. Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

What is most important if these standards are taught in the context of the goal of developing statistical thinking and statistical literacy??
Another Example

Students need to understand that the type of conclusions that you can draw from a statistical study depends on the way that the data were collected.

This suggest that the curriculum should address the following concepts:

- The difference between an observational study and an experiment
- The importance of a representative sample in an observational study
- The importance of random assignment in an experiment
- The difference between a statistical relationship and a cause-and-effect relationship.
The difference between an observational study and an experiment.

When students see a claim like this I would hope they would want to know whether this is based on data from an experiment or from an observational study.

Woman’s World, Feb. 27, 2017
Other Similar Headlines…

- “Spanking lowers a child’s IQ” (Los Angeles Times, 9/25/09)  
  Observational Study

- “Prayer Can Lower Blood Pressure” (USA Today, 8/11/98)  
  Observational Study

- “Stop Hair Loss with Chinese Herbs!” (Woman’s World, 6/27/16)  
  Not Clear if Data Based

- “Joining a ChoirBoosts Immunity” (Woman’s World, 6/27/16)  
  Observational Study
The importance of a representative sample in an observational study

- “San Fernando Valley Residents OK with 1-cent Transit Tax” (LA Daily News, April 2, 2016)

- Based on responses from a sample of 100 San Fernando Valley residents...

- ...who attended a community forum in Van Nuys.
The importance of random assignment in an experiment


- Experiment 1 (of 4) concluded that people cheat more often in afternoon sessions than in morning sessions. But volunteers selected whether to participate in a morning session or an afternoon session...

- Later experiments incorporated random assignment.
The difference between a statistical relationship and a cause-and-effect relationship.

- Examples

- Frying time and water content of tortilla chips
- Prayer and blood pressure
- Shoe size and reading ability
One Last Example

9. Distinguish between correlation and causation.

I can “teach” this standard in 5 minutes. Students learn mantra: Correlation is not causation.

But the usual take away for students is that you can never show a cause-and-effect relationship!

What is most important if this standard is taught in the context of the goal of developing statistical thinking and statistical literacy??

Needs to be linked back to study design—even if that was done in a previous year...
What might this look like in the classroom?

- We could spend more time talking about study design and have students critique studies.
- Bring in a copy of Woman’s World and tear out pages—give one to each group and have them try to track down the actual study. Give them time in class the following week to tell what they found and if the “headline” is accurate. If not, ask them to rewrite the headline.
These are just a few Pages from the January 22, 2018 Issue of Woman’s World!

Look up actual study: No random selection
No random assignment
Conclusion is about improved vision. NO mention of protecting vision, NO Mention of “screen time”
Another Example...  

- If you track down the study behind this headline (Woman’s World, Feb. 27, 2017) you find that the study looked at women who spend more time with friends or regularly engage in a favorite activity and found that they have thicker bones. Baking??? Cause and effect (implied in headline!)???
Sample Activity that Focuses on the Big Goal

The Cookie Game
The Cookie Game

- Statistical Thinking Involved

- Could this have happened by chance if...

- Convincing evidence versus proof

- Acknowledging the risk of an incorrect conclusion
Important Ideas...

- Idea of making a decision based on a probability assessment (unlikely to have happened by chance)

- Models the logic of what will be needed for this standard:

  - Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

- And for those who go on to more formal inference (AP Stat or college intro stat), helps motivate the usual choices for significance levels in hypothesis testing.
Achieving Coherence

- Big Goal (across years):
  Developing statistical thinking
  Developing statistical literacy

- This takes time!

- Key is teaching “standards” in the context of the BIG GOAL.
In the Context of the BIG GOAL...

- Keep one eye on the standards, but keep BOTH eyes on the overall goal.

This leads to a purposeful and coherent curriculum—and not just for one year but across the grades.
Thanks for attending this session

- Questions or Comments Now?

- Questions or Comments Later: rpeck@calpoly.edu