Statistical Literacy: Developing a Purposeful Curriculum Across the Grades

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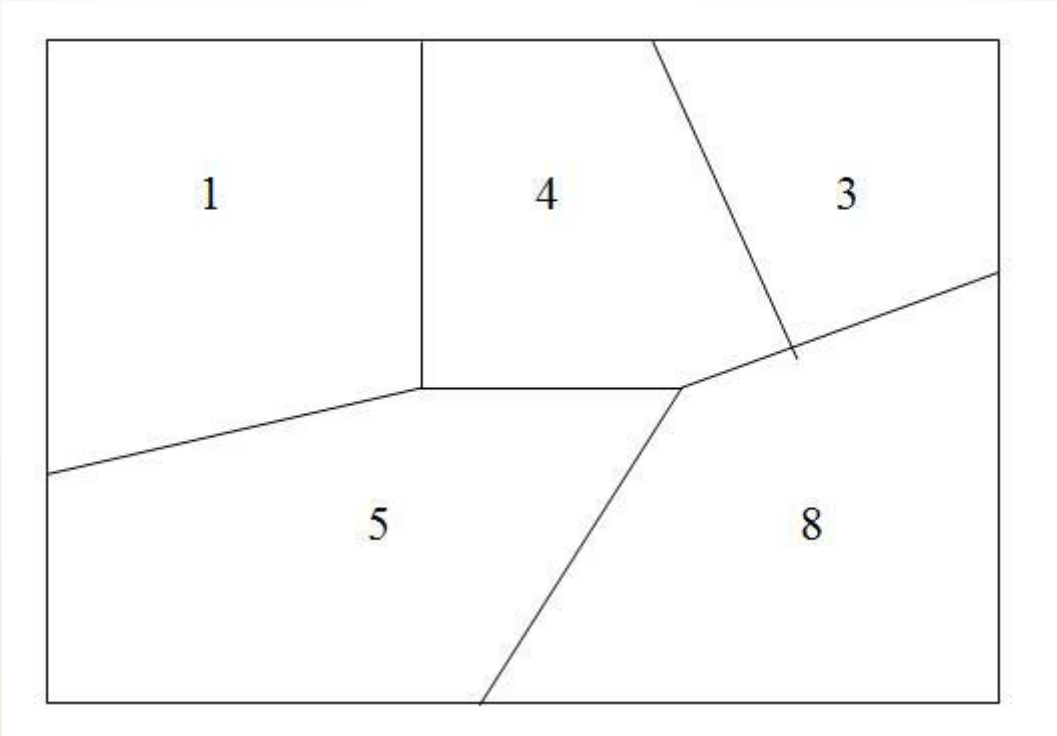
Consider the map of counties shown below. The number in each county is last month's incidence rate for a disease in cases per 100,000 population.

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!”)

Woman's World

January 22, 2018

Circulation: over 1.3 million!

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

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.*

or

  - didn't understand what it means for two groups to be "significantly different"

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.

2 Shrink your waist by standing for 1 minute!

Too tired or busy for a calorie-burning workout? You can still slim down simply by standing for at least one minute every hour whenever you're sitting for long periods. Amazingly, women who do just that have waists that are 1.6 inches smaller than women who don't, reveals research in the *European Heart Journal*.

- 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 Choir Boosts 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

- From "The Morning Morality Effect: The Influence of Time of Day on Unethical Behavior," *Psychological Science OnlineFirst*, October 2013)
- 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.

healthy!

2 Protect your eyes from screen time *with antioxidants!*

Spending hours looking at a computer, tablet or smartphone can cause eyestrain now—and permanently blurry vision in the future! To the rescue: A daily dose of the antioxidants lutein, zeaxanthin and meso-zeaxanthin (such as Best Lutein Featuring Lutemax, $10.71, iHerb.com).

It works! Absorbed by the eye area responsible for visual sharpness, these antioxidants filter out the high-energy blue light from electronics linked to eye fatigue and free radical damage, explains lead study author James Stringham, Ph.D.

Nix neck pain! Keeping electronic devices 15 degrees below eye level (so you look slightly down) prevents your neck and shoulder muscles from tensing, reports the *International Journal of Clinical Practice.*

4 Guard your heart when sitting *with vitamin C!*

Research shows we're sitting for longer stretches than ever before, which can slow circulation and tighten blood vessels, straining the heart. Not to worry: Getting up every hour for tw minutes or taking 1,000 mg. of vitamin C if you'll be sitting for while reverses those negative effects, new research shows.

It works! Briefly standing up reboots circulation. And vitam C releases nitric oxide, which also revs blood flow and revers cell damage due to being sedentary. One option: Nature Made $5.69 for 130 caplets, Target.com.

KO back pain by leaning! Prolonged sitting causing backaches? Leaning back at a 135-degree angle relieves enough pressure on spine and back muscles to keep you ache-free! Or tuck a small lumbar pillow behind your lower back to create a comfortable lean!

3 Sleep soundly after a jam-packed day *by making a list!*

Between work, visiting grandkids, volunteering and other tasks, our to-do lists are longer than ever—which can make it harder to quiet your thoughts at night and fall asleep. The fix: Busy adults who write down outstanding to-dos they need to complete over the next few days fall asleep significantly faster!

It works! Keeping a list of unfinished tasks stops you from worrying that you'll forget them, a worry that we commonly repeat over and over again in our minds as we try to fall asleep.

Deepen sleep with a heart-to-heart! Finding a few minutes to share your thoughts and feelings with your husband or friend strengthens your relationship, dispels anxiety and brightens your mood, all keys to better sleep!

5 KO fat traps *with chili pepper!*

Days filled with busyness and obligations lead to eating on the run, stress and skimping on sle factors that pack on pounds and make losing those pounds hard. To the rescue: Chili pepper! The more of this zingy spice—fresh, crushed or powdered—you add foods, the easier it is to trim dow

It works! Consuming chili pe per not only revs metabolism fo up to 30 minutes, the *Internatio Journal of Food Sciences and N tion* reports it also activates bro fat, the kind that melts calories rather than stores them!

Lose more with green tea Green tea's caffeine and antioxid combine to "turn on" brown fat, s burns more calories, research sho

—Gabrielle Lichterman

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"

WW Your Good Health

Look and feel Younger at any age!

Getting older is a fact of life—but *feeling* older isn't! More than a dozen new studies prove that with a few savvy strategies, you can stay youthful, energetic, healthy and mentally sharp—at any age. The keys:

✓ Revving your energy *with d-ribose*

"One of the most common and bothersome symptoms of aging is loss of energy," says Michael Lam, M.D., coauthor of *Adrenal Fatigue Syndrome.* "Yet this problem can often be remedied with a simple supplement—d-ribose powder." This natural sugar extract is shown to activate mitochondria, the tiny energy-producing furnaces inside your cells, reviving focus, stamina and drop 45% in two weeks. Aim to take 2 tsp. daily. One option: Life Extension D-Ribose powder ($18 for 150 grams, LEF.com/ww). **Tip:** D-ribose is slightly sweet, so an easy way to take it is to stir it into hot coffee or tea.

Important: Always check with your doctor before taking any supplement for the first time.

✓ Boosting your heart health *with eggs and dairy foods*

Just keeping your triglyceride (TG) level low cuts your risk of heart disease as much as 50%. (TGs are blood fats that can clog and stiffen heart arteries if your level is too high.) And University of Tennessee researchers say simply eating an egg a day and two servings of full-fat dairy will do the trick. (A serving is one cup of yogurt or milk or 1 1/2 oz. of hard cheese.) Egg yolks pack lutein and zeaxanthin, and full-fat dairy packs a fatty acid called CLA, nutrients that work together to help your cells burn food for fuel before it can be converted into troublesome TGs.

✓ Staying limber *with broccoli*

Eating as little as 1/2 cup of broccoli, cabbage, bok choy, Brussels sprouts or other cruciferous vegetables each day could give you the joint mobility and flexibility you had six years ago, report Cleveland Clinic pros. Cruciferous vegetables are rich in sulfur, an inflammation- and pain-reducing nutrient that also heals and strengthens the shock-absorbing cartilage in your joints.

✓ Reducing wrinkles *with strong friendships*

Folks over age 70 who stay close to their good friends—either with regular get-togethers, telephone calls or online chats—tend to look and feel up to 10 years younger than their actual age, plus they're 22% less likely to develop serious illnesses, reveals a large-scale study in the *Journal of Epidemiology and Community Health.* Feeling connected to and supported by others cuts your production of damaging stress hormones as much as 25%, which, in turn, slows the aging of all your organs, including your skin, explains study coauthor Lynne C. Giles, Ph.D.

Lower your blood sugar!

Been told your blood sugar is high? A whopping 50% of us are in the same boat! Fortunately, there are drug-free ways to lower your blood sugar, helping you dodge Type 2 diabetes and other health concerns linked to it!

Rev insulin sensitivity with vinegar!
Whether you use it in a salad dressing or take it some other way, apple cider vinegar can improve insulin sensitivity and lower blood sugar. In fact, groundbreaking research in the journal *Diabetes* found that sipping 1 1/2 Tbs. of the vinegar mixed with 1/4 cup water before dinner can reduce the insulin and blood-sugar spikes that occur after eating a high-carb meal 34%! "People with prediabetes benefited the most from apple cider vinegar, cutting their blood-sugar concentrations by nearly half," says naturopath David Friedman, Ph.D., D.N.M., author of *Food Sanity.*

Stop sugar spikes with blueberries!
Blueberries may taste sweet, but research proves they actually help keep blood sugar in check! "Because of blueberries' fiber content, their natural fruit sugar is released slowly into the body and won't cause any unhealthy sugar spikes," says Friedman, adding that research in the *American Journal of Clinical Nutrition* shows that eating fresh or frozen blueberries regularly reduces the risk of Type 2 diabetes 23%. A cup a day is all you need to reap the protective effects.

Sprinkle on a special cinnamon!
Consuming just 1/2 tsp. a day of Ceylon cinnamon for 20 days can improve your insulin response and lower blood sugar 20%! "Ceylon cinnamon contains potent polyphenols that regulate blood-sugar levels," explains naturopath Michelle Schoffro Cook, Ph.D., D.N.M., author of *The Cultured Cook.* Mix it into your morning coffee, oatmeal or smoothie. (Since cinnamon can have such a dramatic effect on blood sugar, consult your doctor if you're diabetic.)

Spice up your walks!
A new study found that people with Type 2 diabetes who varied their speed while walking had far better control of their blood-sugar level. And it couldn't be easier to do: Just alternate walking for

Prevent the hidden heart problem!

As many as one in four of us will be diagnosed with a common problem called atrial fibrillation (AFib)—an irregular heartbeat—which can raise a woman's risk of stroke five-fold! Can it be prevented? Yes!

Cut your risk with chocolate
A new Harvard study reveals that eating just one ounce of dark chocolate weekly can reduce your odds of ever experiencing AFib 17%. "Atrial fibrillation is thought to be caused by inflammation that can lead to scarring of heart tissue, and the flavonol antioxidants found in chocolate may help reduce that inflammation," explains study author Elizabeth Mostofsky, Sc.D. **Tip:** The darker the chocolate, the more beneficial compounds it contains.

Control your blood pressure with pistachios
A systolic (top number) blood pressure reading of 150 or above doubles the risk of AFib, reports the journal *Hypertension.* Luckily, an analysis of 20-plus studies shows pistachios can help. Eating just 1.5 oz. daily dropped systolic pressure almost five points, likely due to the nuts' high level of magnesium and potassium.

Snore? Check for sleep apnea
Snoring is a major symptom of sleep apnea, a condition that multiple studies show raises AFib risk a whopping two to four times. "With apnea, you stop breathing, which results in low oxygen levels—and the lower those levels, the higher the risk to your heart," says cardiologist Micah J. Eimer, M.D., of Northwestern Feinberg School of Medicine in Chicago. Check with your M.D. if you snore regularly.

What are the symptoms?
AFib happens when disorganized electric signals make the heart's upper chambers squeeze very fast and out of sync. Often there are no symptoms. When symptoms do occur, they can include fainting, fatigue, palpitations and shortness of breath.

Lose a few pounds
In a recent Australian study, 45% of obese patients who lost at least 10% of their body weight and kept it off for at least four years stayed free of AFib—without medication! Even shedding just 3% to 9% of their weight completely freed 22% of patients of AFib. "Excess weight is linked to multiple conditions that increase the risk of AFib, including high blood pressure, Type 2 diabetes and sleep apnea," explains Dr. Eimer.

Tip: Enrolling in a local weight-loss program with a supportive friend or relative gives you a 66% chance of keeping off the weight you lost for at least 10 months, University of Pennsylvania research shows.

—Peg Verone

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:

> 5. 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