The Early Career Section offers information and suggestions for graduate students, job seekers, early career academics of all types, and those who mentor them. Angela Gibney serves as the editor of this section. Next month's theme will be jobs in business, industry, and government.

Expanding Your Teaching Repertoire

Ask Good Questions: Becoming a Teacher of Statistics

Stacey Hancock

Last year, Dr. Allan Rossman, Professor of Statistics at Cal Poly–San Luis Obispo, started a new blog about teaching introductory statistics called *Ask Good Questions*. In his inaugural post, he writes,

> I suspect that we teachers spend too much of our most precious commodity—time—on creating presentations for students to hear and writing exposition for them to read. I think we serve our students' learning much better by investing our time into crafting good questions that lead students to develop and deepen their understanding of what we want them to learn. [All19]

When I first started teaching, I modeled my courses off of the courses from which I learned—lecture during class time, write on the board while students take notes, then assign readings and homework outside of class. Years later, my teaching style, especially for the introductory statistics course, has flipped. I now spend more class time on in-class activities and class discussion than lecture, and "lecture" has been moved outside of the classroom in the form of readings, videos, and short content quizzes for understanding. Though fully "flipping" a course can be a daunting task, and it may not be for everyone, bringing good questions into the classroom is one of the most powerful ways to become an effective teacher of statistics.

The Importance of Statistical Thinking

In 2016, the American Statistical Association endorsed the revised Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report [GAI16]. These six recommendations, with two new emphases in the first recommendation, provide broad guidelines for both what

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to teach in introductory statistics courses and how to teach those courses:

1. Teach statistical thinking.
   - Teach statistics as an investigative process of problem-solving and decision-making.
   - Give students experience with multivariable thinking.
2. Focus on conceptual understanding.
3. Integrate real data with a context and purpose.
4. Foster active learning.
5. Use technology to explore concepts and analyze data.
6. Use assessments to improve and evaluate student learning.

These recommendations embody the theme "ask good questions." (Incidentally, Allan Rossman was also on the revision committee for the GAISE College Report.) In particular, statistical thinking is built on the practice of asking good questions. Statistical thinking skills allow students to consume statistical information from a critical eye, recognizing the inherent variability in data and possible sources of bias.

Consider the following example. *The Daily Star* article "Eating chocolate can help you LOSE weight, shock study discovers" reports on a German study that "found that eating chocolate can reduce your waistline, lower your cholesterol and help you sleep" [Lau18]. The study randomly assigned volunteers to three diets, one of which included consuming 42 grams of dark chocolate per day. During the study, the chocolate group lost 10% more weight than the low-carb group, and this difference was statistically significant. As it turns out, however, the study was designed to demonstrate how easily bad science can turn into big headlines.

A savvy statistical thinker would ask: What was the sample size? How many hypothesis tests did they run? The study was conducted on 5 men and 11 women. One of the volunteers was dropped from the study, leaving 15 participants. Such a small sample size ensures high variability in statistics such as the mean weight lost. The number of tests? Eighteen. Even if none of the 18 null hypotheses were false, these researchers guaranteed themselves a $1 - (1 - 0{:}05)^{18} = 60\%$ chance that at least one p-value would be less than 0.05, resulting in a false positive. Just by chance, that false positive happened to be the difference in average weight loss between the chocolate group and the low-carb group.

Journalist John Bohannon explains how he and his colleagues used small sample sizes and p-hacking to find statistically significant benefits of chocolate in data from an actual clinical trial in his *Gizmodo* article, "I fooled millions into thinking chocolate helps weight loss. Here's how" [Joh15]. Bohannon and colleagues published their results in the fee-charging open access journal *International Archives of Medicine*—the paper was accepted for publication within 24 hours—and through a catchy press release, the paper was picked up by media outlets such as *The Daily Star*. (The careful reader may notice that the news article in *The Daily Star* was published in 2018, whereas the *Gizmodo* article explaining the bad science was published in 2015. Once bad science is out, it is extremely difficult to retract!)

We use this pair of articles as a case study in our introductory statistics course during the second week of the semester to underscore the importance of statistical thinking. Bohannon notes that some of the online comments on these news stories posed questions the reporters should have asked—questions about the validity of Bohannon's credentials (the Institute of Diet and Health website that he made up), or why calories were not counted [Joh15]. By focusing our statistics courses around statistical thinking rather than a list of statistical recipes, we are cultivating those readers who critically called out the reporters.

Correlation, Not Causation

As another demonstration of the GAISE recommendations in practice, consider the well-known phrase, "correlation does not imply causation." Though this phrase is often repeated, making causal conclusions from correlational relationships is deeply rooted in the human psyche. We only need to look at a few news headlines to find evidence of our natural causal thinking: "Music lessons improve kids' brain development," "Diet of fish 'can prevent' teen violence," or "The gender pay gap is largely because of motherhood" [The06, Gab03, Cla17]. In his book *Thinking, Fast and Slow*, Daniel Kahneman writes,

> We easily think associatively, we think metaphorically, we think causally, but statistics requires thinking about many things at once, which is something that [the fast part of our brain] is not designed to do. [Kah11, p. 13]

At the heart of the "correlation does not imply causation" principle is multivariable thinking—thinking about the relationships between more than two variables at once. Multivariable thinking is the key to spotting confounding variables in observational data.

What thought first comes to mind when you read the following statement: "People who wear sunscreen have a higher rate of skin cancer than people who do not"? When I pose this fun fact to my statistics class, I hear a variety of surprised reactions: Is that true? How is that possible? Does sunscreen contain cancer-causing chemicals? I then ask, "what other variable are we missing here?" After a pause, someone will eventually say "sun exposure." People wear sunscreen because they are going to be out in the sun. If you are not wearing sunscreen, chances are you aren't planning on being exposed to the sun for an extended period of time. Sun exposure is a confounding variable—it is related to both the explanatory variable (whether one wears sunscreen) and the response variable (development of skin cancer). We cannot conclude that sunscreen causes skin cancer because we cannot know whether the increased rate of skin cancer was due to the use of sunscreen, sun exposure, or some other unknown confounding variable.

Recognizing confounding variables in observational studies takes practice, and this skill, I would argue, is the most valuable skill a student should gain from an introductory statistics course. Traditionally, this course did not go beyond two variables. The curriculum would start with one categorical variable, then one quantitative variable, then move to a difference in proportions, a difference in means, and finally, regression. The modern introductory statistics course, however, engages students with multivariable data sets from the beginning, exploring relationships between multiple variables through data visualization.

Getting Started in the Classroom

The two best pieces of advice that I was given as a new teacher of statistics were: (1) start small, and (2) use existing materials. Like myself, you may be used to the lecture-style classroom, and the thought of fostering active learning may seem uncomfortable and overwhelming. Start with introducing an activity into a single class. Try it out. See how it goes. Slowly, you can begin introducing more activities, adapting course materials to your own teaching style, and eventually, you will build a statistics course which exemplifies the GAISE recommendations.

When looking for existing materials, the GAISE College Report is an excellent place to start. Indeed, the six GAISE recommendations can apply to any statistics course, not just at the introductory level, and the report contains a vast number of classroom activities, projects, data sets, and assessment items. The Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) website, `https://www.causeweb.org`, has a collection of resources for the undergraduate statistics education community from syllabi and cartoons to discussions and suggestions on how to teach simulation-based inference. When you read an interesting news article on a recent study, bookmark the article and save the bookmarks in a folder of potential case studies for your course. I also highly recommend checking out Allan Rossman's *Ask Good Questions* blog [All19].

I'll conclude with one last quote, by the American writer Alice Wellington Rollins:

> The test of a good teacher is not how many questions he can ask his pupils that they will answer readily, but how many questions he inspires them to ask him which he finds it hard to answer. [Ali98, p. 339]

This quote appeared in the *Journal of Education* in 1898, yet it continues to be relevant today. In asking our students good questions, our ultimate goal is to transfer that skill to our students.

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Credits

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Contributing to Open Education: Why, How, and What I am Doing

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My social media timeline has reminded me that five years ago I was reading Bolstad's *Introduction to Bayesian Statistics* [Bol07]. I was a graduate student back then. Now I am a professor teaching statistics and data science. I am currently

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