

Are We Teaching the Right Things in Introductory Statistics?

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This handout summarizes some of my thoughts on how we teach introductory statistics. It is meant to stimulate discussion. Please let me know your reactions by sending me an e-mail at jerry@stat.duke.edu.

Some facts about real-world statistical analyses

1. Most surveys are not simple random samples
2. Non-sampling errors (e.g., misinterpretation of questions, incorrect responses, interviewer effects) are a more serious source of inaccuracy than sampling errors.
3. Simple comparisons of means or proportions are rarely adequate in observational studies attempting to estimate causal effects.
4. Most studies have missing data.
5. Best statistical practice incorporates the science of the data in models. This is done by teams of statisticians and substantive researchers.
6. Decisions are made in the context of cost-benefit analyses.
7. New directions in statistics involve simulation and complex modeling.

Some facts about introductory statistics text books (and probably some courses)

1. Most texts spend little time on study design, usually one or two chapters.
2. Most texts spend little time on non-sampling errors, usually a handful of pages.
3. Most texts warn about the dangers of making causal statements from observational studies, but they offer few genuine examples and approaches that deal with potential confounding (e.g., by using matching methods or by modeling).
4. Most inferential problems and examples are about means and percentages, assuming simple random samples. In fact, many texts pretend that data from complex surveys were collected from simple random samples, primarily to illustrate computations with interesting data.
5. Missing data are rarely dealt with in any depth. Usually the problem of missing data is discussed in a handful of pages and then ignored in inferences. For example, often only respondents are used in problems without any discussion of nonresponse issues.
6. Most problems ask students to read a paragraph in which the science underlying the data is glossed over, if explained at all. Often, understanding the science is not needed to solve the problem, since the problem exists primarily for students to practice computations.
7. Most texts rarely get into aspects of simulation and complex modeling.
8. Most texts are organized in chapters that present methods as general tools rather than as examples of modeling specific phenomena.
9. Most texts do not place statistical analyses in the context of decision-making, except for brief discussions of practical versus statistical significance.

My Concern:

What we teach in introductory statistics does not match actual statistical practice.



Possible implications of the mismatch between real-world analyses and teaching

1. Students do not appreciate the importance of study design. For example, when asked to do their own analyses rather than text book problems, many students make causal statements from observational associations based on means or correlations. I believe part of the problem is because these computations are what text books emphasize, without adequate discussion of the issues related to the study design.
2. Students do not consider the problems of missing data (or noncompliance in experiments) in their analyses or when reading about others' analyses. They are following what they've learned to do in text books, which is to ignore the missing data.
3. Students are trained to analyze data they will rarely see in real life, e.g., simple random samples without any missing values or complicated modeling needs. When confronted with situations that don't meet those criteria, they fall back on what they know how to do, which may be irrelevant, inadequate, or even wrong for the question of interest.
4. The mismatch between teaching and practice leads to a perception that statistics is a set of tools rather than a way of thinking. The fun parts of modeling are rarely communicated to students. This weakens students' interest in statistics.
5. Because of the procedural nature of the way the material is presented, students are fixated on properties of the procedures, such as statistical significance, rather than on the practical implications of their results. This fixation is transferred to researchers and policy makers, who sometimes do not consider cost-benefit analyses.

Some thoughts on re-thinking how we teach statistics

Perhaps we need two types of introductory courses. The first course would focus on statistical literacy. We could emphasize study design, non-sampling errors, and decision-making more than we do currently, perhaps dropping some methods of inference. For example, we can drop chi-squared tests and ANOVAs, which are only valid in simple random samples or completely randomized experiments. We don't need to teach all the varieties of hypothesis tests and confidence intervals (e.g., is it really more important to distinguish between z-tests and t-tests as compared to talking more about study design?), which again have limited applicability.

The second course (which has no statistics pre-requisite) would be aimed at students potentially interested in research experiences. This course would include modeling exercises and discuss real-world analyses beyond simple means and percentages. I see no reason why we cannot teach introductory students about inference in the context of complex (linear and logistic) regression modeling, about matching methods in observational studies, about analysis of complex surveys, or about ways of dealing with missing data. I suspect such courses would increase the appreciation students have for statistics, give students a stronger foundation for further study, and more closely match statistical practice.