Seven Challenges for the Undergraduate Statistics Curriculum in 2007

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"Nothing tunes the neurons like a little disagreement." – David Moore, "The Craft of Teaching," *MAA Focus*, 15, 1995, number 2, pp. 5-8. Available at
`www.stat.purdue.edu/~dsmoore/articles/Craft.pdf`

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1. How does statistical literacy / reasoning / thinking fit in?

GAISE Goals for Students in an Introductory Course: What It Means to be Statistically Educated (`www.amstat.org/education/gaise/GAISECollege.htm`)

Students should believe and understand why:

- Data beat anecdotes.
- Variability is natural and is also predictable and quantifiable.
- Random *sampling* allows results of surveys and experiments to be extended to the population from which the sample was taken.
- Random *assignment* in comparative experiments allows cause and effect conclusions to be drawn.
- Association is not causation.
- Statistical significance does not necessarily imply practical importance, especially for studies with large sample sizes.
- Finding no statistically significant difference or relationship does not necessarily mean there is no difference or no relationship in the population, especially for studies with small sample sizes.

Students should recognize:

- Common sources of bias in surveys and experiments.
- How to determine the population to which the results of statistical inference can be extended, if any, based on how the data were collected.
- How to determine when a cause and effect inference can be drawn from an association, based on how the data were collected (e.g., the design of the study)
- That words such as "normal," "random" and "correlation" have specific meanings in statistics that may differ from common usage.

Students should understand the parts of the process through which statistics works to answer questions, namely:

- How to obtain or generate data.
- How to graph the data as a first step in analyzing data, and how to know when that's enough to answer the question of interest.
- How to interpret numerical summaries and graphical displays of data - both to answer questions and to check conditions (in order to use statistical procedures correctly).
- How to make appropriate use of statistical inference.
- How to communicate the results of a statistical analysis.

Students should understand the basic ideas of statistical inference:

- The concept of a sampling distribution and how it applies to making statistical inferences based on samples of data (including the idea of standard error)

- The concept of statistical significance including significance levels and *p*-values.
- The concept of confidence interval, including the interpretation of confidence level and margin of error.

Finally, students should know:

- How to interpret statistical results in context.
- How to critique news stories and journal articles that include statistical information, including identifying what's missing in the presentation and the flaws in the studies or methods used to generate the information.
- When to call for help from a statistician.

Some texts for Stat 100:

Statistics (4th ed.), by David Freedman, Robert Pisani, and Roger Purves, W.W. Norton, 2007.

Seeing Through Statistics (3rd ed.), by Jessica Utts, Duxbury, 2005.

Statistics: Concepts and Controversies (6th ed.), by David Moore and William Notz, W.H. Freeman, 2006.

"Dogged attention to data analysis often comes at the expense of missing the bigger picture of statistical reasoning." – Dan Schafer, "Statistical Literacy for Efficient Citizenship," blog available at `http://oregonstate.edu/~schaferd/blog/?p=11`.

More on statistical and quantitative literacy:

Statistical Literacy, `www.statlit.org`

National Numeracy Network, `www.math.dartmouth.edu/~nnn/`

MAA Special Interest Group on Quantitative Literacy, `www.maa.org/sigmaa/ql`

International Research Forums on Statistical Reasoning, Thinking, and Literacy, `http://srtl.stat.auckland.ac.nz/srtl/`

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2. Do we really need umpteen flavors of introductory courses?

Cal Poly Statistics course descriptions are available at www.calpoly.edu/~stat/courses.htm. The "Stat 100" course is STAT 130. Some "Stat 101" courses are STAT 217, 218, 221, 251.

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3. Should we re-center the Stat 101 universe?

"We need to throw away the old notion that the normal approximation to a sampling distribution belongs at the center of our curriculum, and create a new curriculum whose center is the core logic of inference."

"Computers have brought us opportunities for change as potentially revolutionary as the opportunities brought by rural electrification and the invention of the internal combustion engine, but to a greater extent than we realize, our curriculum is still mulishly pulling a tractor behind it, and our students are still going from room to room with a single light bulb."

– George Cobb, "The Introductory Statistics Course: A Saber Tooth Curriculum?," USCOTS after-dinner presentation, 2005. Available from `http://statweb.calpoly.edu/csi`.

The MythBusters experiment is described, along with a very faulty analysis of the data, at www.omninerd.com/2007/04/19/articles/75. The sleep deprivation study is described in "Visual Discrimination Learning Requires Post-Training Sleep," by R. Stickgold, L. James, and J. Hobson, *Nature Neuroscience*, 2000, pp. 1237-1238. Data are courtesy of the authors. The student learning activity is presented in *Investigating Statistical Concepts, Applications, and Methods*, by Beth Chance and Allan Rossman, Duxbury, 2006. The data are available from www.rossmanchance.com/iscam/files.html (SleepDeprivation).

"The statistician does not carry out this very simple and very tedious process, but his conclusions have no justification beyond the fact that they agree with those which could have been arrived at by this elementary method." – R.A. Fisher, "'The Coefficient of Racial Likeness' and the Future of Craniometry," *Journal of the Royal Anthropological Institute of Great Britain and Ireland*, 1936, pp. 1387-1393.

The "Concepts of Statistical Inference: A Randomization-Based Curriculum" project is described at http://statweb.calpoly.edu/csi.

Bootstrap Methods and Permutation Tests, by Tim Hesterberg, David Moore, et al., is published by W.H. Freeman, available from www.insightful.com/Hesterberg/bootstrap/

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4. How do we deal with success in Stat 101?

"Please, sir, I want some more." – from *Oliver Twist*, by Charles Dickens

Preliminary data from the 2005 CBMS (Conference Board of the Mathematical Sciences) Survey are available at www.math.wm.edu/~lutzer/cbms2005/, specifically Tables S.1 and S.2 from chapter 1.

"Statistics is like grout – the word feels decidedly unpleasant in the mouth, but it describes something essential for holding a mosaic in place." – from *The Statistical Sleuth: A Course in Methods of Data Analysis* (2nd ed.), by Fred Ramsey and Dan Schafer, Duxbury, 2002. See the preface at www.statisticalsleuth.com

"At last, a second course in statistics that is serious, correct, and interesting." – Persi Diaconis, found at www.stat.berkeley.edu/~census/quotes.pdf

Some texts for Stat 102:

The Statistical Sleuth: A Course in Methods of Data Analysis (2nd ed.), by Fred Ramsey and Dan Schafer, Duxbury, 2002

Statistical Models: Theory and Practice, by David Freedman, Cambridge University Press, 2005.

The "Stat 2 Labs" project, led by Shonda Kuiper, is described at http://web.grinnell.edu/individuals/kuipers/stat2labs/.

5. Have we forgotten about math and stat majors?

A text for Stat 201 is *Investigating Statistical Concepts, Applications, and Methods*, by Beth Chance and Allan Rossman, Duxbury, 2006. A review by Jerry Moreno appears in the February 2007 issue of *The American Statistician*, pp. 98-99. Instructor resources are available at `www.rossmanchance.com/iscam/`. Also see "A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Methods, and Theory" in *Proceedings of the Sixth International Conference on Teaching Statistics*, available at `www.stat.auckland.ac.nz/~iase/publications/1/3i2_ross.pdf`.

Some mathematical statistics texts:

Stat Labs: Mathematical Statistics Through Applications, by Deb Nolan and Terry Speed, 2001.

Modern Mathematical Statistics with Applications, by Jay Devore and Ken Berk, Duxbury, 2007.

Mathematica Laboratories for Mathematical Statistics, by Jenny Baglivo, SIAM, 2004.

6. How should we prepare future teachers?

"In most teacher preparation programs appropriate background in statistics and probability will not be provided by simply requiring a standard probability-statistics course for mathematics majors. It is essential to carefully consider the important goals of statistical education in designing courses that reflect new conceptions of the subject." – CBMS *Mathematical Education of Teachers* (chapter 5), `www.cbmsweb.org/MET_Document/index.htm`.

A collection of articles about teacher preparation and professional development in statistics is *Thinking and Reasoning with Data and Chance*, edited by Gail Burrill, National Council of Teachers of Mathematics, 2006.

A forthcoming book on teacher preparation in statistics is *Developing Students' Statistical Reasoning: Connecting Research and Teaching Practice*, by Joan Garfield and Dani Ben-Zvi, Key College Publishing, 2008 (to appear).

Information about teacher preparation courses in statistics at the University of Georgia is available at `www.stat.uga.edu/courses/welcome.html`; see 4/6050 and 4/6070.

An article about a course for prospective teachers at Cal Poly is "A Post-Calculus Introduction to Statistics for Future Secondary Teachers," by Allan Rossman, Elsa Medina, and Beth Chance, in *Proceedings of the Seventh International Conference on Teaching Statistics*, available at `www.stat.auckland.ac.nz/~iase/publications/17/2E2_ROSS.pdf`.

An upcoming study, conference, and book on teacher training in statistics is being co-sponsored by ICMI (International Congress on Mathematical Education) and IASE (International Association for Statistical Education). Potential contributions are to be submitted by October 1, 2007. Information is available at `www.ugr.es/~icmi/iase_study/`.

7. What do we want statistics majors/minors/concentrators to know?

Cal Poly Statistics Department (`www.calpoly.edu/~stat`) Student Learning Objectives

The graduate will

1. Have good working knowledge of the most commonly used statistical methods including
    a. statistical modeling
    b. efficient design of studies and construction of effective sampling plans
    c. exploratory data analysis
    d. formal inference procedures
2. Have background in probability, statistical theory, and mathematics, including especially calculus and linear algebra
3. Be able to synthesize and apply this knowledge and to tailor methods used to the problem at hand, understanding the limitations of the procedures and the appropriate scope of conclusions
4. Communicate effectively (written and oral) with skills in collaboration (within and between disciplines) and teamwork, and in organizing and managing projects
5. Have good mastery of several standard statistical software packages and facility with data management strategies
6. Have a focused concentration in an area of application outside the discipline of statistics

The graduate will have received:

1. Experience with real data and authentic applications
2. Frequent opportunities to develop communication skills
3. Capstone experiences for students
4. Frequent interaction with faculty and timely advising
5. Exposure to statisticians and statistical applications outside the Cal Poly community

Cal Poly Stat 465 Statistical Consulting and Communication, John Walker and Heather Smith
`http://statweb.calpoly.edu/jwalker/jsm2006/STAT465-062.pdf`

Learning Outcomes:

By the end of the quarter each student should be able to:

1. Understand the characteristics of an effective consultant, a satisfied client, and a successful consulting session.
2. Plan and implement a consulting session.
3. Facilitate effective communication with a client.
4. Ask appropriate questions in a consulting session.
5. Deal effectively with a variety of consulting situations.
6. Be aware of issues involving statistical ethics.
7. Find appropriate technical solutions to consulting problems, both individually and as part of a team.
8. Effectively present oral and written arguments.
9. Utilize professional publications and resources in statistics and other related fields.

Course Activities:

1. Lectures and reading on technical statistical topics important in statistical consulting.

2. Lectures and reading on communication topics important in statistical consulting. Communication theories by Zahn and Derr are included.
3. Research in the field of statistical consulting obtained through published articles, textbooks, and interviews with practicing statistical consultants.
4. Multiple mock consulting sessions that will be recorded and reviewed.
5. Team-based project work including the development of statistical analyses and the development of written and oral presentations for different contexts. The presentations will be recorded and reviewed.
6. An individual consulting project including the development of a statistical analysis and the development of a written and oral presentation. The presentation will be recorded and reviewed.

Some texts for a capstone course:

The Practice of Statistics: Putting the Pieces Together, by John Spurrier, Duxbury, 2000.

Statistical Consulting: A Guide to Effective Communication, by Janice Derr, Duxbury, 2000.