

Subscribing to EDSTAT-L

Bitnet Users: Send the following command as the first line of a mail file to list-serv@ncsuvvm:

```
subscribe EDSTAT-L Your full name
```

IBM VM users in Bitnet may add themselves to the mailing list with this command:

```
tell listserv at ncsuvvm subscribe EDSTAT-L Your full name
```

VAX/VMS users in Bitnet can subscribe in a similar way:

```
send listserv@ncsuvvm subscribe EDSTAT-L Your full name
```

Internet Users: Send the following command as the first line of a mail file to list-serv@ncsuvvm.cc.ncsu.edu:

```
subscribe EDSTAT-L Your full name
```

Appendix D: Report of Workshop on Statistical Education

by Robert V. Hogg, UNIVERSITY OF IOWA

On June 18-29, 1990 thirty-nine statisticians gathered for a workshop on statistical education at the University of Iowa in Iowa City, Iowa. These persons represented universities, colleges, consulting firms, business, and industry. This workshop was sponsored by the University of Iowa and the American Statistical Association (ASA). Financial assistance was provided by the National Science Foundation, the ALCOA Foundation, the Ott Foundation, the Statistics Division of the American Society of Quality Control, and the Quality and Productivity Section of ASA.

As we prepared for the workshop, most of the participants, and several others not attending, wrote position papers on some aspect of statistical education, the majority of which concerned a first course in statistics. As a group we recognized several poor characteristics of science and mathematical education, including statistical education:

- Improvements are needed in the K-12 curriculum as there is widespread science and mathematics illiteracy in the United States.
- There is little effort given to recruiting students to these areas, often because we want only students like ourselves.
- There is a lack of truly qualified teachers because the pool from which they come is drying up.
- College and university instructors are often required to teach large introductory classes that allow little or no interaction with students and severely limit student involvement with others.
- Frequently students view courses as being "hard" because the class periods are dull and it is difficult to get good grades despite spending long hours doing homework.

Reprint of a report of a workshop on statistics education, especially at the introductory level, organized by Robert Hogg and held June 18-20, 1990.

- Sometimes there is a communication barrier. The instructors often forget to emphasize the “big picture” by concentrating on the solutions of the problems under consideration and eliminating any in-depth discussions of the basic ideas.
- In most universities and some colleges, there is no sense of community among most students in these areas. Accordingly, there is not much discussion during and after class periods. Somehow we should encourage teamwork and stress the importance of it.

Many of us in higher education use the excuse that the students should be better prepared. They probably should be, and there are many efforts to improve education in K–12. However, the fact that we have these poorly prepared students does not excuse us from doing much better than we do. Besides, many of these “poor” students are really extremely good, and we, in colleges and universities, are turning them off because:

- We fail to communicate our enthusiasm and excitement about mathematics and science (in particular, statistics).
- We do not encourage teamwork, which often results in the joy of discovery through lively discussion, observation, and analysis.
- There are “grade wars” and students believe that they must beat others to get high grades.
- Formulas are often not motivated and are presented as an “end” rather than the “means.”
- Introductory courses have low priority among faculty and administrators, and students observe this.
- Computer use is perfunctory or nonexistent.

Many of us believe that those of us in universities must “reach out” more to a number of groups, including:

- The high schools, in particular working with future and present high school teachers, strengthening mathematics and science requirements and curricula, and often serving as role models.
- Colleges, with much more interaction between university and college professors and students.
- Graduate students, working with them on their teaching as well as their research.
- Junior faculty, serving as mentors in teaching as well as research.
- Colleagues in other fields, interacting and working on joint research projects.
- Business/industry/government, because many more joint efforts are needed here if America is going to continue to be in the “first class” category. Moreover, these persons can offer faculty and students glimpses of practical applications.
- The public, trying to improve numeracy and science literacy.

However, it is time-consuming to do these things. Thus we must change the present system if our faculties are to get credit for these efforts. As it is now, most of us find it to our advantage to be “loners” doing research. None of us are against research; we support it strongly. On the other hand, we seek a better balance in our reward system recognizing that good teaching and valuable service are as important as research. We want to recruit strong, but possibly different, students to science and mathematics by improving our courses.

The preceding comments apply to statistical education as well as science and mathematics in general. We believe that some of the leaders in our profession must help in serious efforts to address these concerns, and we hope this report will encourage them to do so.

Certainly ASA has taken some very positive steps with its Quantitative Literacy program in improving statistical presentations in K-12. Much more can be done, and it will take enormous efforts on the part of many to shake up the system enough to change science and mathematics education for the better.

It is interesting to note that the "second Sputnik" (Japanese cars, electronics, etc.) has arrived for industry and business, but an equivalent impact on science education as followed Sputnik in the late 1950s and 1960s has not occurred. Some of us had hoped that the 1983 report *A Nation at Risk* would shock our leaders into action. Even though it was short and printed in big type, we are afraid few leaders read it—or, if they did, they did not take it seriously enough to cause substantial action. Thus, we continue our decline to becoming a second-rate nation. Wake up America! Let us create demand for a return to quality education which is competitive with other industrialized countries.

Problems in Statistical Education

Clearly in a three-day workshop we could not address all of the problems listed in the preceding section even though they apply to statistics as well as to science and mathematics. We thought that we could do the most good by addressing the problems associated with our introductory courses. Inspiring courses early in students' college career would help improve their numeracy and possibly encourage some to consider careers in science. We believe students should appreciate how statistics is used in the endless cycle associated with the scientific method: we observe Nature and ask questions, we collect data that shed light on these questions, we analyze the data and compare them to what we previously thought, new questions are often raised, and on and on. It has proved to be an exciting process for many years; but, most of the time, the students do not observe this excitement in our classes. There is a consensus among statisticians that statistics offers a unique and useful way of looking at the world and helping to solve real problems—or to exploit opportunities, but that statistics teaching in colleges and universities fails to communicate the potential, the utility, or the joy of discovery through investigation.

Unfortunately, statistics courses are seldom designed with any idea of what it is that students are supposed to be able to do as a result of having taken the course. Course objectives, if formulated at all, are expressed in terms of the specific topics covered in elementary texts rather than meeting the needs of the students. Statistics is seen as a "subject" rather than as a problem solving tool to be used in the scientific method, or as a useful way to look at the world around us. Some of the many problems associated with our introductory courses include:

1. Statistics teaching is often stagnant; statistics teachers resist change. The most popular elementary texts have evolved slowly over the decades. There is a tendency to present the same subjects, the same way, from the same books year after year. Meanwhile statistics is progressing rapidly.
2. Techniques are often taught in isolation, with inadequate motivation and with no connection to the philosophy that connects them to real events; students often fail to see the personal relevance of statistics because interesting and relevant applications are rare in many statistics courses. The applications, if any, are often contrived, even "phony." Elementary courses are often taught by the youngest and least experienced teachers, who have limited, if any, personal contact with serious applications. The open-ended

nature of statistical investigations and the sequential nature of statistical inquiry are not brought out. The students are not pushed to question their environment and seek answers through investigations.

3. Statistics is too often presented as a branch of mathematics, and good statistics is often equated with mathematical rigor or purity, rather than with careful thinking. ("Statistics has no reason for existence except as a catalyst for learning and discovery." — George Box.)
4. Teachers are often unimaginative in their methods of delivery, relying almost exclusively on traditional lecture/discussion. They fail to take into account the different ways in which different students may learn, both individually and in groups, or the many possible modalities of teaching.
5. The "customers" of the statistics course are often the statistics teachers themselves—not their students, not other areas in which the students study, and not the students' ultimate employers. There is little attempt to measure what statistics courses accomplish; statistics is too little *used*.
6. Many teachers have inadequate backgrounds in knowledge of the subject, in experience applying the techniques, and in the ability to communicate in English. The word "statistics" has itself acquired bad connotations.
7. Statisticians may put their subject in a bad light for the students. They often fail to see any need to convey a sense of excitement.
8. Some teachers are technically incompetent, either in aspects of statistics or in the underlying mathematical tools. They may mislead by treating statistical investigations as if they entailed random sampling from some finite population.
9. Statistical notation is unnecessarily complex and inconsistent; the Greek alphabet is routinely used rather than reserved only for those occasions in which it is essential.

Although the problems of statistical teaching are severe, the picture should be seen in proper perspective. Innovative texts are available and achieving some degree of market penetration. More are needed. However, statistics teachers often face obstacles to good teaching that are imposed by the institutions for which they work, such as the following:

- a. There are the unpleasant realities in college and university teaching environments, like "mega-classes" which make it hard to do anything beyond lecture/discussion and seem almost to be designed to make students dislike the subject matter and to spur them into apathy. There are less extreme, but still annoying, constraints such as the impossibility of changing short class periods into longer periods thus allowing for laboratory-type instruction and learning.
- b. University incentives do not encourage faculty to collect good examples, improve teaching methods, or spend time inspiring students.
- c. The content of the courses (including the text) may be specified by others, leaving little freedom for an innovative statistics teacher to make improvements. The course may be required to attempt to cover more material than is reasonably possible.
- d. Location of statistics courses in the mathematics department is seldom ideal.
- e. Traditional grading systems may perform some necessary functions, but they often divert students from the fundamental objectives of learning statistics as well as other subjects. Examination requirements may be unnecessarily rigid.

- f. University logistical support for statistics teaching (and teaching in other areas as well) is often weak. Students may have no or, at best, limited access to computers or good interactive statistical software. Classroom amenities like good projection equipment may be lacking.
- g. Some obstacles are posed by the students themselves. While the instructors must try to motivate students, it is difficult to change the attitudes of many of them.
- h. Students often have a fear of formulas and mathematical reasoning. An even more serious problem is the desire for props, such as rote memorization or problems with quick and clean answers that avoid the need for students to think, but make it easier for them to perform well on examinations. Some students may even like formulas because they are props. Students may be used to reading large volumes of materials relatively superficially, rather than a relatively few pages carefully, as is more suitable in statistical instruction. Unlike some courses, statistics is cumulative and does not lend itself to crash-cramming sessions at the end of the term.
- i. Statistical thinking is different from that to which most students have been exposed. The ideas of uncertainty and variability are either ignored or dealt with poorly in everyday discourse and even academic study. Statistical thinking may even be counter-intuitive, as illustrated by the appearance of “hot streaks” and “momentum” or the notion that the “sophomore jinx” is a mysterious plague of nature.
- j. Much of the statistical reasoning students encounter in everyday life represents misuse rather than sound use of statistics. The bad reputation of statistics courses may become a self-fulfilling prophecy.

General Suggestions

During the workshop participants were divided into four teams. Most of the time was spent in team meetings, with occasional plenary sessions to summarize the activities of each team. Although the four teams met separately and had lively discussions, there were several common suggestions.

STATE OUR GOAL(S)

Stating the aim of the course is an important, and often over-looked, step toward successful teaching. Participants spent much time debating the skills and knowledge they expected to impart to students in an introductory course, as opposed to the list of methods they wished to cover. One team came up with the following:

Our aim in a first course is to develop critical reasoning skills necessary to understand our quantitative world. The focus of the course is the process of learning how to ask appropriate questions, how to collect data effectively, how to summarize and interpret that information, and how to understand the limitations of statistical inferences. Statistical thinking is central to education.

Unfortunately, the typical introductory statistics course does not meet this goal, as it stresses mathematically precise statements and formulas applied to artificial data that are of little, if any, interest to most students. A typical textbook example begins with a question that has been formed to address one feature of data that has already been collected. Students gain little insight into how and why data are collected, how experiments are designed, and how analysis of one set of data leads to new questions, new experiments, and subsequent

analyses in a continuing cycle of scientific inquiry. Statistics is presented as a formal ritual, rather than as a dynamic study of processes.

Every team agreed that the typical introductory course should change by giving more attention to graphical techniques, to simple topics in the design of experiments, and to the scientific method, with much less time to hypothesis testing. Most introductory textbooks devote a great deal of space to hypothesis testing, which workshop participants saw as being much less important than current coverage would indicate.

There was some agreement that this type of statistics course is valuable for students of all interests, although some participants favored the idea of tailoring courses to different clienteles. Another goal could be the identification of the interests of a group of customers and focus the course content and presentation on the needs of that group, possibly through joint efforts of statisticians and members of the other group.

There was also agreement that undergraduates interested in mathematical statistics, who are the largest pool of future graduate students in U.S. statistics programs, should depart from current standard practice and also take an additional introductory course in statistics that features data analysis and applications.

ANALYZE DATA AND DO PROJECTS

There was widespread agreement among workshop participants that students should work more with real data and with graphs. Many advocated projects in which students collect their own data and analyze them in written reports. Such projects combat apathy by allowing students to work with data that they find interesting. Moreover, projects give students experience in asking questions, defining problems, formulating hypotheses and operational definitions, designing experiments and surveys, collecting data and dealing with measurement error, summarizing data, analyzing data, communicating findings, and planning "follow-up" experiments that are suggested by their findings.

TO COMPUTE OR NOT TO COMPUTE

Properly used, the computer is a powerful and effective tool in teaching students about variability in data, particularly through statistical graphics. Most participants strongly support the use of the computer in introductory statistics courses. Having a computer available during class facilitates "on the spot" analyses of data, which teach students that there are often many analyses that can shed light on a problem and that simple graphics can tell one a great deal.

However, a variety of problems, including lack of equipment, lack of adequate projection systems, and lack of staff to operate statistical computing laboratories, severely limit current computer use in statistics courses. Indeed, a small group of participants saw such obstacles, coupled with the concern that teaching students to use the computer can shift attention away from statistical ideas, as sufficient reason to avoid computers in their teaching at the introductory level.

LECTURE LESS, TEACH MORE

Much time was spent in team sessions exploring various modes of teaching and learning. Lecturing is but one way to communicate ideas to students. Classroom demonstrations and data collection (for example, analyzing the color distribution in a bag of M&Ms, or examining the distribution of the numbers of M&Ms in several bags), add variety, as do

experiments that are run in class. Much effective learning takes place when students work together in teams. Student projects can be done in small groups, but some experiments can be conducted in class.

Of course, some teachers are faced with very large classes. Two ways to make a large class seem small are emphasizing project work and lecturing to a small sample of students who are brought to the front of the room at the beginning of each class period.

WHAT CAN THE PROFESSION DO TO HELP?

It was repeatedly suggested that a "First Course Corner" or "Activities Corner" be added to *The American Statistician*, in addition to the existing "Teacher's Corner," which deals mainly with issues that are only of interest in teaching graduate level courses. Such a new section in this publication would provide a place to share interesting sets of data, experience with projects and classroom experiments, and other ideas to improve the introductory course. It would also signify a commitment on the part of the profession to improve the teaching of introductory statistics courses.

Other suggestions included short courses at meetings to teach teachers about such topics as process improvement (which few current statistics teachers studied in graduate school) or the effective use of student projects in the introductory course. Of course, it would be quite helpful if universities assigned their best teachers (and those most experienced with analyzing data) to introductory courses and reward appropriately excellent and innovative teaching.

In addition, some participants of the workshop are developing sample syllabi to share with other teachers. This idea has been used successfully in the calculus reform movement in the U.S., as it helps the hesitant teacher pare old lists of topics and methods down to the essential items, thus creating space in the curriculum for fresh ideas, such as student projects.

Detailed Suggestions

Clearly, with 39 individuals grouped into four teams there were many suggestions and there certainly was not unanimous agreement on each of these. However, listed below are suggestions that most of the participants supported. The first list consists of topics that seem important for a first course (1-4 are highest priority, 5-9 second, 10-13 third, 14-17 fourth).

IMPORTANT TOPICS FOR AN INTRODUCTORY COURSE

1. Recognizing that statistics surround us in everyday living. Reported statistics are sometimes incorrect or misused; thus it is important for each of us to be a critical consumer of statistics given by the media. We must ask questions about the quality of the data and the reliability of the analysis.
2. Understanding variability: bias, sampling error, systematic error, measurement error, regression effect, etc. In particular, understanding "Actual Observation = Fitted + Residual," and that in statistics we try to detect the pattern (fitted) and describe the variation (residual) from that pattern.
3. Collection and summarization data, including basic exploratory data analysis. (Some felt we should do more with writing up and explaining results.)

4. Graphs, including plotting data taken sequentially (that is, basic time-series concepts).
5. Sampling and surveys, including the importance of getting quality data.
6. Elementary designs of experiments, with some discussion about the ethics of experimentation and the distinction between observational and experimental investigating.
7. Formulation of problems and understanding the importance of operational definitions and the process of inquiry. That is, understanding the iterative nature of scientific method, including: Plan-Do-Check-Act. We want the capability to make and understand predictions.
8. Basic distributions (normal, binomial, etc.) as approximations to variability in data sets: modelling.
9. Correlation and regression and other measures of association. For example, there should be some illustrations of Simpson's paradox.
10. Elementary probability, including event trees and conditional probability (some included Bayes' Theorem).
11. Central limit theorem and law of averages.
12. Elementary inference from samples, recognizing there are not unique answers in statistics.
13. Ability to use at least one statistical software package.
14. Outliers and how statistical measures change with various changes in the data (that is, aspects of robustness).
15. Statistical significance vs. practical significance.
16. Categorical data and contingency tables.
17. Simulation.

In addition to these topics, there were these other suggestions that could be used by instructors and students:

1. We need to produce syllabi so that less confident teachers can mimic more experienced teachers. Nondeterministic thinking often seems unnatural and we must help the inexperienced teacher and student.
2. Let us think more about processes rather than bowl models. Multiple sets of data should be analyzed, perhaps by multiple analyses. Certainly we should understand the difference in what Deming calls enumerative (bowl) and analytic studies.
3. Students rely too much on formulas rather than on thinking. Do everything possible to improve student's self-esteem and his or her appreciation of and self-confidence in statistical studies.
4. Even with large classes, we need some interaction with students. Try using a small subsection as "your class" with the others as observers. Also select a few students each day for Mosteller's one-minute drill (list on a small sheet of paper the most important topic of the day, the muddiest, and the one about which the student would like to know more—or other short appropriate comments).
5. Find appropriate articles, in the popular press and technical sources, for students to read. Think of projects (questions) for which students can collect and analyze their own data.
6. Statisticians are sometimes overconfident, even arrogant, about the intrinsic importance of their subject. This puts statistics in a bad light, and we should be aware of this and

try to change this attitude.

7. Occasionally have a guest lecturer or colleague in another field or one from industry or government (could consider retired statisticians). These might be held as informal sessions in the late afternoon or evening. The setting should encourage interactions between students and the visitor so as to expose the skills of an experienced statistician.
8. Work on improving our presentations (there was one suggestion that many of us should take acting lessons). Some find it valuable to include some humor into courses.
9. Provide extra problems and old exams through the many "copy stores" that most colleges and universities attract.

SUGGESTIONS FOR THE PROFESSION

Other suggestions were made that cannot be accomplished by an individual instructor, but we would need an effort by a collection of people, like the ASA:

- Constructing a journal on teaching statistics like the MAA's *The College Mathematics Journal* (at least have a "First Course Corner" in the *American Statistician*).
- Newsletter on statistical education.
- Providing information on teaching TAs to teach (MAA has one which was edited by Bettye Anne Case). Encourage extensive TA training and mentoring.
- Developing teachers' network.
- Workshops on teaching at ASA meetings.
- Short courses on teaching.
- Poster sessions on teaching, student projects, and data sets.
- Supporting faculty efforts to change the system.
- Diagnostic tests for students.
- Encouraging position papers, each prepared by two or three like-minded persons.
- Funding for future conferences or workshops on statistical education.
- Collection of "tidbits," namely good ideas for classroom teaching.
- Writing a "Point of View" article for last page of *The Chronicle of Higher Education*.
- Supporting efforts to modify the academic system, in particular, the reward structure and grading procedure.
- Becoming aware of difference of jargon. For example, an engineer might call the statistician's independent variable (or factor) a "parameter."
- Center for collecting materials like projects, videos, and case studies.

Final Thoughts

Clearly, with 39 statisticians involved, we could not agree on the topics to be included in that first course. There will be a continuing need for several first courses. For example, one person clearly thought χ -square tests must be in such a course because his colleagues at his college expected it (and he thought his students appreciated it). Most, however, would decrease the role of tests of hypotheses; some eliminated that topic altogether.

We should ask ourselves what it is that we want the students to remember about that one statistics course that they took ten years ago. We hope that it is not "The worst course I took in college," although that is frequently the answer that we get today. In thinking about ways to improve the answer, we should re-read the goals of the course as suggested

above. Whether we agree with this or not, it will make us think hard about the process of continually trying to improve our introductory course.

We certainly have not solved everything and we must continue our efforts to improve statistical education. Many suggestions have been made in this report on how to do so. Certainly we should seek appropriate funding to get statisticians together to produce tangible materials. If we have future workshops, each team probably should focus on a very special and important topic (at this one, all teams worked on "the first course").

At professional meetings, we must have sessions devoted to statistical education, particularly what improvements are actually being made in these early courses. However, one good sign is that ASA is doing something: in addition to the QL program and the Center for Statistical Education, the topic of the 1992 Winter Meeting is Statistical Education. Hogg has agreed to serve as program chair, and a huge effort will be made to get graduate students to attend. One way to do this is to get many employers (academic, business, industry, government) there to interview students. This Winter Meeting is an excellent time for these interviews. But, beside these employment opportunities, we want to provide a program that students and those interested in statistical education can enjoy. This includes statisticians from industry, business, and government too, because much of the program will be devoted to education beyond that in the traditional academic community.

So, as we left our workshop, there was a great deal of determination that we would not let this topic drop. Education is too important to our profession.

Special Thanks

As indicated in the introduction, we appreciate the sponsorship of the University of Iowa and ASA, as well as those groups that helped financially. In addition, there were the leaders of the four teams: Harry Roberts, Bob Miller, Tom Moore, and Ed Rothman/Bobby Mee. Ed and Bobby jointly took over the fourth team at the last minute. There were some excellent note-takers in Mel Alexander, Jim Sconing, and Jim Calvin. Three persons stayed an extra day to help organize all the notes and thoughts, namely Harry Roberts, Jeff Witmer, and Peter Hackl. Hogg, working under considerable strain due to personal reasons, would have had a most difficult time preparing this report without their help.

Finally, it is fair to say that all participants took this workshop very seriously. While there were disagreements (a few wanted more revolutionary actions suggested), every one of the 39 statisticians made some contributions and their work before, during, and after the meeting is truly appreciated.

Workshop Participants

Mel Alexander, Jim Calvin, Patti Collings, Jon Cryer, Marilyn Dueker, Andrew Ehrenberg, Herman Friedman, Barry Griffen, Bert Gunter, Peter Hackl, Gudmund Iversen, Mark Johnson, Brian Joiner, Jim Landwehr, Bob Lochner, Richard Madsen, Bobby Mee, Bob Miller, Tom Moore, Peter Nelson, Ron Patterson, Harry Roberts, Tim Robertson, Ed Rothman, Ed Schilling, Jim Sconing, Elliot Tanis, Aaron Tennebein, Neil Ullman, Joe Voelkel, Ray Waller, Ann Watkins, Roy Welsch, Carl Wetzstein, B.F. Wink Winkel, Jeff Witmer, Lianng Yuh, and Arnold Zellner.