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Book Review...

Teaching Statistics at Its Best

Edited by David Green

Teaching Statistics Trust, 1994

ISBN 0946554080

This excellent and very worthwhile volume represents a collection of the best articles from volumes 6-14 of *Teaching Statistics*. "It includes almost all articles which have won the C. Oswald George prize awarded by the Institute of Statisticians (now administered by the Royal Statistical Society) for the best article in each volume. ... The publisher, The Teaching Statistics Trust, was established in 1978 for the purpose of furthering for the public benefit the study and research in statistical education." The aim of the journal is to inform, entertain, encourage and enlighten all who use statistics in their teaching of geography, biology, the sciences, social sciences, business studies, economics, and so forth, or those who teach primarily statistics. By measure of the articles that appear in this volume the Trust has succeeded in this particular goal. You can obtain information about subscribing to the journal and obtaining a copy of this volume by writing to *Teaching Statistics*, University of Sheffield, Sheffield, SR 7RH, England.

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The volume is divided into seven major categories: Articles dealing with 1) statistics in the classroom; 2) students' understanding; 3) teaching particular topics; 4) practical and project work; 5) using computers; 6) statistics in other subjects and at work; and last but certainly not least 7) miscellany.

Indeed, the last section contains some of the more important articles when it comes to exploring and cementing the fundamental underpinnings of all work in mathematics. Leslie Glickman's article entitled "Isaac Newton—The Modern Consultant" contains a poignant example of how Newton "left us a legacy of guidelines on how to go about solving a problem when consulted by others." One of "the others" in this case was Samuel Pepys, the famous diarist. Pepys wanted to know about the relative orderings of the probabilities of throwing multiple dice to obtain certain combinations of sums. Newton's response to Pepys's question concerned itself with salient fundamental consulting principles as, "Examine the natural language formulation of a problem carefully. Discuss the problem with the 'customers' in an attempt to understand the requirement," and "If the problem seems complex, try a few simpler versions first. They may provide you with insight to solve the original problem," among others. This article would make excellent reading for the students who have attained the stage of being able to calculate probabilities of events and their complements.

Newton's reference to operational definitions as recounted in Glickman's article would surely have warmed the hearts of W. Edwards Deming were he alive today. Deming emphasized over and over again the importance of operational definitions. "If you change the definition of the measure, you're going to change the number you get. The thing you are measuring hasn't changed at all, has it?" he used to say at his world famous seminars. (Think about Celsius and Fahrenheit thermometers or dents in door panels leading to defect rates.)

Equally pleased would Deming have been, for this very reason, with the article by Francis Lopez-Real, "The Statistics of Safe Travel." This article provokes one to examine carefully the operational definition of metrics used to compare accident rates among different modes of travel. Lopez-Real proposes, for the sake of argument, deaths per million passenger hours and shows that this leads to different orderings of the safety of various modes of transportation.

Ignore the exchange of letters at the end of this article. The critic misunderstood entirely the author's point of argument. Had he not been to a Deming seminar?

This and all the subsequent articles in the section make good readings for students. They can predict the rate at which rumors fly through a finite community; construct on-site demonstrations of taste testing sampling and data analysis; analyze what changes in the way the game of tennis is scored do to potential fortunes of the opposing players; delve into how the judging systems of various sports events such as skating, diving and gymnastics can create some wacky outcomes; and some literally fishy reporting of causative behavior.

Incidentally, all of the articles are eminently readable by students and teachers who possess a modicum of probability and statistics skills. Most articles are between 3 and 6 pages long. They all include references at the end.

In terms of depth and insight, the articles in Section 1 entitled "Statistics in the Classroom," match very closely the articles just cited in the miscellany section. In "Stem-and-Leaf Plots in the Primary Grades," Lionel Pereira-Mendoza and Andrejs Dunkels "show how young children can use such (stem-and-leaf plots) representation as a major tool in their educational development." Some intriguing examples are provided.

Equally as engrossing is the article by Margaret Rangecroft entitled "Graphwork—Developing a Progression" in which she outlines her view of a detailed, comprehensive progression in graphwork from primary through secondary grades. This article is filled with keen insights into how children learn to interpret graphs and why, and at what age they can make the transition from one form to another. A must read.

Leslie Glickman treats a very important topic in "Why Teach the History of Probability?" Glickman notes appropriately that "while other disciplines are forging ahead with the involvement of their histories in the curriculum the history of mathematics lags behind. So does the history of probability!" Glickman argues cogently that the history of probability is rich with motivational material to help teachers present difficult probability concepts in the classroom.

In "Bar Charts Revisited—Beyond the Rubric" Graham Newson provides a remarkable perspective on all of the assumptions, nuances and the mental processes that go into the construction and interpretation of bar charts. The discussion goes well beyond the mechanics of chart construction. This article would make worthwhile reading for everyone.

Also in this section are articles on clustering in one dimension and probabilistic simulation in the classroom.

Section 2 is entitled "Students Understanding." The thrust of this section is to capture common misconceptions and gaps between our intuition and what the laws of probability under the assumptions on randomness and equiprobability would tell us; as well as to capture difficulties in students' perceptions of common mathematical and statistical concepts. There are articles that deal with students' misconceptions of the average; how the width of the classes in a survey sample can distort and confuse proper interpretation of the data; how the choice of scale can likewise confuse the issue and give seemingly disparate results; the concept of randomness and what constitutes a random sequence of occurrences; how students often go astray in constructing their own reports on statistical projects (most used the wrong types of charts, omitted the scales on the axis and the labels); on symmetry in the outcomes under assumptions of equiprobability; and an article on accuracy and precision in calculating solutions to problems. All of these articles give good definition to the perception problem and offer to greater or lesser degrees some hints for correcting the difficulties.

Section 3 is entitled "Teaching Particular Topics." In "Probability and the Unit Square" in this section, Alan Sykes, using the simple statistical experiment of choosing a point at random in a square, shows how to explore the elementary theory of probability distributions; probabilities and random variables, distributions and densities of sums and products of random variables. One example is given of how to calculate the expectation of a random variable on a mixed type continuous and discrete distribution.

James Hanley's article entitled "Lotteries and Probability: Three Case Reports," uses three case studies from the lay press about lotteries. The author throws light on fallacies in the way the probabilities associated with a win are often calculated by people who overlook one or two fundamentals of probability.

"How Large is a Large Sample?" by Frank Dunstan and Barry Nix demonstrates through the use of microcomputers that the sample size needed for the Central Limit Theorem to inveigh depends to a great extent on the parent distribution. The aim is to help students appreciate the theorem and when it can be safely used. The authors have used computers to illustrate these points.

Jeffrey Dodgson, in the article "Illustrating the Dangers of Hunting the Process Mean," captures the essence of another one of W. Edwards Deming's teachings: An operator will increase the variability of a process by trying constantly to make adjustments to the mean of that process based on its output.

In Section 4, "Practical and Project Work," Howard Cotton describes how pupils were introduced to survey sampling, taking experimental data and analyzing it, devising safety tests and guidelines, all in the article entitled "Safety in a Child's Environment." In this exercise, all of the work "has involved all the children, from the least to the most able, in testing, recording, retrieving and representing data generated by devices and surveys devised by themselves. The results were discussed and analyzed and conclusions drawn." This is an excellent example of how statistics concepts can be comfortably, almost naturally, interwoven into most classroom subjects.

David Green teamed up with Mary Rouncefield in "Condorcet's Paradox," in which they illustrate how to construct various hexagonal spinners that demonstrate a counter-intuitive probabilistic result of non-transitivity of the binary relation "outscores." Also given are examples of dice that possess the same property of non-transitivity in the probability of one die outscoring another. This is an exercise that forces pupils to think deeply about the assumptions of equiprobability and unusual properties of varying outcome spaces—all in familiar setting.

Looking for a good classroom project involving statistics? Author Owen's article, "A List of Statistical Investigations," provides a list of fifty fascinating activities to consider. Examples: #35 "Is it likely that a number of marbles/dog biscuits/nails/washers were all made on the same machine? (Use a micrometer.)" Quality Management programs at most corporations trying to improve their competitive advantage teach employees about variation using these techniques. #27 "Try organizing your own opinion poll on political or local matters. How accurate would a generalization to a larger population be?" Everyone should try this activity. It is much harder to pull off in actuality than at first appears. There are many more of the same ilk. It seems details are left to the reader.

The article "Practical Hypothesis Testing Using the Sign Test" by Mary Rouncefield and Peter Holmes provides "pupils who have studied the binomial distribution (or probability tree diagrams at least)" an opportunity "to enjoy some experimental work in their statistics lessons and test hypotheses of the kind: 'Do people improve with practice?'" Data were taken in situations in which subjects are tested before and after on a reaction timer, a sorting activity, and a tracing task. Interesting is the fact that Gottfried Noether, one of the developers and pillars of non-parametric statistics saw fit to comment on this article. The sign test itself is a powerful determiner of fairness, randomness, chance and other fundamental questions we ask of complex situations. Here the authors provide an early introduction to this gem of a test.

Also in this section are articles about accident statistics and simulating the results of experiments with certain design characteristics—an agricultural setting is incorporated for the latter.

There are articles in Section 5 "Using Computers" that help students visualize the concept of correlation using spreadsheets in popular applications programs; that help them improve their understanding of basic concepts such as distribution of runs (of heads or tails, zeros or ones); and that force the student to think about scrutinizing the results of computer generated output such as "normally distributed values" from a random number generator routine.

Section 6 is entitled "Statistics in Other Subjects and at Work." There the reader will find two fascinating articles. The first, entitled "Romeo and Juliet: Fate, Chance or Choice?" by Judith Zawojewski, Jeri Nowakowski and Robert Boruch, describes the use of probability, conditional probability and probability trees to explore the underlying role of fate in Shakespeare's play. The reader will learn what effects slight alterations in the plot line might have had on the outcome. Romeo went to the party at Capulet's. Why did he go? Was it chance? Romeo killed Tybalt. Why didn't Romeo walk away? And Friar Laurence's letter never got to Romeo. Was this a chance happening? The authors of this article artfully consider various alternatives in sorting out chance from fate through the use of probability trees.

"Statistics in High School Science" by Carolyn Maker and John Pancari describes efforts to illustrate to high school physics students possible sources of error in experimentation. The students were actively engaged in the interpretation of scientific data through the use of exploratory data analysis. Students were asked to relate their experimental findings to the theory (in this case the acceleration of a falling body due to the gravitational attraction of the earth). The focus is on the use of summary statistics based on large samples to reduce random error. The statistical exploration of the data by the students described in this article begins where most traditional laboratory reports end. Also in this section are articles on statistics in English and literature studies and traffic modeling.

Two towering pillars that help support the structure that is modern day mathematical statistics are the Taylor series expansion and the Central Limit Theorem. This volume contains ample examples of how to illustrate the Central Limit Theorem. The reader will look for but will not find an article dealing with Taylor series expansions. Many an advance in mathematical statistics drove forward on the strength of the Taylor series expansion theorem. It appears this would be fertile ground for mathematics and statistics educators to bring into the classroom in the same creative manner in which they have conveyed the concept of the Central Limit Theorem and other statistics concepts in this fine volume.

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Jerry Senturia lost a long battle to leukemia shortly after having written this article. He was a first-class statistician with terrific vision, and a wonderful friend. He has been missed by many.

—The Editor

Resource Books Review...

Series of Popular Statistics—Five Interesting Resources

Marcel Dekker, Publisher

There are some that feel statistics is the "essence" of the scientific method. After all, hypotheses that lend themselves easily to statistical analyses often originate from a simple observation. And it is the interpretation of this observation that suggests the premise to be tested further. Only after careful scrutiny and reflection can the claim become a "theory" to be used for decision-making and prediction. Unfortunately, individuals often interpret what they observe incorrectly, and hypotheses become "theories" when they should not. For this reason, it is very helpful to have resources available like those in the ***Series of Popular Statistics*** published by Marcel Dekker.

This series, edited by D. B. Owen and Nancy R. Mann, is a collection of texts with a wide range of appeal. And while the flavor and focus of each is somewhat different, the beginner through the advanced reader will find the material both informative and interesting. One objective of the series is to develop in the reader the insight necessary to see through flawed statistical reasoning presented in both the media and literature. I feel this goal is achieved in a readable, and oftentimes entertaining way.

The first text in the series, ***How to Tell the Liars From the Statisticians*** (ISBN 0-8247-1817-8, $59.75), is a collection of commentaries that requires no prerequisite knowledge on the part of the reader. The author, Robert Hooke, without the use of formulas and with illustrations to emphasize key points, successfully shows how statistical reasoning affects nearly all aspects of our lives. Each reader will find topics that are of personal interest. Whether the topic is drug-testing, sports, cancer research, political polls, or opinion surveys, a constant theme that is present through out the book is to be wary of the "data pushers!" These are individuals who knowingly or unknowingly use statistics to achieve their own purposes. There are flaws to be found in their presented arguments. Whenever people begin quoting numbers, watch out!

The author makes many worthwhile points in this thought-provoking text. For example, we have all heard the quote: "Most car accidents happen within *X* miles of home." Well, this should be the case! Most of us spend much of our time relatively close to home. Note too that an overemphasis of totals can lead to false impressions. Even in a country of millions of people, a very rare event can be made to sound almost commonplace by the simple act of telling how many people it happens to. What should be given, instead, are the chances of the event's occurrence. Additionally, not all claims of discrimination are well founded. In 1980, the median income of women was only 59% of the median for men. However, earnings figures that do not provide a breakdown by such categories as experience, educational qualifications, and job content are not very meaningful. Blame cannot be placed solely on the classification of sex. Is the unemployment index the precise number we would like it to be? Just how does one define the term "unemployed?" Shouldn't the inflation rate be subject to scrutiny? Does the price of each commodity increase at the same rate? And with respect to experimental design, can't comparisons be made much more convincingly within blocks? Why then, ignore their existence? These are just some of the numerous questions addressed.

The Statistical Exorcist: Dispelling Statistics Anxiety (ISBN 0-8247-7225-3, $49.75), by Miles Hollander and Frank Proschan, is somewhat different. It contains 26 vignettes that illustrate real-life applications of statistics. In fact, with limited use of algebraic symbols, the text manages to successfully address topics in such areas as decision-making, sampling, data analysis, and probability estimation. For not only is statistics taught through example, but problems are also provided at the end of each vignette. The intent here is to encourage further thought on the subject matter.

A thorough discussion of the material would be impossible. Indeed, a true appreciation for the creative and educational aspects of this collection could only be achieved by a careful reading. Several vignettes were of personal interest to me. For example, the section on control charts is very clearly written. As with each vignette, key terms are in bold print, and a summary of important points is given at the reading's end. And while not lengthy, the discussion on predicting the reliability of complex systems effectively illustrates the use of several rules of probability. Also, the presentation and interpretation of a life table of U.S. population in a earlier era makes for informative reading.

The Fascination of Statistics (ISBN 0-8247-7329-2, $55.00), the third available text in the series, is quite similar. It too is a collection of writings on topics to which statistical methodology can be applied. However, each chapter has its own primary author(s). The contributors represent a wide range of areas of expertise, and most present a discussion accessible to a fairly general audience.

The chapters are arranged in seven groups around common themes, and each group is preceded by an introduction. There are numerous noteworthy discussions. For example, "Probabilities, Meeting, and Mating" is enjoyable and quite humorous! In it, the author discusses the odds of finding one's "ideal" mate. Of course, the chances of finding **the one** are very small indeed! In "Understanding Patient-Physician Communication," the authors illustrate how factor analysis can be utilized in analyzing a process such as a conversation. A careful review of their study of one portion of the medical interview, medical-history taking, is provided for the reader. Additionally, in "Statistics and Suicide Prevention," the authors consider multiple regression as a tool useful in predicting suicidal risk.

Misused Statistics, Straight Talk for Twisted Numbers (ISBN 0-8247-0211-5, $49.75, *2nd ed. now available*), by A.J. Jaffe and Herbert F. Spirer, is perhaps my favorite in the series. For not only is it well organized, it is also well written. The authors possess a nice writing style, and this make for enjoyable reading.

The text is actually an expansion of a series of articles on misuses of statistics that appeared in the *New York Statistician.* Misuses have been classified into categories, and categories have been grouped into chapters. Of course, as the goal is to develop a critical eye in the reader, the authors also illustrate the proper use of statistics.

There are five categories of statistical misuse addressed in this text. One concerns the design of studies and the presentation and interpretation of resulting data. In particular, the authors provide numerous examples in which graphical representations do not tell the whole story. Graphs illustrating the "sin of the missing zero" and the "sin of the distorted horizontal scale" are among those considered. Also, the authors stress the distinction between association and causality. Specifically, they discuss a fictitious example in which the divorce and death rates are "negatively correlated." Six major pitfalls and cautionary recommendations with regard to surveys and polls are also carefully discussed.

Sense and Nonsense of Statistical Inference—Controversy, Misuse, and Subtlety (ISBN 0-8247-8798-6, $45.00), the last available text in this series, also addresses the misuse of statistics as found in various sources. It, however, focuses on the abuse of statistical inference in scientific journals and statistical literature. For this reason, it is intended for the reader with some prerequisite knowledge in these areas. Nevertheless, this text by Chamont Wang could serve as a valuable resource for future teachers of statistics.

The book is organized around the following topics: tests of significance, statistical generalization, statistical causality, and subjective inference. Of particular interest to myself was the chapter entitled "A Critical Eye and Appreciative Mind Toward Subjective Knowledge." For in this section, the author discusses his involvement as the statistical consultant in an educational study intended to assess the effectiveness of the use of computers and graphing calculators in the teaching of Calculus I and II. The design of the proposed experiment, one that utilized a "control" group consisting of students taught by traditional methods, is described and assessed. In fact, while the design resembled two-sample comparisons that are commonly used in biomedical research and other areas, the author makes careful mention of problems with utilizing this model for such a study. He clearly discusses the problems of nonrandomness, of the Hawthorne and ceiling effects, and of the lack of double-blind control that is generally used to lessen the effects of confounding factors. Additionally, he describes this suggested method of evaluation, an example that illustrates the kind of thought that must be used in designing a valid study.

In summary, there is a considerable amount of useful information in this series. Statistics educators, in particular, will find a wide range of real-life applications to draw upon and to motivate class discussion. Teachers of statistics at many levels are sure to find a resource in this collection that would serve as an excellent supplement of a more traditional text. In fact, the numerous examples and discussions presented are sure to enlighten even the "more seasoned" reader.

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Statistics in the Classroom...

Some Students and a t-Test or Two ... Part Three

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In part 1, I introduced the scope of the statistics course that was given to a self-selected group of twelve third and fourth graders at the Onaway Elementary School in Shaker Heights, Ohio. The course was one of 15 courses offered as part of the Onaway School's Enrichment Cluster program. In part 1, I gave an overview of the course and detailed the efforts of the first two classes which were to get students accustomed to the idea of variation and summary measures through the use of histogram plotting. In part 2, I gave the details of the third and fourth sessions that involved comparing several groups and cementing the idea that the mean is a center point of balance. In this final installment, I will describe the efforts of the fifth and sixth sessions that introduced measuring variation using standard deviation and conclude with using the t-statistic to make a decision. I will close with some final thoughts and observations.

Fifth Session—Shapes and Tests

Since the students had had difficulty understanding the idea of two distributions being the same even though their averages were slightly different, I brought back the red M&M's from the first session and posted the original histogram on the board. The students drew the numbers from that histogram and, splitting the class in half, I had the two groups plot their results on two separate graphs. We computed the averages for these two graphs, scrambled the numbers, and repeated the exercise. With all these graphs and their resulting averages I showed them how all of these sample averages hovered around the "true" average which was the average of all 24 bags.

Again I couched the "different" distributions in terms of the elephant and its shadow and posed the question as to whether or not these small differences mattered. I reminded the students that we knew that the numbers were all from the same distribution because we had taken them from the distribution posted on the board. We talked about this fact and I again pointed out that the only way to tell if the averages were really different was to remember that the averages were only one "word" describing the distributions and that we would have to consider "other words"—e.g., the width of the distribution—in order to decide if the averages were really different.

Letting the matter rest for awhile we returned to the issue of computing the width of the distribution. I warned the students that what we were about to do was going to be difficult but that it was essential that they try this calculation at least once. We reviewed the result that we had from last time—that all deviations added to zero. We rewrote the deviations, but this time squared each one before adding, divided by n-1, and took the square root. I went back to the histogram, drew the standard deviation on the plot, and I showed the students that a little more than 2 times this thing called "sigma" gave a width that just about equalled the width of the distribution.

Sixth Session—t-time and M&M's

This session was the culmination of all of our prior efforts. We started with a brief review of what we had been doing and then I introduced the Students t-test equation and told them what it did and why. Once again, they were given the complete equation which was full of unusual but now familiar symbols (square roots, mu, and sigma). I gave the students a brief biography of Gossett, explained the economic importance of the t-test, and told them how the test got its name.

For our first exercise, the students were provided with a sheet with the averages, pooled standard deviations and the sample sizes for each of the histograms in lesson #3. The students computed the t values for pepperoni vs sausage etc. I explained that a *t* value less than 2 indicated that there was no **significant difference** between the averages. Or, in other words, the averages did not indicate that there was any reason to care whether you like pepperoni or sausage when it came to your test scores. Since I do not like pepperoni, I expressed relief at our discovery that eating pepperoni really wouldn't make you smarter than eating sausage. As expected the other differences in averages were also not significant.

With these calculations as a warmup, we repeated the first lesson with an entirely new lot of M&M's (Note: I bought the first lot of M&M's about 6 months before the class and I bought the second lot of M&M's about 2 hours before class time). I had the histograms from the first time as well and by using both graphics and the t test we found a significant shift in the number of blue M&M's between November and May. I made it a point to overlay the histogram from the first session with the newly developed histogram (I had copied the first on a very large sheet of clear plastic) and I again discussed the issue of the elephant and his shadow. In the case of the blue M&M's we were able to show that we did indeed have two distinct elephants.

With the comparison out of the way, I again held up two mystery bags and asked for an estimate of the most probable number of red M&M's in each bag. The discussion this time would have warmed the heart of the most hard bitten purchasing agent. The air was filled with the voices of 12 students giving their estimates of targets and tolerances—the focus was now on the *distribution* of the red M&M's and the myopic focus on just the mode was a thing of the past.

In the last few minutes of our session, with the students munching away on M&M's, I gave them a brief review of where we had been and just how far we had come. Some of them wanted to know just how "advanced" this effort had been. I told them that, when it came to undersanding the issues involved in comparing two averages, they now knew more about these issues than most college graduates and most adults in the world.

Changes and Improvements

Significant as opposed to numeric difference proved to be the most difficult concept for the students to grasp. My efforts using the elephant and his shadow were not as effective as I had hoped. I may have another chance to teach this class in 1999. This time I will try to illustrate the concept by treating the average as an umbrella pole and the distribution as the umbrella itself. The question that I will pose is this: How far away from the umbrella pole would you have to stand before you would need another umbrella to keep you dry? I am developing some graphics to go along with this and it is my hope that by moving umbrellas instead of elephants and shadows that the students will be better able to grasp the idea of significant differences in the averages.

Keep Us Informed...

The Statistics Teacher Network is a newsletter published three times a year by the American Statistical Association—National Council of Teachers of Mathematics Joint Committee on Curriculum in Statistics and Probability Grades K–12.

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