A case-oriented introduction to the statistics discipline

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Introductory statistics courses come in many different styles. Service courses tend to be aimed at specific application areas (e.g. life sciences, or business) while statistics foundation courses usually require some university-level mathematics as prerequisites. In another category of introductory statistics course are the statistics appreciation courses. A classic text relating to this genre is the text by David Moore that was first published in 1979 and is now in its third edition Moore (1991). Courses based on this type of text are neither "service" courses nor "stat foundation" courses. They are not aimed at any particular application area and they require only minimal math preparation. They aim to describe what the discipline of statistics is about, without necessarily arming the student with tools they can use to analyze data by themselves. Once the goal is abandoned of training students to do their own data analysis, more options for the "statistics appreciation" course become available. In this paper I will describe a case-oriented introduction to the discipline of statistics that has been successful with students and may appeal to some instructors.

The philosophy behind a case-oriented course has been clearly described by Cobb (1993): "In teaching, one wants data sets to illustrate the methods, of course, but ultimately the correct emphasis should be that a set of methods is used to illuminate each data set, not that the data sets are there to serve the methods. An effective way to instill this attitude is to organize the course as a series of applied problems." The course STAT 100 "Chance and Data Analysis" initiated at my university had no real textbook, but did make fairly extensive use of the "reader" edited by Tanur, Mosteller and others (1988). This reader was also to become a classic of its type being first published in 1972 – a fourth edition with completely new articles is expected soon. The aim of this book was "to prepare a volume describing important applications of statistics and probability in many fields of endeavor". From the forward it was clear that the audience in mind was "the public" and certainly did not presume any background in mathematics. This book had the potential to introduce statistics to a general audience, with no prerequisite courses required. This fit well with the role of the new course.

This new course “Chance and Data Analysis” was first offered in 2002. It was partly based on the Tanur reader, partly on some data collection exercises, and partly on certain simulations I described in the lectures. The idea of the simulations was to show that certain interesting and useful real-world applications of statistics could be illustrated using simulations no more complicated than the equivalent of a fair coin toss, or picking a digit from a uniform distribution on the integers 0,1,…9. To give the flavor of the course, I describe a few examples of topics covered.

From the reader:

The Plight of the Whales, by D.G. Chapman described the general problem of estimating animal populations, and why the usual capture-recapture method would not work in this case. He then shows that information seemingly impossible to get can nevertheless be inferred by visualizing the time series of catches. The graph shows as an extra the dramatic drop in the Antarctic blue whale, emphasizing the power of this kind of data to influence public policy.

Making Essay Test Scores Fairer with Statistics, by Henry I Braun and Howard Wainer. In a situation where many essay graders had to be used because of the large number of essays, a strategy had to be devised make adjustments for different average grade levels of each grader. The article involved some aspects of experimental design as well as issues of calibration. The experimental data showed that 12 readers ranged from 12 percent below the overall average to 17% above it. The need for adjustment of scores was very clear. The use of statistics to help make the evaluation fair interested most students.

Simulation Demonstrations:

Sports Leagues: The idea here was that, in a competitive league, the assumption that every game was 50-50 would produce league scores surprisingly close to those seen in some actual leagues. The implications for gambling or sports commentary were explored. Students could actually produce the phenomenon using a small scale league and a fair coin. The idea of using simulation to study a complex phenomenon is incidentally introduced.

Portfolio Diversification: A “risky company” is simulated using two fair coins, producing each of the following alternatives 25 percent of the time, as the return to a $1 investment after 1 year. $0, $0.50, $1, $4. The simulation shows what would happen to a portfolio of independent companies like this. The illustration shows the power of diversification of investment as well as the meaning of independence and dependence.

Stock Markets: The symmetric random walk with step sizes ±1 demonstrates the illusion of patterns that apparently trend up or down, even though these trends offer no advantage for prediction. The artificial aspect of the ±1 step sizes can be removed by using, for example, a normal step size (positive or negative); most introductory students would be familiar with the normal model. The resulting path over 250 days could be compared with the actual stock market index over a calendar year – the nature of the graphs will appear very similar. This demonstration not only teaches students about the illusions caused by randomness but also some very practical information about interpretation of time series.

Data Collection Demonstrations:

Driving Risk: Each student is asked to provide the date of their first driver’s license and whether on not they have been involved in an accident, anonymously, on a scrap of paper. These scraps can be summarized, making certain homogeneity assumptions, to estimate the chance that a student that has not had an accident will have one in the next month. It turned out to be about 1 percent. The ability to get this kind of information from such innocuous and minimal data was a surprise to some. The idea of survival analysis as an area of statistical expertise is simultaneously conveyed.

Marijuana Use: The randomized response technique for obtaining an unbiased answer to a sensitive question can be effectively demonstrated. One asks if the respondent uses marijuana at least once a week. Again, the toss of a fair coin determines whether the respondent answers the sensitive question, or the question whose response is known probabilistically. The estimate in one class was 20% using marijuana once per week or more.

The handouts for the first offering of the course are available at www.stat.sfu.ca/~weldon.

Some Findings and Discussion

Examples like these are designed to accomplish the following goals:

1. They show that statistical tools can extract information from data that is not obtainable using common sense.

2. They show that the information that statistical tools expose can be interesting and important even for the lay population.

3. They show that at least some of the useful concepts of statistics are understandable without a heavy mathematical preparation.

4. They suggest that statistics is a discipline that can be useful for almost anyone, like reading, writing and arithmetic, and also that an understanding of variability broadens one's world view.

Some data was obtained from students to determine what they understood, what they found confusing, and what they wanted more information about. The "minute papers" device recommended by Mosteller(1988) was used.

Although the case studies were presented without emphasizing the statistical tools, nevertheless students learned which tools were important. For example, without prompting, 36 percent chose random sampling and the square root law as "most important concepts" during a mid-course survey. At another stage, after the discussion of sports leagues and portfolio diversification, 32 percent realized that simulation was the common tool that enabled the study of such phenomena without advanced statistical training – other students chose other important ideas, like seasonal adjustment and time series smoothing, as "most important". The small point here is that the general tools were not overlooked because of the focus on interesting applications.

Student acceptance of the course was also fairly high. In anonymous student evaluations, submitted by about 70% of the students, only 18% said the course content was "not valuable". 66% of the students rated the course as a whole in the top 2 categories of a 5 point likert scale, and 92% in the top 3 categories. It was not the easy grades that put the students in an appreciative frame of mind – averages on the midterms and final exam were lower than traditional norms. These tests were designed to test understanding rather than calculation rituals, and the grades were as usual for this kind of test. Although this was the first offering for a course of this particular style and content, the content was accepted as valuable and interesting by most students.

A survey of graduates who were employed in data-based research was performed in New Zealand by Harraway (2003). These graduates were asked what aspects of statistics they needed in their work and how that related to what had been included in their courses. Without reporting the full details, it is worthwhile noting that topics like modeling and simulation needed more emphasis in undergraduate programs for those eventually working in bioscience, and time series methods needed more emphasis for those finding employment in economics and finance. The case-oriented approach introduces these topics in almost any selection of real-world problems, and this was certainly the case in our particular course.

One question that will require more time to evaluate is "Are students who complete this course able to cope with the second service course, which explores methods for multiple regression and analysis of variance?" I would speculate that the concepts in this first course are actually more "mind-expanding" than the basic ideas of prediction with regression or mean comparisons via analysis of variance. In other words, I would predict that progression to the usual second course to be fairly smooth. The evidence from students who choose this route will be interesting to see.

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