Reform and Renewal in the Introductory Statistics Courses

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Abstract

It is time to eliminate or reformulate topics in the introductory statistics courses. Some topics have become obsolete by changes in technology while others need revision due to further developments in statistics. A number of topics for possible deletion or reformulation are considered in this talk.

For example, Excel's BINOMDIST makes obsolete the need for the normal approximation to the binomial distribution. Also, the widespread use of statistical software calls into question how much computational development of regression needs to be included. Separate chapters on simple and multiple linear regression, especially when authors use different formulas in the two chapters, are redundant. This material can easily be revised to use the same formulas for both chapters. Other problems occur with various tests of hypotheses, such as the test on a one population mean where the standard deviation is known - but the stated situation is almost never the case with realistic data sets. Problems with the proliferation of different t-tables are also noted. These and other ideas are considered.

Key Words: introductory statistics, deletions, reformulations

Prologue

The evolution of the textbook began with lecture notes completed by students and/or their teachers which were compiled and sometimes put into book form. Aristotle, Plato, and their mentor Socrates were among the first in the Western world to have books derived from their teachings. The same process continues to this day. Professors and graduate students' notes continue to evolve into textbooks. Statistics textbooks have evolved with a number of different topics usually relegated to similar chapters or sections of chapters. This paper discusses the idea of considering a common core of topics and treatments that the authors believe all introductory statistics books should include. The primary focus in this discourse will be the one or two semester introductory business statistics courses but the comments, in general, apply to all introductory statistics courses.

Many topics in today's statistics courses are there by virtue of longevity. They were included early on in the development of statistics texts. Some of these will always be integral to the study of statistics while others, in our opinion, have outlived their relevance or are obsolete due to technology. This paper suggests some possible revisions

and deletions that could be applied to a number of topics, examples, and in some cases to the extent of the explanations found in today's introductory statistics courses.

Statistics professors are like Egyptian Mummies – Pressed for time. In general, statistics instructors are expected to cover too much material in far too little time. Thus a need for pruning and revising some topics in the area is not only desirable, but necessary. Faculty members are well aware of the change in the students' relationship with their textbooks. Massive sized business statistics books, often over 1000 pages long, have led to escalating prices for the texts with the result that fewer students are purchasing the texts. Every publisher is familiar with the cry that "X university will not adopt a statistics text that does not contain a chapter on topic Y". Because of the vast number of different "Y" topics, publishers seem to have adopted the "kitchen sink" strategy – put in every possible topic, so they will not be excluded from college X's adoption.

In the following, the authors will note a number of topics that they believe all first business statistics texts should include and also some topics that they believe should definitely be revised, if not deleted. A few topics that may be included, but are not deemed to be essential in the authors' view, will also be pointed out.

It should be clear that this paper is just one viewpoint of how to proceed in refining and revising the introductory statistics text material and only reflects the views of its authors. Each reader is encouraged to critique this paper and suggest other topics for deletion or revision. Possibly, ASA may wish to consider a formal study of this issue with possible recommendations to be disseminated after their study.

Introduction

For this study the representative texts by the following authors were considered: Anderson, Sweeney, and Williams (2011); Aczel and Sounderpandian (2009); Bowerman, O'Connell, and Murphree (2011); Kohler (2002); Sharpe, De Veaux and Velleman (2010); Stine and Foster (2011) and Weiers (2011). Some topics are in separate chapters in some of these texts and are combined into single chapters in other texts. The books in this sample range from 800 to over 1200 pages in length. The texts contain between 17 and 27 distinct chapters plus numerous (non-paginated) appendices. Throughout the chapters one notes that texts contain various worked out computer examples and exercises utilizing various computer statistical packages which we believe need to be fully integrated throughout the chapters. Recommendations for deletions and revisions are numbered in the discussion that follows.

Chapter Critiques

The format of this paper will be to consider reform and renewal by individual chapters in the order they typically appear in first statistics texts.

General Introduction Chapter

Virtually all such texts begin with an introductory chapter explaining the ideas of a population, parameters, sample data, statistics and related terms. Most importantly, this chapter must include motivating examples that indicate why the study of statistics is important in the student's field of study (here, for example, in business investigations). Some authors use this chapter or the next to introduce the use of various types of statistical packages and software that will be utilized in the rest of the book. Examples

from these software packages are usually first introduced here, expanded in later chapters and sometimes appear in appendices. The introduction of examples from statistical packages, early on, is extremely important. This should be considered as an absolutely essential topic in any text in statistics.

Descriptive Statistics Chapter(s)

Sometimes authors break up descriptive statistics into two chapters. Whether in one or two chapters, there are often inaccuracies and misunderstandings possible from the way material is presented. Often authors do not understand the distinction between bar and column charts, and even USA Today gets it wrong! Similarly, some authors fail to include spaces between the columns (bars) in the column (bar) charts. These spaces emphasize that these are qualitative tools (as opposed to the histogram – a quantitative tool). All texts should give an accurate and consistent discussion of these charts.

Next, the histogram needs to be reconsidered. The construction of the histogram is often somewhat confused. Many authors consider the class limits as something like: 20 and under 30; 30 and under 40; etc. In reality, however, the data gathered is usually rounded so that a data value of 29.7 would be rounded to 30 and then be assigned to the second class above instead of in the first class where it actually occurs. Earlier text treatments of the histogram made this explicit with the class boundary concept. Any business student using a histogram, bar, column, pie or Pareto chart in a business report, will most assuredly not construct them by hand. For exam purposes, the student should be able to construct simple charts by hand, while with the histogram it is more important that they understand how to use and interpret it rather than how to construct one by hand. That is why statistical software is useful – it saves the time and effort needed for hand drawn figures as well as making figures uniform and clear. Again, there is a problem of consistency and accuracy in both texts and current statistical software that generate histograms. One of the most convoluted software treatments of the histogram is Excel's 2007 version. The 2010 version is no better.

Dot plots and stem-and-leafs are not essential for any further understanding of later topics in statistics and therefore can be deleted or de-emphasized. Some would argue that ogives also fit into this category.

A number of texts include a section on misusing graphs and charts. While these are often optional we believe that this is an important topic and should be included in any text at this level. The recent Wall Street meltdown should be reason enough why business students need to cover this material.

While the ideas of the mean, median, mode and the population and sample variances and standard deviations are of course essential, the introduction of the "short cut" method to calculate the sample variance and standard deviation is superfluous. Calculating any sample variance or standard deviation involving more than a few simple data values, will be done by students either with their calculators (the button) or by using Excel or a similar statistical package. While it is true that the "short cut" method is used in the statistical package calculation, the student has no need to know or even be aware of this fact.

Percentiles and quartiles are essential topics to consider. Bowerman, O'Connell, and Murphree (2011) point out that, "several procedures exist, and, for example, different statistical computer packages use several somewhat different methods for computing the

quartiles" which unfortunately yield different results. Perhaps it is time to arrive at a single formula that texts and software should all use in these calculations.

Many courses do not have time for the topic of box and whisker plots. Also, weighted means and grouped data are topics optional in many texts, if they appear at all, and could be dispensed with as they are not essential for any of the later material in the texts. Similarly, this applies to the material on grouped means. Covering all the essential topics required, e.g. for accreditation by the American Assembly of Collegiate Schools of Business (AACSB), leaves little time for many minor topics.

The coefficient of variation is introduced as an exercise in some texts, while others devote a chapter section to the topic. We prefer the latter. Authors often introduce concepts, to be developed in later chapters, as exercises in earlier chapters such as this one. A number of authors introduce the idea of the level of significance in exercises in the binomial chapter – asking the students to calculate a given cumulative probability and then deciding, based on their answer, if it suggests that the original given value of p may be questionable. Such early introductions could be more widely represented in exercises in earlier chapters.

Probability Chapter

Most texts continue with a chapter on probability. However, many business students, especially those at universities with AACSB accreditation, or seeking it, already are required to take Finite Math as a prerequisite for the first course in business statistics. Finite Math has a chapter on probability in its syllabus. For business students without Finite Math, a few pages on introductory material and note of the binomial coefficients will be sufficient for the later text material on the binomial distribution.

Bayes' Theorem and conditional probabilities are nowhere covered in later chapters of texts at this level unless the text includes a chapter on decision theory. In these cases, such material would be better situated in the decision theory chapter, a topic covered in the second semester of the sequence, than in an early chapter covered in the first semester.

Discrete and Continuous Random Variables Chapter(s)

Most texts continue with chapters on discrete and continuous random variables, or in some cases with the topics combined and in a single chapter. Generic discrete random variables and the formulas for calculating their means and standard deviations are useful topics.

The binomial distribution usually begins with 3 or more pages of exposition involving calculations with factorials and terms of p^k (1-p) ^ (n-k). These are a bit much. One such example is more than enough for any text at this level, since in any real world problems, the students will resort to the binomial tables or more likely to software like Excel's BINOMDIST which calculates both individual and cumulative binomial probabilities for any choices of *n* and *p*. Examples utilizing Excel or another statistics package are essential elements that should be included in this chapter of any business statistics text. The binomial distribution has important applications in the area of yield management.

The Poisson, hypergeometric, negative binomial and other discrete random variables really have no place in a statistics course at this level. Even in the event that a text contains a chapter on queuing theory – this material would be more appropriate in that later chapter.

The material on continuous distributions, especially the normal distribution, is essential to the development of statistics in any first statistics course. The inclusion of the normal probability plot can be useful, especially when the later material on regression considers the need to check the underlying normality assumptions of these models. However, the normal approximation to the binomial distribution is a classical case of a topic now rendered obsolete by technology. This approximation was used when n was very large and p was very small (and np was moderate) to approximate the binomial probabilities by using the normal curve (normal distribution). Now the exact binomial probabilities can be easily calculated for any p and n values using Excel's BINOMDIST or similar routines in other statistical computer packages. Virtually every first statistics course has at least 3 pages, often more, to explain how to approximate probabilities when exact values can be easily obtained using computer statistics packages.

The exponential distribution (optional in many texts) really is unnecessary unless a chapter on queuing theory is included in a later chapter, in which case it should be included in that chapter.

Sampling Distributions Chapter

A separate chapter on sampling and sampling distributions is helpful for the student understanding of the theoretical ideas underlying confidence intervals and tests of hypotheses. Material on the Law of Large Numbers and the Central Limit Theorem, with illustrative examples of the distributions of various sized sample means, is especially helpful. Alas, most instructors do not have the luxury of time to fully treat of this material.

Confidence Intervals Chapter

A chapter on confidence intervals for population means is standard in most texts and has numerous business uses. Because of time constraints, the material on confidence intervals for proportions needs to be skipped by most instructors. The topic of confidence intervals for parameters of finite populations is often optional, if included at all, and probably has no place in a first statistics course.

Tests of Hypotheses Chapter

A chapter on tests of hypotheses on a single population mean is usually the next chapter in most texts. In addition to the usual material, a discussion of Type I and II errors and their importance need to be covered adequately. The material on p-values in addition to the alpha levels of significance needs to be covered more completely since statistics packages give p-values, but occasionally do not give the critical table values.

Some texts consider confidence intervals for a population variance and use this as an excuse to introduce the chi-square distribution. This is somewhat artificial and too often appears out of nowhere with no motivation. Most two semester texts have a later chapter on Chi-Square tests and this would be the appropriate place to introduce the distribution. The confidence intervals for a population variance would then fit here as one of its applications.

Statistical Inference Chapter

Most texts continue with a chapter on statistical inference based on two population means. The various *z* and *t* tests, with a variety of underlying assumptions, are an integral component of all statistics texts at this level. The paired t-test and confidence intervals for the difference of two population means should also be covered in this chapter.

Linear Regression Chapter

A later chapter on simple linear regression and correlation is usually considered as the final chapter utilized in the first business statistics course. One issue that needs to be addressed in any review of the statistics core topics is the relationship between the chapters on simple and multiple linear regression. Virtually all texts give an example calculating the various sums of squares, etc., with real, non-integer valued data. We believe one worked out example, using integer values is sufficient, since in the real world these calculations will be done with a statistical software package.

All texts define the correlation coefficient by different, but of course equivalent, formulas in the chapters on simple and multiple regression. Similarly, the calculation of the regression coefficients is often presented in different ways, in these two chapters. The same formulas should be used in both chapters since this reinforces the idea that multiple regression is simply the generalization of the simple regression model.

Many texts leave the residual analyses for the chapter on multiple regression – a more intensive chapter not covered in the first semester of the statistics sequence. A few texts carry this analysis out in both chapters, but we believe it should be covered in the latter chapter on multiple regression, a topic for the second course on business statistics with an audience more likely to utilize this material.

Often authors give short cut formulas. These are really redundant since the calculations in regression problems will be done with computer statistical packages. While it is true that computer programs utilize these "short cut" formulas, this fact is of no importance to the students as a useable tool in their calculations.

Multiple Linear Regression Chapter

The chapter on multiple linear regression is much more technical and is not covered in first statistics courses, but in the second statistics course. Virtually all texts cover the usual topics including F and partial F tests, residual analysis, dummy variables, and confidence and prediction intervals.

Other Issues

Additional Chapters

A number of later chapters focus on a variety of different topics including experimental designs, ANOVA, time series, chi-square tests, quality control, non-parametric tests, model building, decision theory and the like. These topics are at a more advanced level. This reflects the fact that the early chapters are pre-requisite to these later chapters which comprise the second course in business statistics. The second course usually consists of a selection of these later chapters. We believe that the chapters on non-

parametric methods and decision theory are less appropriate topics for a second course in business statistics.

Quality control is an important topic and some argue that it should be included in the first statistics course. A number of business schools offer more than one undergraduate course in quality control. While many would like to see it in the first course, we believe the present required topics leave no room to add it to the first course.

Tables

A few words need to be said about the various statistical tables included in texts. For some reason, the tables seem to have changed in inappropriate ways. The bottom line of *t*–tables gives the corresponding *z*-values but, unfortunately, some give incorrect values in this bottom line. For example, $t_{.05}$ (for one tail) on the bottom line is not 1.64, not 1.65 and certainly not 1.649, but should be 1.645. Similarly, the value for $t_{.025}$ (for one tail) is not 1.957, but 1.96. It appears that some authors have written their own algorithms to generate these tables and have not come up with the standard table values in some cases. Also a great number of different *t*-tables have appeared. Some fill in the degrees of freedom values for $n = 30, 40, 50 \ldots$ or $n = 30, 31, 32, 33 \ldots$ or $n = 30, 60, 90, 120 \ldots$ Different tables in different texts, often with conflicting values, do nothing to convince the students that statisticians really understand what they are doing. Let's clean this up, now!

Software

The use of statistical software is another topic that is evolving and merits some mention. In a time of ever tightening budgets, a number of colleges and universities are no longer using SAS, SPSS or Minitab, but rather are depending on Excel and various ADD-IN discs of statistical programs developed and bundled with the various publishers' texts. The shortcomings of Excel's charts and Data Analysis routines are well known to students and statistics professors. In addition to Excel, the various ADD-IN discs included with many textbooks vary widely in quality and quantity of topics as well as in their user friendliness. As a result, many faculty members are turning to the internet and inexpensive, and sometimes free, statistical software. Examples of such software, which provide easy access along with samples and tutorials, include R at http://www.r-project.org , Stat Crunch at http://statcrunch.com , and Wolfram Alpha at http://reference.wolfram.com/mathematica/howto/DoStatistics.html .

Perhaps it is time for ASA to address the computer software issue by drawing up some guidelines about what topics, and to what depth, all statistical software packages and ADD-IN discs should follow. For example, Excel's ANOVA program includes the F-test to determine if significant differences in means exist, but provides no test, like Tukey's or Duncan's, to determine which means are significantly different.

Conclusions

This paper considers a number of possible adjustments to the core or canon of topics for a first statistics course. The authors encourage the readers to take part in a dialogue so that essential topics are included in this course and in texts of size and cost that will not inhibit the students from acquiring them. Any questions or comments will be greatly appreciated and may be addressed to any of the authors at their email addresses: leveillen@uhd.edu , rosenthala@uhd.edu and barnes@dt.uh.edu .

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