IMPROVING THE TEACHING OF BASIC STATISTICS TO BUSINESS STUDENTS: THE 2^+-PASS METHOD

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ABSTRACT

In response to a declining success rate of Business students taking Basic Statistics in our College and elsewhere, this paper offers a method for improving the teaching and learning of the subject matter. The method is called 2^+-pass. During the *first pass* which would last approximately 4-5 hours, an instructor teaches only the *core* materials covering core concepts and core techniques for one variable. The *second pass* follows the planned syllabus, chapter by chapter. It is therefore an extension of the core materials of the first pass, which includes (1) detailing the core materials and (2) extending them to two means, two proportions, and two variances of two samples in two populations and beyond. The **+** sign denotes the student's effort beyond the 2-pass lectures. The more passes students go through the materials the better they will become. The paper pays particular attention to *why we define the concepts and why we do what we do* in each step of the core techniques. The method used has yielded a higher success rate.

INTRODUCTION

The textbooks on Business Statistics come in three flavors. The first is commonly labeled as "Basic", Essentials", "Introduction", or "First course" covering basic concepts from descriptive statistics to inferential statistics with sampling distribution, confidence interval, hypothesis testing and linear regression [1]. The second termed as "Complete" includes additional and introductory application areas such as index number, time series, statistical process control and an introduction to decision theory [2]. The third involves treatment of statistics in specialized application discipline such as finance, production management, and others, with a lot more mathematics [3]. The textbooks are not always easy to read.

The average B-students are fearful of Statistics, in general. They commonly confess "I am not good in Math" as an excuse for failure. They are discouraged by the jargon used in the course. They are not accustomed to think in terms of uncertainty. They avoid practicing or do not do it enough. The fear aggravates rather than is properly addressed. Instructors, depending upon the level of the courses, cover a selected textbook in one or two semesters. The common method is chapter-by-chapter. No instructors can go over the materials in the textbook in full. Relatively difficult to grasp topics are considered optional. Supplements and other facilities accompanying the textbooks are underused. Furthermore, due to time constraint, the instructors are forced to focus more on teaching the "how-to", and play down the "why". The average success rate in Basic Statistics of B-students has been, reported alarmingly, declining. The paper addresses two main objectives: (1) take the fear out of the students, and (2) assist the instructors in doing a better job of teaching Basic Statistics and the students in better learning. It involves a new approach to teaching and learning termed as the *2^+-pass method*.

THE 2+-PASS METHOD

The first pass to the course: Core concepts and Core techniques

The first pass commonly is conducted within 4-5 hours. The first pass can be labeled as Chapter 0 (Core Basic Statistics in 4 hours) or Quick tutorial and is offered at the beginning of the semester. For Basic Statistics, the first pass addresses the following topics (core *concepts and techniques*) with just enough simple exercises and demonstrations to substantiate the learning.

Table 1: Topics on Core concepts and Core techniques organized by Module

Module I: Descriptive statistics:
1. Data and *scale of management* (nominal, ordinal, interval and ratio), *Scale of understanding* (data, information, and knowledge) and business decision making 2. Concepts of *mean*, *proportion* and *variance* (*standard deviation*), their calculations and Pivot charting
Module II: Probability foundation:
3. Three *counting methods* by examples (multiple-step, permutation and combination), two *axioms of probability* and three *probability rules* (complement, addition and multiplication) with the introduction and use of marginal, joint and conditional probabilities 4. Core probability distribution (*standard* normal table and how to use it)
Module III: Inferential statistics:
5. *Sampling distribution* and its characteristics per predictions of the central limit theorem 6. *Interval estimation* and why the concept of *confidence interval* and technique 7. *Hypothesis testing*, Null hypothesis formulation, Type I error, test statistic and why the concept of *null hypot*hesis and *rejection rule* and technique and (optional) simple linear regression

Topics (1) and (2) above constitute the essential introduction of descriptive statistics including definitions with calculation examples. In particular, topic (1) is discussed in the context of business decision making, linking statistics and business data. Topic (2) is done via a set of qualitative and qualitative data as examples to arrive at basic formulas for mean and proportion, variance and standard deviation. In topic (3), three experiments with a coin, a die and a deck of cards respectively are used to establish the two axioms of probability. The same experiments are used to draw tree diagrams or tabulation for illustration of (unconditional) marginal probability, joint probability and conditional probability. These probabilities are essential to arrive at probability rules (complement, addition and multiplication, with two special cases: mutually exclusive and independent events). Topic (4) is limited to the standard normal distribution and how to read the standard cumulative probability table in *forward* problems (given Z, find probability ($\leq$ b, $\geq$ a, and between [a, b]), and *backward* problems (given probability, find Z). Topic (5) is on the three characteristics of sampling distribution of means and of proportions, derived from the central limit theorem, namely (a) for large enough sample size, the sampling distribution behaves normally, with an expected value E(X) = μ and standard deviation equals to $\sigma/\sqrt{n}$ in preparation for topics (6) on *interval estimation* and topic (7) on *hypothesis testing*. While presenting these two techniques, we restrict to the case of σ known, and not only we explain the *what* and the *relevancy* among the concepts but also address "*why the concept*" e.g. *95% confidence interval*, and "*why each step in the technique*" is used, e.g. in hypothesis testing: *Why H_0 designated as null hypothesis has an implied equality? Why a H_0: $\mu = \mu_0$ suggests a two-tailed test (or a H_0: $\mu \leq \mu_0$ suggests* *a upper-tailed test)? Why the concept of level of significance and its meaning? Why working with the unlikely evidence for the rejection of H_0, etc.?*

The second pass to the whole course (chapter by chapter): Going for details and extensions

The *second* pass is to follow the syllabus as planned, chapter by chapter from a selected textbook. During the second pass, students will revisit the *core* materials of the first pass the second time in more details. For example, they will see other measures of location (e.g. *median, mode*) besides the *mean*, and other measures of dispersion (e.g. *range*, *interquartile*) besides the variance and standard deviation. Different ways to chart and graph the data for analysis give the students a taste of an effective and appropriate presentation. The extension from "σ known" case to "σ unknown" case gives them a good appreciation on dealing with a distribution other than the standard normal curve. Reasoning about credibility evidence leading to the conclusion, therefore decision in hypothesis testing gives the students a feel of what the unlikely evidence is about. In pass 2, other concepts and techniques can be related to core concepts and techniques formerly presented. This relevancy actually substantiates the student's previous understanding and its extension of the core.

As an addition, each chapter is introduced and summarized using an introductory sketch and a summary sketch. The introduction and summary are not a shopping list of items discussed. The introduction links the topics to be discussed and the summary is shown as a diagram with annotations where links among the chapter topics (past and future chapters) are drawn and explained. For chapters grouped as constituents of a module, e.g. Module 1 on Descriptive Statistics", there are also Module Introduction sketch and End of Module summary.

The + pass by the students

Besides the two passes above, the students are advised to read multiple times the assigned reading. Together with chapter summary and exercises, students are given selected business-context sensitive problems and simple cases. For those who desire to excel further, more relatively complex cases are given using the textbook databases. This pass and subsequent passes are of the student's responsibility.

PACKAGING THE TEACHING MATERIALS FOR 2+-PASS METHOD

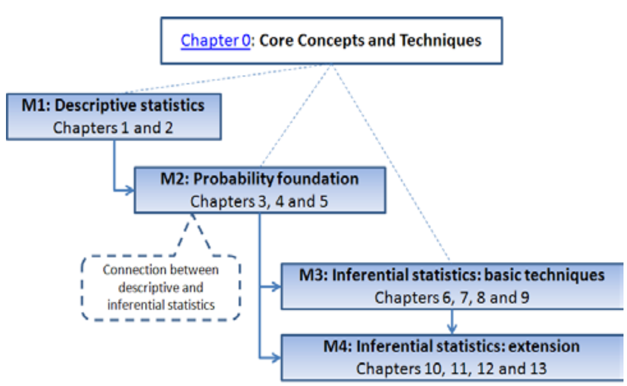

Figure 1: Basic groundwork for statistical techniques

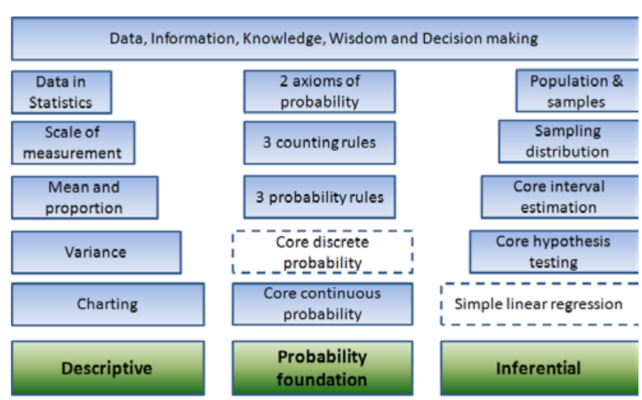

Figure 2: Chapter 0 topics

Most textbooks offer plenty of materials and online supporting services. Our first step is packaging the teaching materials to be exercised by the proposed method. The core materials (concept sand techniques) will be extracted from the textbook for the first pass to the course. This constitutes what we'd call Chapter 0. In addition to Chapter 0, we find that introductory and summary information on Modules (namely Descriptive Statistics, Probability Foundation and Inferential Statistics) and their constituent chapters are helpful. The dotted annotation is to show that probability foundation is essential for M3 and M4. Details of Chapter 0 are summarized in Figure 2.

TEACHING THE COURSE DURING THE FIRST AND SECOND PASSES TO THE COURSE

Focus on the repetition and "relevancy"

As presented, the first pass (core materials or chapter 0) and the second pass (chapter by chapter) constitute the necessary repetition to enhance the understanding of the materials. Both passes, for example discuss the core concepts: *means, proportions, variance* and *shapes* but in the second pass, we discuss also the *relevancy* between the concepts. Not only students are being exposed at multiple times to the defined concepts, they now better understand them thanks to the relevancy. Charting the data in practical Excel examples shows the relevancy. Example follows.

In the first pass, we define the mean as $\mu = \sum X_i / N$ and proportion as $p = x/N$, and illustrate them by simple numerical examples. *In the second pass*, however, we (1) *compare* the mean to the median and mode, (2) *evaluate* their relative positions in terms of non-zero skewness in a particular distribution, (3) *discuss* on the amount of information the mean and the tabulation of frequencies in proportions which provide from the same collection of ratio data, and (4) *substantiate* the use of the concepts by a demonstration of Excel summary statistics in Data Analysis and Pivot table.

Another example is the *relevancy* between (1) the empirical rule for symmetric shapes discussed in Descriptive Statistics (95% of sample means between ±2 Standard Deviations), and (2) interval estimation in inferential statistics, between the confidence interval estimation formula is $[\bar{x} - Z_{\alpha/2}\, \sigma/\sqrt{n}, \bar{x} + Z_{\alpha/2}\, \sigma/\sqrt{n}]$ derived based on sampling distribution properties (normal, $E(\bar{x}) = \mu$, $\sigma_{\bar{x}} = \sigma/\sqrt{n}$).

Focus on the "why"

The *why* discussed here come in two flavors: *why the concept* and *why we do what we do*. The why of the concepts are easier to handle since they are covered sufficiently in most textbooks. For example *why the concept of interval estimation*? The reason is that one would be happy to determine an interval such that the true μ falls within it instead of a particular value of an estimate of μ. The *why of the concept of confidence interval* at some (1-α)% is a little more tricky. Consider for example 95% of sample means which belongs to an interval centered on μ in a sampling distribution of means of samples of size n, i.e. $\mu \pm Z_{.0250}\, \sigma/\sqrt{n}$ (where 1-α = 95%, or α = 5% and therefore α/2 = 2.5% = .0250). Thus, if the same interval (of equal length, i.e. $Z_{.0250}\, \sigma/\sqrt{n}$) centered on $\bar{x}$, we can say that **for 95% of** $\bar{x}$ the true **μ** would belong to the said interval. Hence **the concept of 95% confidence interval.**

Likewise, it is found that showing the hypothesis testing technique can be straightforward in 5 steps, however, explaining *why we do what we do* is a little more involved. The 5-step technique consists of:

1. *Express a claim in terms of null hypothesis and alternative hypothesis*
2. *Set a level of significance called α*
3. *Take a sample and compute the test statistic*: **$Z = (X- \mu_0)/(\sigma/\sqrt{n})$** *and find its p-value*.
4. *Compare p-value to α (if p-value approach): If p-value ≤ α, reject* H_0, *and do not reject otherwise*
5. *Conclude/Decide accordingly*

Students can apply blindly these steps to solve hypothesis testing problems without understanding them. However if they understand the following they would much appreciate the technique. For example:

Why H_0 has an explicit or implied equality in its expression? First, any claim of μ with respect to some μ_0 fall into one of those six possibilities: =,≠ , <, ≥, >, or ≤ relations between them. There is only one possibility of equality in each of the three possibilities: {=, ≤ or ≥} while there is a myriad of possibilities of differences or inequalities when comparing μ to μ_0 in expressions involving one of the {≠, > or <}. Thus, we will express H_0 called the null hypothesis as the one which has an implied or explicit equality, and call H_A the opposite of H_0.

Why the rejection region? Set α. This "α%" corresponds to a (1-α) % of sample means of the sampling distribution. Given α= .05, there are two regions: (1) the region associated with (1-α)% or 95% of sample means, and the region with α% or 5% of sample means. Of course, if a sample of size n is taken, it would be very unlikely that the sample mean falls into the region corresponding to p-value ≤ (α =5%), we will call this the *rejection* region. The one corresponds to 95% is the non-rejection region then.

Details and extensions

Extensions to more than one population, one sample, one mean, one proportion, one variance, and/or more than one variable, and to additional application topics such as time-series, forecasting, non-parametric data are much more appreciated since they are based on the core materials discussed during the first pass. For example in testing the difference between μ_1 and μ_2, or μ_1- μ_2, we simply frame it as (μ_1 - μ_2) with the parentheses and consider it as one measure. Then we express the total variance as the sum of two variances (σ_1^2/n_1) and ((σ_2^2/n_2). So the average standard deviation is $\sqrt{[\sigma_1^2/n_1 + \sigma_2^2/n_2]}$, as opposed to $\sigma/\sqrt{n}$ for one μ. The rest of the topic can be easily shown.

Similarly, when the topic of inference about two variances is discussed, we only have to explain that the expression "$(n\text{-}1)\ s^2/\sigma^2$" is actually "$\sum(X_i – X)^2/\sigma^2$" by replacing s^2 with $[\sum(X_i – X)^2 /(n\text{-}1)]$. Then, the sampling distribution of $(n\text{-}1)\ s^2/\sigma^2$ is actually the sampling distribution of $\sum(X_i – X)^2/\sigma^2$, which is the sum of squares $\sum(X_i – X)^2$ per unit of σ^2. The sampling follows a χ-square distribution of (n-1) degree of freedom. Therefore χ-square distribution is used for interval estimation of σ^2, and "$(n\text{-}1)\ s^2/\sigma^2$" is the test statistic in hypothesis testing of population variance. The interval estimation and hypothesis testing techniques learned previously for population means can be quickly mapped analogously to aid the students' understanding of techniques involving variance.

Use for other occasions

The content of the first pass can be segmented, trimmed and/or added to be used for any length of tutorial teaching. It can be offered for one-hour review, 1-day, or with added information from pass 2 to handle a 2-week, 4-week, or 6-week course, as well as quarter-long course. It can also be used as part of a review chapter before embarking on Stats II, MBA-level statistics or more sophisticated quantitative analysis and quantitative methods.

BENEFITS AND CONCLUDING REMARKS

When the first pass, which is significantly much more than an overview, is taught to students over a period of 4-5 hours (with demonstration exercises) during the first two weeks of the semester, students are exposed to core concepts and core techniques as well as the whole scope of the course. The students are exposed to concepts repetitively during the second pass. In addition, relatively difficult-to-grasp concepts for example permutation and combination can be explained via simple counting techniques in a deck of cards. These counting techniques for the determination of the total sample space and the favorable occurrences for the calculation of likelihood of outcomes or events become more exciting and more appreciative to students. Simple tools such as the applets using [4] can be used to elaborate properties of the sampling distribution based on the central limit theorem. Once the concepts are understood, the students begin to exercise their critical thinking and they don't need to remember the formula for expressions such as margin of error, standard error or confidence interval. They can actually derive them easily. As a result, the remaining chapters on extensions can be delved with much faster, leaving room for other practices or more complex questions/issues. The students learn faster towards the latter part of the semester as the materials are extended from the basics that they already master. They actually read the later chapters before class, which normally does not happen to the average students.

We have used the methods last year for two consecutive semesters with large classes and regular classes. Student scores and student evaluations have increased a great deal with respect to those of the prior semesters where chapter-by-chapter method was used (to be provided upon request). The 2^+-pass method described here, as well as other features such as chapter 0, chapter introduction and summary sketches, and module introduction and summary sketches are implemented in [5].

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