

Reinventing Business Statistics: Statistical Literacy for Managers

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Abstract: Introductory statistics (which would be better titled as Research Statistics) should not be a required course for business students majoring in Management or Marketing. Replacing Research Statistics with an existing quantitative business course (such as Intermediate Microeconomics, Managerial Economics, Management Science, Operations Research or Cost Accounting) is not appropriate either. Management and marketing majors are primarily data consumers: they need to read and interpret data to make better decisions in their courses and on the job. They need a business statistics course that we describe as Statistical Literacy for Managers: critical thinking about numbers in business. This course should focus more on understanding all types of influence on a statistic and on using association as evidence for causation. This paper provides evidence for these claims. Based on a well-tested catalog course in Statistical Literacy, this paper makes recommendations as to what should be included in Statistical Literacy for Managers – as an alternative course for management and marketing majors.

STATISTICS REQUIREMENT IN BUSINESS

Statistics should not be a required course for management and marketing majors. This is controversial since business majors world-wide are generally required to take statistics. Some misunderstanding may be due to an ambiguity in *statistics*. As a course, *statistics* refers to research statistics: a course on random sampling and assignment, sampling distributions, margin of error, confidence intervals, hypothesis tests, and statistical significance. This is essentially a mathematics course: the focus is calculations. Appendix A presents data showing the big gap between the statistics studied in research statistics and the statistics used by managers in practice.

Research statistics is an appropriate requirement for business students in quantitative majors: finance, economics and accounting. It may be a good elective for other business students – but it should not be a requirement for all business majors. Research statistics is too narrow. While all managers should understand margin of error, statistical significance and the benefits of randomization, this doesn't require a full course in research statistics. Some may argue that Business Statistics is different from the regular or non-business statistics. One test of this is whether the Registrar will grant students credit for taking both courses. If not, then they are very much the same.

Management and marketing majors are primarily data consumers: they need to read and interpret data to make better decisions. They need a statistics course that we describe as Statistical Literacy for Managers. This course content is more closely aligned with what is needed in practice. The reasoning skills in this course are more aligned with those tested on the GMAT.

STATISTICAL LITERACY

Statistical literacy is critical thinking about everyday statistics in tables, graphs, statements, surveys and studies. Statistical literacy involves four kinds of thinking:

- 1) **Statistical thinking:** Recognizing that *statistics are numbers in context where the context matters*. This takes a while for students to understand since they've had at least 10 years of school math where the numbers never depend on the context. *Understanding the influences on a statistic*. Knowing that all statistics can be influenced by their context (by what is – and is not – taken into account and by study design), by how they are assembled, by randomness and by error or bias. Recognizing that association does not imply causation, but an association may give strong support for causation. Understanding how sensitive statistics are to choices in the definition of groups or measures. For example, did you know that Uzbekistan has the best health care, highest GNP per capita and the lowest unemployment rate among countries having U, Z, B and K in their name? 😊 While this is far-fetched, you've certainly heard the phrase “best in its class.” Sometimes there's not much difference. Another example is how the definition of bullying can easily influence the percentage of middle-school students involved in bullying.
- 2) **Hypothetical thinking:** What is an alternate explanation for an observed association? How could these categories, measures and statistics have been created? How could the definition of a group or measure influence a statistic? How could the type of comparison influence its size. For example, the smaller the group or measure, the easier it is to get large percentage increases. The larger the group or measure, the easier it is to get large numerical differences. Students must learn to think hypothetically about how a rate or percentage would change if a related factor [confounder] were taken into account. For example, the hospital with the high-

est patient death rate in any US state is probably a highly-regarded research hospital. Ordinarily having the highest death rate would be grounds of sacking the managers, retraining or replacing the staff, etc. But in this case if we take into account patient condition, what was the hospital of death may emerge as having one of the lowest patient death rates. Statistical Literacy studies how taking into account a related factor can influence statistical significance. In the case of the hospitals, the difference in patient death rates between a rural hospital and the top research hospital may be statistically significant. But after taking into account patient condition, the difference may be statistically insignificant. See Schield (2006 and 2010).

- 3) Evaluative thinking: How strong is the statistical evidence in supporting a particular conclusion or decision? There is little need for evaluative thinking in most math or math-stat courses. Answers are either right or wrong. There is no statistical test to determine whether bias has a stronger influence on a statistic than randomness or what was not taken into account. This analysis requires evaluative thinking where reasons are required. Students who analyze arguments using numbers as evidence need to learn the art of evaluation.
- 4) Judgmental thinking: Making a decision about what to believe or to do based on statistical data. Giving reasons why that decision is best. Students need to take into account the costs and benefits, the risks and rewards, of what to believe or do. Students who make decision using numbers as evidence need to develop the art of judgment: a critical thinking skill.

The phrases “statistical thinking”, “hypothetical thinking”, “evaluative thinking” and “judgmental thinking” are not standardized terms in discussing statistics. But they are needed to describe skills that managers need to develop in order to make better decisions using numbers. While evaluative thinking and judgmental thinking might be combined under decision making, they are

separated to help students understand the difference. For more on statistical literacy, see Schield (1999, 2004a, 2004b, 2005, 2006, 2008 and 2010).

STATISTICAL LITERACY FOR MANAGERS

Statistical Literacy for Managers should focus on everyday statistics in business. In addition to the many of the standard topics in research statistics and statistical literacy, there are some new topics that are most relevant to business:

- Greater focus on coincidence in big data. See how after-the-fact coincidences become more likely as the size of the group increases. Flipping 10 coins gives an expected run of at least 3 heads (one chance in 8) every time! See Schield (2012a) and video (2012b).
- Study how to measure intangibles. See Hubbard (2010). Study how the choice of numerical goals can introduce unwanted activities.
- Greater focus on forecasting, on the sensitivity of model results to assumptions, on risk management (e.g., the chance of ruin), and on the correlation between variables in models. This may require the use of Monte-Carlo simulation software.
- Distinguish prevalence and incidence. This is like distinguishing between stocks and flows in economics, or between debt and deficit in accounting. Can unemployment be going up and down at the same time for the same group of workers? Yes. Incidence may be going down over time but if incidence is still positive, then prevalence must go up.
- Study the benefit of separating groups (e.g., new and returning customers) or events (e.g., defects or claims by frequency and severity). These separations are similar to those in cost accounting: fixed vs. variable, controllable vs. uncontrollable, and direct vs. indirect.

- Study how causally-related differences among subjects can influence statistical significance in clinical trials. Consider a randomized experiment of an effective weed killer. Suppose some weeds are doomed regardless of which group they are in. A high percentage of doomed weeds can result in a statistically-insignificant difference. Random assignment can control for confounders but not for causal heterogeneity. (Schield 2012c).

See Ehrenberg (1976) and Cryer (2005) for more details on the teaching of Business Statistics..

REINVENTING STATISTICS

Introductory statistics has long resisted attempts to make major changes in the course curriculum.

Reasons for the lack of change include:

- the preference for mathematical topics that do not vary by discipline or over time,
- the preference for calculation (deduction) instead of practical reasoning (induction),
- the ease of teaching a deductive math course versus an inductive critical thinking course,
- the large number of students taking statistics. Schield (2008) estimates that half of recent U.S. college graduates studied statistics.
- and the need for standardized courses and textbooks to allow a high percentage of statistics courses to be taught by adjuncts.

Any attempt to reinvent introductory statistics must deal with each of these elements.

But introductory statistics is facing change. This pressure for change includes:

- an increase in the amount of data (big data),
- a shift in the type of data from experiments to observational studies,
- a shift from before-after longitudinal studies to “snapshot” cross-sectional studies.

- an increase in the need for managers to make decisions based on data.

Appendix B contains evidence for change in statistical education.

CONCLUSION

Of all the courses in the business core, introductory statistics is most in need of reinvention. Requiring business students in non-quantitative majors to spend an entire course studying the statistics of random samples is unnecessary and unproductive. These students need a quantitative course that helps them think more critically about statistics – all kinds of statistics – as evidence in arguments. Business students in non-quantitative majors need Statistical Literacy for Managers as an alternative to Research Statistics. They should have the option to take either course depending upon their interests.

The Business Department at Augsburg College is developing a Statistical Literacy for Managers course based on these ideas. This course is based on Augsburg's Statistical literacy course: a catalog course that was developed under a grant from the W. M. Keck Foundation. Both courses are being designed to be taught face-to-face, hybrid or online to small or large size classes.

RECOMMENDATIONS

The faculty of business departments should review their business statistics course to see how much value it contributes to business students in non-quantitative majors. If the traditional sample-based inference course is not adequate, these students might be better served by having a choice: the regular Research Statistics course or a Statistical Literacy for Managers course. This can be done without increasing the number of sections being taught by converting some sections of the traditional statistical inference course to the new Statistical Literacy for Managers course.

Those teaching business have an obligation to prepare their students for practice. The faculty teaching business statistics have the same obligation. If sample-based statistical inference is almost as distant as cost accounting from the needs of most business students in non-quantitative majors, then those teaching business statistics must find new options.

The faculty teaching business statistics and the publishers of business statistics textbooks should engage in a discussion of how Business Statistics could be reinvented for business students in non-quantitative majors. The result of this effort could be the biggest change in the design of business statistics courses and textbooks in decades.

Re-inventing business statistics to include Statistical Literacy for Managers could provide business students in non-quantitative majors with the statistical tools needed for practice in a data-driven world.

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BIOGRAPHICAL SKETCH

Dr. Schield is a Professor of Business Administration at Augsburg College in Minneapolis, MN. He received his PhD from Rice University. He has been involved in entrepreneurial start-up companies, worked as a Senior Consultant with a CPA firm and worked as a Senior Operations Research Analyst with a large property-casualty insurance company. He is the US Director of the International Statistical Literacy Project, an elected member of the International Statistical Institute, the President of the Twin Cities Chapter of the American Statistical Association in Minnesota, a member of the Making Statistics More Effective in Schools and Business (MSMESB) and the webmaster of www.StatLit.org: a website dedicated to providing information on statistical literacy.

APPENDIX A: STATISTICS USED IN BUSINESS

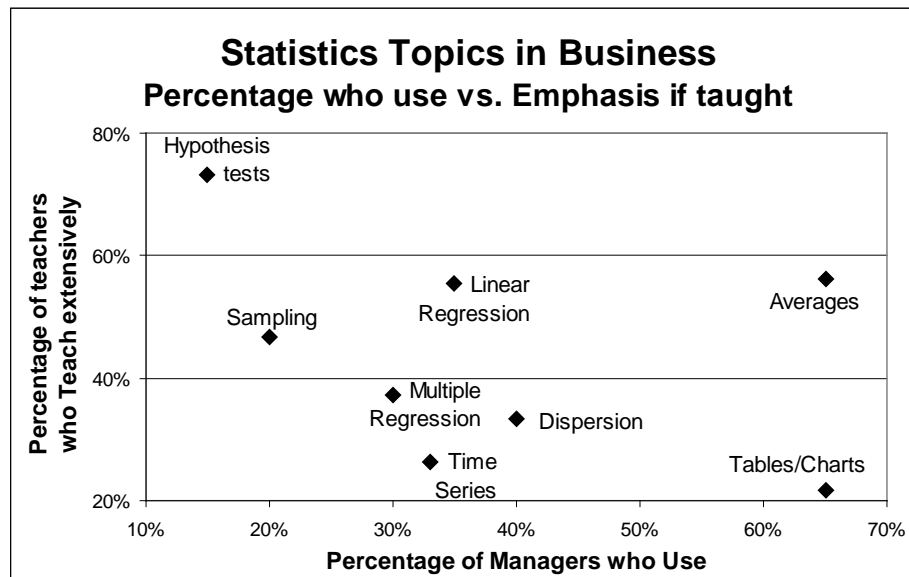
Table 1 gives data on the statistical needs of young business professionals. (Holmes, 1981).

Table 1 Percentage of Young Workers in Business who Use these Statistical Topics

60%	draw up tables of data
54%	read and interpret tables of data
53%	assess accuracy of someone else's data
53%	write reports based on data for others
52%	decide what data to collect
51%	calculate the mean
40%	detect and estimate trends
38%	simplify tabulated data
37%	allow for variability in data
37%	make decisions using data
35%	make projections
27%	draw bar charts and time series graphs
20%	use words such as likely and uncertain
19%	calculate variance or standard deviation
19%	use logarithm or other specialist scales
19%	draw trend lines; read/interpret histogram
17%	calculate median and quartiles
17%	assign probabilities to events
15%	allow for non-response to questionnaires
14%	select the questions on questionnaires
14%	read and interpret scatter diagrams
13%	use statistical tests to compare sets of data
13%	use probability as measure of uncertainty
12%	read and interpret results of simulations
9%	calculate correlation coefficients
8%	calculate moving averages
6%	use a statistical test of significance
4%	use the normal distribution
2%	calculate index numbers

While 54% read and interpret tables of data, only 13% use statistical tests.

Stroup and Jordan (1982, 1983) surveyed 151 business statistics teachers and 1,495 business managers. Topics were classified by how often they are used in business (horizontal axis) and how often they were taught extensively in introductory statistics (vertical axis).

Figure 1 Topics in Business

Note the negative association between what is taught and what is used. If usage in business were the standard for determining the content of instruction, then hypothesis tests are over-taught while multiple regression, time series, dispersion and tables/charts are under-taught.

Isaacson (2006) obtained more recent data on the prevalence of statistical activities in practice:

Table 2: Managers' Statistical Activities

1) MAKE/DO: (70%) Make tables summarizing data. (60%) Calculate rates and percentages. (50%) Make other charts or graphs; Calculate differences (actual – plan); Calculate percentage change. (40%) Calculate percentiles. (30%) Make projections. (20%) Calculate means. (10%) Calculate sample sizes; calculate medians and/or quartiles; calculate standard deviations; calculate validity and/or reliability; make time series charts; design a study/survey; design an experiment. (5%) Make fishbone chart of causes; calculate confidence intervals; perform statistical tests (p-values); calculate Z-scores; calculate coefficient of variation; calculate correlation coefficients. (<5%) Calculate index numbers.

2) INTERPRET/DECIDE: (70%) *Make decisions from data. (60%) Read and interpret graphs and charts. (50%) Read and interpret data tables; assess accuracy of someone else's data. (40%) Write reports based on data for others. (30%) Decide what data to collect; detect and estimate trends. (20%) Evaluate explanations for associations; read and interpret results of simulations.*

(10%) Assess influence of bias, assess influence due to chance, use probability to measure uncertainty, allow for variability in data, use the normal distribution; (5%) Assign probabilities to events, use confidence intervals, use statistical tests (p-values), allow for non-response to questionnaires, use statistical process control (6 Sigma), require regression analysis, use logarithms or other special scales. (<5%) Require discriminant analysis, require factor analysis, quantify uncertainty using chance or risk.

Any course labeled as Business Statistics should address those items that are most common in Table 2. This entails a heavy emphasis on reading and interpreting summary data presented in graphs, tables, media articles and internal reports.

Big data has increased the importance of all of the omitted topics. For managers, coincidence and confounding are much more relevant than hypothesis testing and statistical significance. Data is different in the social sciences than in the physical sciences or Psychology.

- Observational studies are common in business since randomized trials are often impossible, illegal or immoral. Yet most business statistics course are either silent on observational studies or dismiss them as being inadequate to support a causal claim.
- Longitudinal (time-based) data is common in business. Yet few introductory statistics textbooks introduce longitudinal studies.

- Cross-sectional data may be as common in business as longitudinal data. Cross-sectional data is cheaper and quicker to obtain. Cross-sectional data is often used to support causal claims. For example, suppose managers notice that workers that come to work early are more productive than workers that come late. Should management stress the importance of coming to work on time in order to increase productivity? If all workers come to work early, can managers expect an increase in productivity? This kind of case should be studied in statistical literacy for managers.
- Confounding is a major problem – if not the major problem – in analyzing business data. Simpson’s Paradox (an extreme form of confounding) is not a rarity. Most business statistics textbooks never mention confounding or Simpson’s Paradox. And if they do, they have no way for students to work problems, so the topic seldom appears on their tests.

Data is changing. Consider these examples:

- Sample sizes are getting bigger, so smaller differences are statistically significant.
- “Big data” is now measured in terabytes. As data sizes increase, coincidences (spurious association) become more likely while almost everything is statistically significant.

Business students in non-quantitative majors need a statistics course that better equips them to deal with today’s data in making business decisions.

APPENDIX B: STATISTICS COURSE GUIDELINES

A recent review of major issues in introductory college-level statistics courses, Pearl, Garfield, delMas, Groth, Kaplan, McGowan and Lee (2012) concluded that:

“As the field and practice of statistics has changed, it has become more difficult to provide an agreed upon list of specific topics or procedures that all students should learn. There are,

however, some guidelines that may be useful in the development of such a list. Two examples are the organization of outcomes distinguished in terms of statistical literacy, reasoning and thinking (see Garfield and Ben-Zvi, 2008) and the GAISE report, which defines a set of learning outcomes for first courses that describe ways of understanding and thinking about statistics but does not list topics or content to be covered.”

This lack of agreement on a “list of specific topics or procedures that all students should learn” can be viewed in a number of ways.

- This lack of agreement could be the sign of a discipline that has lost its bearings. Perhaps the leaders should acknowledge that teacher-based standards for all students is an illusionary goal and switch to audience-based standards for relevant sub-groups.
- This lack of agreement could be a sign that the statistics being studied have changed. With the advent of large observational data sets, almost all associations are statistically significant. Confounding is now a much bigger issue than statistical significance. And as the designation of groups and the methods of measuring become more arbitrary, the social construction of statistics now has the ability to influence – if not determine – the size of an association and the statistical significance of that association. See Best (2001).
- This lack of agreement could be a sign that statistics is shifting from being a discipline-based course (the first course for student in quantitative majors) to being a general-education course for students in non-quantitative majors.
- This lack of agreement could be a sign that the mathematical definition of statistics as the property of samples is no longer acceptable all those teachings statistics.

The Pearl report provided some evidence for all of these in the first priority:

(1) Cognitive Outcomes: "Research Priority 1: What are the core learning outcomes of statistics that students should develop in order to be statistically literate citizens, to be prepared to use statistics in their careers or future courses and/or to be statistical thinkers, having a statistician's approach to problem solving? Examples of questions:

1. What core learning outcomes employed in a particular profession do individuals need to develop in order to perform well in that profession (e.g., the outcomes that are common and those that are unique to disciplines such as psychology, biology, and economics)?
2. What core learning outcomes help people to make informed decisions based on data on a daily basis (e.g., what types of statistical literacy are needed to understand statistical information in the media and other public forums)?
3. What are the new learning outcomes that students will need to develop given the changing nature of the discipline of statistics (e.g. what new learning outcomes result from the changing nature of data, availability of computing tools, or changes in available analysis methods)?"

The Pearl report stressed the importance of answers to these questions: "If we knew the answer to these questions, then:

- Curriculum developers and other resource developers would have guidance in choosing content and progressions of content aligned with the student audience.
- Instructors would have guidance in choosing written curricula and classroom pedagogies to enact a curriculum and meet the needs of their students.
- Textbook authors would have guidance in sequencing topics and providing supplementary materials for classroom use that would be effective in supporting student learning."

This cognitive research priority represents a major – if not a monumental – change in statistical education. No longer is demonstrating the logic of statistical inference the starting point – the given – in the design of an introductory statistics course. No longer are teacher-selected goals – even if held by a majority of those teaching statistics – the determining factor in selecting the learning outcomes for a college introductory statistics course or textbook. This first cognitive priority is arguably the biggest change in statistical education in decades. It marks the change from an authoritarian approach (a top-down, controlled, rationalistic or Platonic approach) to an empirical or user-needs approach in the teaching of statistics. This recommendation marks the further separation of statistics from mathematics: arguably the most authoritarian top-down discipline in the academy.

Still, it may take many years for this change to work its way through statistical education.