Excerpts
"Assessing Statistical Literacy: Take CARE"

By Milo Schield

Ch 11, *Assessment Methods in Statistical Education: An International Perspective* (2010)

Abstract: **(Not included in the published version of the chapter)**

Statistical literacy is argued as being (1) empirically based on the statistical needs of educated adults in a modern society, (2) defined as the ability to read and interpret summary statistics in the everyday media: in graphs, tables, statements and essays, (3) needed by data consumers (the 40% of college students in non-quantitative majors) and (4) empirically based on the prevalence of various statistical ideas in the everyday media.

To give students an analytical framework, statistical literacy topics suggested by subject-matter experts were grouped into four categories: Context, Assembly, Randomness and Error. Context includes what is taken into account by comparisons and ratios, by epidemiological and statistical models, by study design and by what is not taken into account (plausible confounders). Attending to context and confounding requires a multivariate focus. Assembly includes the choices in defining groups and measures and the choices in summarizing and presenting the results. Randomness includes the influence of chance on what is expected (margin of error) and on what seems unexpected (coincidences). Error and bias include systematic differences such as between population and sample. The prevalence of these four categories in news stories indicates that Context and Assembly must be the primary focus for statistical literacy.

Given the extensive influence of human choice on numbers, the W. M. Keck Statistical Literacy Project grouped these four sources of influence under the age-old admonition, 'Take CARE' where each of the four letters in 'CARE' signified a distinct source of influence on any statistic: Context, Assembly, Randomness and Error.

Examples of objective-answer assessment are shown for each of these statistical literacy categories. A simple graphical technique for taking into account the influence of a binary confounder is presented. This technique is used to assess student understanding of how taking into account a factor can change the direction of an arithmetic association (Simpson's Paradox), can change the number of low birth-weight babies attributed to the mother being a smoker, and can change a statistically-significant difference into one that is not statistically significant (and vice versa).

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Excerpts from Chapter 11: Assessing Statistical Literacy: Take CARE.

11.3 Statistical literacy: For whom

Statistical competence is the ability to produce, analyse and summarise detailed statistics in surveys and studies. Statistical competence is needed by 'data producers' – students in quantitative majors that have a statistics requirement, such as business, psychology, sociology, economics, biology and nursing – and possibly majors that have a calculus requirement such as those in science, technology, engineering and mathematics (STEM).

Statistical literacy is the ability to read and interpret summary statistics in the everyday media: in graphs, tables, statements and essays. Statistical literacy is needed by data consumers – students in non-quantitative majors: majors with no quantitative requirement such as political science, history, English, primary education, communications, music, art and philosophy. About 40% of all US college students graduating in 2003 had non-quantitative majors (Schield, 2008b).

11.6 Take CARE

Schield (2008a) reviews the topics – the sources of influence on the value of a statistic – identified by subject matter experts. The goal is to classify these influences into a small number of categories that are exhaustive, exclusive and fundamental. Now, all too often there is something omitted so the categories are not exhaustive, there are borderline cases so the categories are not exclusive and identifying what is essential is certainly contextual so that in a different context the categories are not fundamental. Nevertheless consumers of statistics – people who are not working with statistics regularly – can benefit from focusing on a smaller number of categories, even if they are not logically pristine, provided they are fundamentally different.
All the factors that influence a statistic have been classified into four categories:

- **Context** The influence of factors taken into account (1) by comparisons of counts, averages, ratios and comparisons of averages and ratios; (2) by epidemiological models (cf., deaths attributable to obesity); (3) by regression models; and (4) by the study design (cf., controlled vs. uncontrolled; longitudinal vs. cross-sectional; experiment vs. observational study) or by selection (cf., in tables and graphs). The influence of related factors (confounders) that were not taken into account in the study and were not blocked by the study design.
- **Assembly** The influence of choices (1) in defining groups or measures, (2) in selecting the summary measure (e.g. mean vs. median), the type of comparison (e.g. simple difference versus times more), and the type of ratio (e.g. the confusion of the inverse or the prosecutor's fallacy), (3) in selecting the group in forming an average, the base in a comparison of numbers and the denominator in a ratio (e.g. rate or fraction) and (4) in selecting the graph, table or statistic in presenting statistical results and summaries.
- **Randomness** The influence of chance on averages and coincidences (e.g. hot hand, too unlikely to be due to chance and regression to the mean). The difference between statistical significance and practical significance in large samples or between 'no statistical effect' and 'no effect' in small samples. The influence of a confounder on statistical significance.
- **Error (or Bias)** The influence of any factor that generates a systematic difference between what is observed and the underlying reality: subject bias (people can lie), measurement bias (instruments can fail, questions may lead and researchers may manipulate) and sampling bias (the difference between the sampled and the target population influences the result).

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Given the extensive influence of human choice on numbers, the W. M. Keck Statistical Literacy Project grouped these four sources of influence under the age-old admonition, ‘Take CARE’ where each of the four letters in ‘CARE’ signified a distinct source of influence on any statistic: Context, Assembly, Randomness and Error. If students were to remember to ‘Take CARE’ in analysing statistics, that would be a considerable achievement. The choice of ‘Context’ for the first category is based on the importance that context plays in the liberal arts and on the importance that statisticians place on context in distinguishing statistics from mathematics.

11.9 Assessing statistical literacy: Context
To understand the influence of context on a statistic, a statistically literate person must understand the features and benefits of different types of study designs (observational vs. experimental, longitudinal vs. cross-sectional, controlled vs. uncontrolled, and randomly-assigned). They must also understand the simplest ways of taking related factors into account (comparing subgroups, using averages, comparisons, ratios, comparisons of ratios and relative risks), and the more complex ways of taking related factors into account (using weighted averages to adjust rates and percentages for the influence of a binary confounder). Statistically literate adults must understand association-generated measures involving epidemiological models: the percentage – and number – of cases that are attributable to an associated factor. They must also be able to describe and compare rates and percentages presented in tables and graphs.

11.10 Assessing statistical literacy: Assembly
Recall that ‘assembly’ means the choices in defining, selecting or presenting statistical Relationships.

11.11 Assessing statistical literacy: Randomness
Even before learning anything mathematical about chance, a statistically literate person should recognise the law of Very-Large Numbers: the unlikely is almost certain, given enough tries. More specifically, a random event with 1 chance in N of occurring on the next try is expected – is more likely than not to occur at least once – in the next N tries. (Schield, 2005).

Even before they can calculate a margin of error, a statistically-literate person should recognise that statistical significance can be determined, given two sample means and their associated margins of error or confidence intervals. If two 95% confidence intervals do not overlap, that test indicates the difference between these sample means is statistically significant at the 5% level. When they do overlap, that test indicates the difference is not statistically significant. A more accurate test (e.g. a t-test) will find that some of these cases of statistical insignificance are actually statistically significant. But a more sophisticated test (resampling) may find that some of the t-test cases of statistical insignificance are actually significant. Statistical significance is determined by the test.

11.13 Assessing the influence of confounding
Ridgway *et al*. (2008: 1) note that ‘most interesting problems are multivariate’, and so ‘the curriculum (and ideas about statistical literacy) should encompass reasoning with multivariate data.’ Statistical educators may question whether it is possible teach students about the influence of a confounder on a statistic without teaching multivariate regression and the associated diagnostics and assumptions. Schield (2006) demonstrates a simple graphical technique for a binary predictor and a binary confounder that bypasses the need to discuss the assumptions of linear regression. This graphical technique involves weighted averages and uses a statistical principle from the 1960s called ‘standardising’.

The following exercise uses this technique to show the influence of a confounder on three things: the size of an association; the number of cases attributable to a related factor; and the statistical significance of a difference between two groups.

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Figure 1 Raw Hospital Death Rates

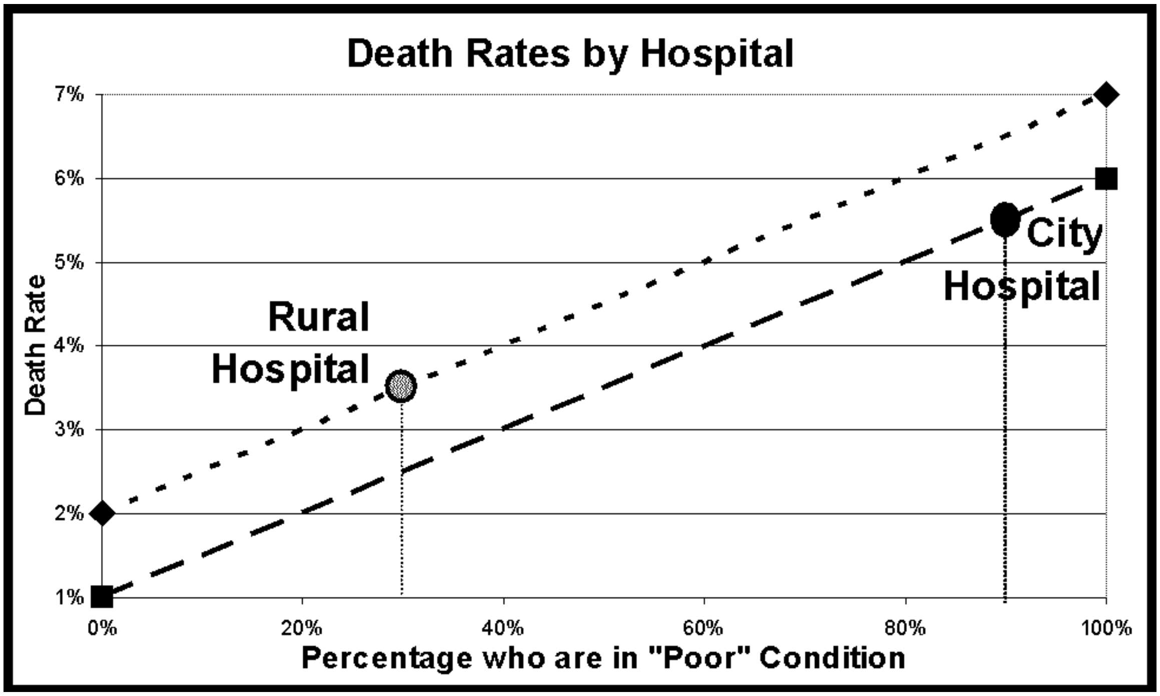


Figure 2 Standardized Hospital Death Rates

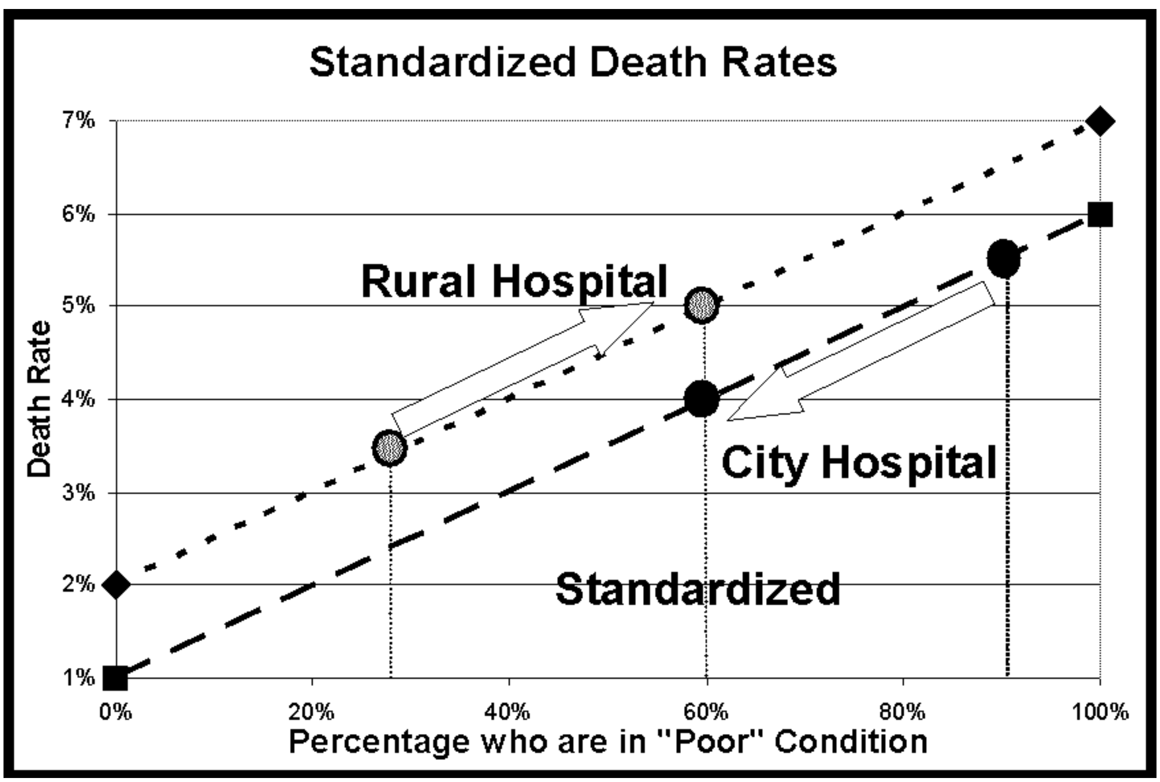
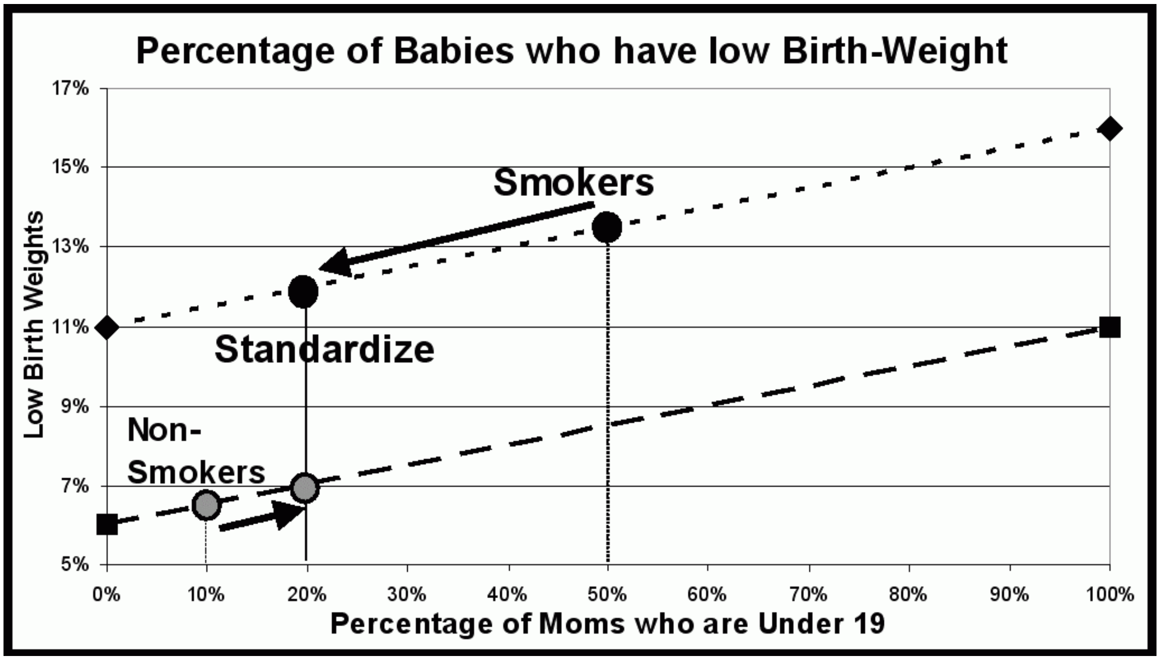


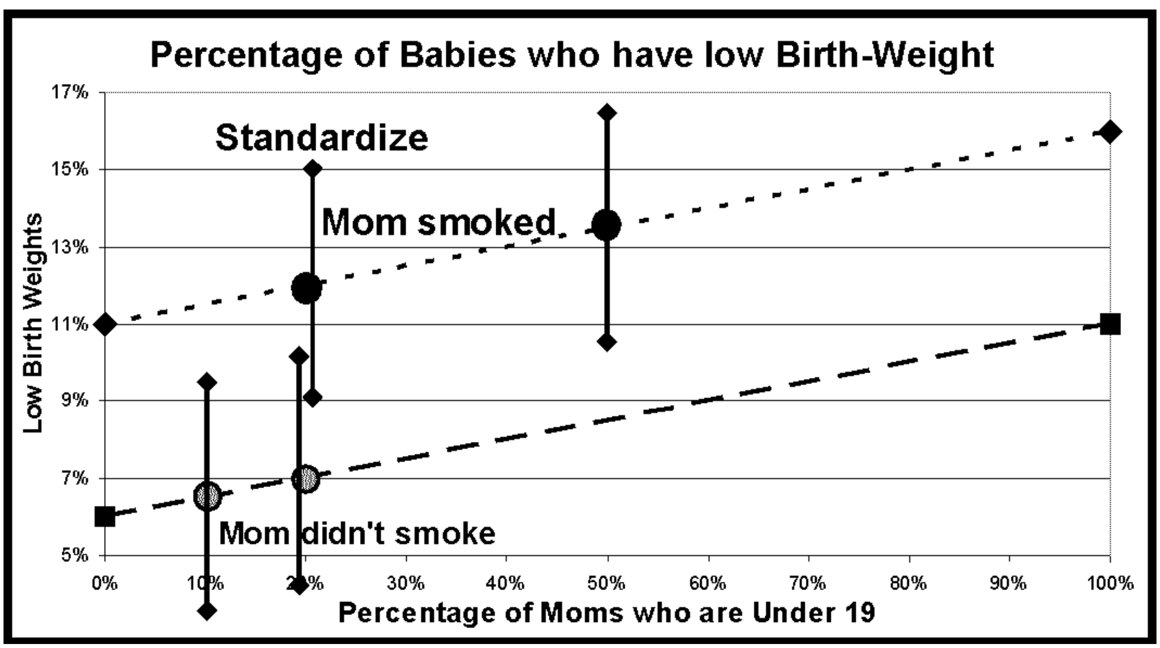
Figure 3 Influence of Confounding on Percentages and Cases Attributed



11.13.3 The statistical significance of a difference between two groups

Controlling for a confounder can influence whether a difference that is statistically significant becomes statistically insignificant – or vice versa.

Figure 4 Influence of Confounding on Statistical Significance



11.15 Assessment

These exercises provide a basis for assessing student knowledge of the various influences on a statistic. Assessing content knowledge is important, but assessing student attitudes is more important. Macnaughton (2004) argues that the primary goal of an introductory statistics course should be to give students 'a lasting appreciation for the value of statistics'. This may be difficult and not as important in teaching statistical competence when students have no idea of how valuable statistical inference is in certain situations. This should be easier and more important in teaching statistical literacy where students can readily find examples of statistical illiteracy in the everyday news.

11.16 Conclusion

Statistical literacy and statistical competence are related but different. Neither guarantees the other. Students in non-quantitative majors need statistical literacy. Students in some quantitative majors may need both.

A statistical literacy course should be designed to satisfy the needs of citizens in a modern, data-driven society, to help them think critically about statist when used as evidence in arguments. There are many ways to design a course to achieve these goals. However, if a course is to carry a statistical literacy designation and meet these goals it should: (1) study all sources of influence on a statistic; (2) choose topics based — in large part — on their prevalence in the everyday media; and (3) inspire data consumers to see a positive value in the material presented.

Statistical literacy courses are becoming increasingly common in US four-year colleges. This increase allows the 40% of US college students in non-quantitative majors a better chance to think critically about numbers in the news. With empirical data on statistics in the media, with a distinct content and with new forms of assessment, statistical literacy is rapidly emerging as a new course in the liberal arts.