STATISTICAL LITERACY 2007

Milo Schield

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Milo Schield

Third Edition

TABLE OF CONTENTS

Typography: **Bold** indicates a term that is being defined. Any term in bold should be found in the Glossary. *Italics* indicate an important concept, point or claim. In part-whole ratios, <u>underscoring</u> indicates a part while SMALL CAPS indicates a whole.

DEDICATION

To[1]

Florence Nightingale, Jerome Cornfield,

Dennis Haack, Victor Cohn

and Joel Best

GOAL

To help students see

the story behind the statistics

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[1] Florence Nightingale (1820-1910) – the "Lady with the Lamp", the founder of modern nursing and the first female member of the Royal Statistical Society – used observational statistics to argue the need for nurses in the military. Dr. Jerome Cornfield, (1912-1979) – the creator of the Odds Ratio and Relative Risk, and a fellow of the American Statistical Society – used observational statistics to argue that the association between smoking and cancer was adequate to claim that "smoking causes cancer." Dr. Dennis Haack's 1979 textbook, "*Statistical Literacy*" appears to have been the first use of that phrase. Victor Cohn (1920-2000) – a former Science editor for the Washington Post, a fellow of the American Statistical Society, and author of *News and Numbers* – argued that students need to be able to read the story behind the story when statistics are involved as evidence. Dr. Joel Best – Professor of Sociology and author of *Damned Lies and Statistics* and of *More Damned Lies and Statistics* – argued that the social construction of statistics was essential in evaluating statistics as evidence in arguments.

Introduction

STATISTICS are words with precision. Saying "Up to 60% of a village died during the plague" is much more precise than saying "Most villagers died in the plague." Saying, "Before 1930, 20% of infants died," is much more precise than saying, "Before 1930, many infants died."

Statistics can help you become aware of things you might not see. You could observe the birth of boys and girls but with statistics you could become aware that a baby is more likely to be a boy than a girl. You could visit the Central American civilizations at the time the Spanish attacked and see many natives dying, but with statistics you could become aware that up to 90% of the natives died – not from battle, but from disease. In a modern society you could attend many funerals but with statistics you could become aware that women tend to live longer than men. You could visit South Africa or Swaziland today and meet people with AIDS but with statistics you could become aware that 10% to 30% of the population has AIDS. You could visit families and notice that tall parents tend to have tall children (short parents tend to have short children), but with statistics you could become aware that tall parents are more likely to have children shorter than themselves while short parents are more likely to have children taller than themselves.

Statistics raise interesting questions. Why are babies more likely to be boys than girls? In the 1500s, why were the Central American natives more likely to die of disease than were the Spanish invaders? In modern society, why do women live longer than men? Why do sub-Saharan Africans have the highest rate of AIDS in the world? Why do children of tall parents tend to be shorter than their parents?

A primary goal of this book is to help you see statistics as your friends that can give you advice and counsel, but friends that must always be monitored and evaluated since they have their own strengths and weaknesses.

A supplementary goal is to help you improve your critical thinking – your ability to reason about argument – to help you in making sense out of your world and to help you make better decisions.

Statistical Literacy: Seeing the Story behind the Statistics

Not all statistics are your friends. Some statistics are false, while others are ambiguous, ill-defined, misrepresented or spurious. As a reader you have three choices: (1) treat every statistic as a fact, (2) ignore every statistic since it might be an error or an opportunistic misrepresentation, or (3) learn how to distinguish good and bad statistics. Some people get overwhelmed or feel trapped when they see a statistic. If they accept the statistic as strong evidence, they may be hoodwinked. If they reject the statistics as evidence, they may make a bad choice.

The primary goal of statistical literacy is to help you evaluate the credibility of a statistic – to be able to read everyday news stories that contain statistics: to go beyond simply reading the statistics to reading 'between the lines' – to see the story behind the statistics.

It takes training and practice to read people or to see the theme of a movie or the direction of play in a sport. It takes training and practice to read an article or untangle an argument. And it takes training and practice to read a news story that uses statistics as evidence. The goal of this book is to give you that training so you can practice what you learn.

Statistical literacy is critical thinking about everyday arguments that use statistics as evidence. The math – mainly arithmetic – is not as central as the words. Words carry more action than the numbers. If a company has a 60% market share in the Eastern US and a 70% market share in the Western US, do they have a 130% market share in the entire US? No! The phrase, "market share," is the key. Or if 40% of Republicans always vote Republican and if 40% of Democrats always vote Democratic, then does that leave 20% of all voters to determine an election? No! The phrase, "of all voters," is the key.

Statistical literacy is closer to critical thinking than to mathematics. Math is deduction: black-white, right wrong. Critical thinking involves induction: shades of grey, strength of evidence supporting a conclusion.

As human beings, our primary method of thought involves generalizing from some to all, from observed to unobserved. Since we are not omniscient; we need to evaluate the strength of our reasons. Thus, our method of thinking (generalizing under uncertainty) is more fundamental than the content of our thinking (words vs. numbers). That is why this book maintains a strong focus on critical thinking. This is why statistical literacy is a bit dif-

ferent from quantitative literacy. They both focus on similar topics, but statistical literacy typically focuses on arguments in which the conclusion is not a number: arguments where the conclusion is disputable, where there is no answer at the back of the book.

Statistical literacy is fast becoming a functional requirement for survival in our computer-based society. The invention of the printing press (~1450) made the reading of text a functional requirement by producing books and newspapers. The invention of the modern computer is making statistical literacy a functional requirement by generating data at an increasing rate. Journalists are also helping to make statistical literacy a necessity for citizens in a democracy. While statisticians thrive on numbers; journalists thrive on words. While statisticians try to avoid controversy and ambiguity; journalists live on controversy and ambiguity.

Statistical literacy – the ability to read and interpret data – is a requirement to understanding issues and making intelligent decisions in modern society where anyone can find a statistic to support their view.

Statistical Literacy is an emerging discipline. Welcome aboard.

Other Books and Sources

Popular books that illustrate statistical or quantitative literacy include:

- *Mathematics and Democracy: Quantitative Literacy* by Lynn Arthur Steen (2001)
- *Damned Lies and Statistics* by Joel Best (2002),
- *News and Numbers* by Victor Cohn (1989) and Lewis Cope,
- *How to Lie with Statistics* by Darrell Huff (1954),
- *Innumeracy: Mathematical Illiteracy and Its' Consequences* by John Paulos (1988) and
- *More Damned Lies and Statistics* by Joel Best (2004).

Textbooks that involve statistical literacy or critical thinking include:

- *Statistical Literacy* by Dennis Haack (1979)
- *The Art of Reasoning* by David Kelley
- *Logical Analysis: A New Approach* by Richard Connell.

For more information on statistical literacy, visit www.StatLit.org.

Audience for this book

The primary audience for this book is college students in majors that do not require a math course but who need a quantitative reasoning course for graduation. Majors in political science, journalism and the liberal arts are prime candidates. A secondary audience is college students in majors that require a traditional statistical-inference course (e.g., sociology, psychology or business) but need a bridging course to prepare them for that course.

This text is not a substitute for a traditional statistical inference course for students in majors that require statistics as a prerequisite for another course (e.g., majors such as in Sociology, Psychology, Economics, Finance or Marketing) or for students taking an MBA. It may be adequate for students in majors that require statistics but do not require it as a prerequisite for other courses in their major (e.g., Management, Accounting or MIS).

This book is suitable for both two-year and four-year colleges. It is being used in a traditional teaching format and in an on-line course. This book can serve as a textbook for a half-semester, quarter or full-semester course. It can serve as a supplement or reference book for students in other courses that satisfy a quantitative reasoning requirement.

Design and Use of this book

This book gives all the important topics in the first two chapters and then gives supporting detail in the subsequent chapters whereas most statistics textbooks leave the difficult topics toward the end. While students may overload initially, they have an entire course to learn that material.

In teaching a half-semester course, students cover all of chapters 1 and 2, stop at Spread in chapter 3, stop at Missing Margins in chapter 4, omit chapters 5 and 7 entirely, and stop at Predicting Influence in Chapter 6.

Level of this book

This book is at the basic principles level. An intermediate text would focus much more directly on how different disciplines use statistical association as evidence of causal connections and treat this material as a prerequisite. An intermediate text would focus more on the choice of an association (relative risk, attributable fraction, odds ratio, Phi, etc.), on the size of the association and on its sensitivity to confounder influence (e.g., the size confounder needed to nullify or reverse an observed association).

Web-based Support for this textbook

    This textbook is being used in an on-line course. Students in that environment need web-based tools. The following tools are available.

    The www.StatLit.org web site contains a 'Five Table' survey. This short survey (~7 minutes) asks respondents which statements accurately describe the circled percentage in five different tables. This survey is available in a web version with immediate grading and also in a paper version.

    The www.StatLit.org web site contains an interactive program that helps users develop their skills in using ordinary English to describe and compare rates and percentages as presented in pie charts, statements, tables and graphs. Access to this on-line drill program is currently unrestricted. This program and documentation are available at www.StatLit.org/GC

    The www.StatLit.org web site contains an interactive program that helps users see how standardizing works. Standardizing is a new graphical technique for taking into account the influence of a related factor. This site contains several articles on confounding, standardization and Simpson's Paradox and contains two web-based interactive Excel programs that demonstrate this technique. Go to www.StatLit.org/Tools.htm.

Background on Statistical Literacy

    For more background on statistical literacy and the relation to quantitative reasoning, quantitative literacy, numeracy and statistical thinking, see the statistical literacy website: www.StatLit.org.

    For an overview of statistical literacy, see Schield's article, "*Statistical Literacy and Liberal Education at Augsburg College*" in Peer Review, a publication of the AAC&U at www.StatLit.org/pdf/2004SchieldAACU.pdf.

    For background on the history of the phrase "statistical literacy," see www.StatLit.org/Haack.htm. For articles directly related to this approach to statistical literacy, see www.StatLit.org/articles.htm.

The Author

Milo Schield is a Professor of Business Administration at Augsburg College in Minneapolis and has a Ph.D. in space physics from Rice University and a CMA Certificate in Management Accounting. He has been a Senior Consultant with a national CPA firm, a Senior Operations Research Analyst in the Actuarial department for a large property-casualty insurance company, and the President of a small computer business. During his last 20 years as a college teacher he has taught a variety of subjects including operations research, accounting, finance, management, marketing, microeconomics, traditional statistics and critical thinking. He has taught statistical literacy (GST 200) at Augsburg College since 1998.

Dr. Schield is the project director of the W. M. Keck Statistical Literacy project at Augsburg College. The aim of this project is "*to support the development of statistical literacy as an interdisciplinary curriculum in the liberal arts*." This book is a result of that grant.

In 1995 he was a visiting scholar at the Royal Statistical Societies' Centre for Statistical Education at the University of Nottingham where he studied with Peter Holmes. Since then he has given papers on statistical literacy in England, Australia, China, Japan, Singapore, South Africa, Brazil, Sweden, Scotland, Wales, Canada and the US. He has organized sessions on statistical literacy at annual meetings of the American Statistical Association (1998-2006). He has given talks at the US Bureau of the Census, the US Bureau of Labor Statistics, and the South African Statistical Organization. He has presented papers at the Mathematics Association of America (MAA) national conferences (2005-2006), at the International Statistical Institute (ISI, 2005) and at International Conference on Teaching Statistics (ICOTS 1998, 2002 and 2006).

For copies of his other publications, see www.StatLit.org, www.augsburg.edu/statlit or www.augnet.augsburg.edu/~schield.

E-mail questions, suggestions or comments to schield@augsburg.edu.

Statistical Literacy and Quantitative Literacy

In Current Practices in Quantitative Literacy, editor Rick Gillman noted, "There is consensus that the mathematical skills necessary to be quantitatively literate include elementary logic, the basic mathematics of financial interest, descriptive statistics, finite probability, an elementary understanding of chance, the ability to model problems with linear and exponential models, estimations and approximation, and general problem solving." A goal of this textbook is to introduce most of the mathematical skills involved in being quantitatively literate.

Of these skills, this text is strongest on descriptive statistics, finite probability and chance, and is weakest on estimations, approximations and general problem solving.

Statistical Literacy and GAISE

In 2005 the American Statistical Association approved Guidelines for Assessment and Instruction in Statistics Education (GAISE). The GAISE College report recommended that *"introductory courses in statistics should, as much as possible, strive to (1) emphasize statistical literacy and develop statistical thinking, (2) use real data, (3) stress conceptual understanding rather than mere knowledge of procedures, (4) foster active learning in the classroom, (5) use technology for developing conceptual understanding and analyzing data and (6) integrate assessments that are aligned with course goals to improve as well as evaluate student learning."*

The GAISE College report stated, "*We define statistical literacy as understanding the basic language of statistics (e.g., knowing what statistical terms and symbols mean and being able to read statistical graphs), and understanding some fundamental ideas of statistics*." The college report suggested that teachers assess statistical literacy by students *"interpreting or critiquing articles in the news and graphs in media*."

This textbook is arguably GAISE compliant on those concepts needed to read and interpret statistics in the everyday media. It emphasizes statistical literacy and encourages hypothetical thinking. It uses data that is both real and relevant. By avoiding formulas and related computational problems, it stresses conceptual understanding. It uses innovative web-based technology to teach the grammar of conditional probability. It supports an essay evaluation form that helps students "critique articles in the news."

To Teachers of Statistics

This book is different – very different! But that is because statistical literacy is very different from traditional inferential statistics. Statistical literacy is more about literacy than about the statistical tests, more about regression and confounding than about chance. Statistical literacy:

o   Focuses more on how groups are defined and statistics are measured. .
o   focuses more on the type of study than on the details of the data.
o   focuses more on what is not in the data than what is in the data.
o   focuses more on alternate explanations (hypothetical thinking) than on deductive thinking.
o   focuses more on systematic sources of variation than on randomness.
o   focuses more on large observational studies and confounding (e.g., Simpson's Paradox) than on small randomized experiments and chance.

This book classifies the influences on a statistical association into four categories using the admonition: Take C.A.R.E. The "C" indicates *Context* or *Confounding*: an omnipresent source of systematic variation. The "A" indicates *Assembly*: the choice of what to measure, how to measure it, and how to present it. The "R" indicates *Randomness.* The "E" indicates *Error*.

Statistical literacy is very different! To prepare yourself, read Schield 2004 AACU paper, *Statistical Literacy and Liberal Education at Augsburg College* and Isaacson's 2005 ASA paper: *Statistical Literacy – An Online Course at Capella University*. Study the first two chapters of this book before deciding to use it. Use the essay evaluation template to evaluate some arguments in the everyday news. Since describing and comparing percentages and rates is central to this text, read Burnham and Schield's 2006 IASSIST paper *Introduction to an Online Ratio Statement Validator* and then go on-line[2] to take the survey and use the grammar checker to test your skills. Investigate the availability of on-line training. For more details, read Schield's 2004 IASE paper, *Statistical Literacy Curriculum Design*.

Finally, focus relentlessly on helping students evaluate the strength of arguments in the every day media that use statistics as evidence.

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[2] Survey: www.StatLit.org/Survey   Grammar checker: www.StatLit.org/RSVP

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Thanks to Joel Best (author of *Damned Lies and Statistics*) for his quintessential contribution – that all statistics are socially constructed – and for his support of this project in his book, *More Damned Lies and Statistics*.

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Finally, a special thanks to the W. M. Keck Foundation for their grant to Augsburg College in 2001 "*to support the development of statistical literacy as an interdisciplinary curriculum in the liberal arts*." Their entrepreneurial grant made this project viable and this book a reality.

What is Statistical Literacy?

"*What is statistical literacy? What every educated person should know.*" David Moore, past-President of the American Statistical Association.

"*Statistical literacy goes beyond numeracy by focusing on reading and communicating those topics studied in numeracy.*" Peter Holmes, Royal Statistical Society Centre for Statistical Education.

"*I see statistical literacy as standing in relation to traditional statistics as quantitative literacy is related to mathematics: they serve different purposes, but in each case the former is typically more useful than the latter for citizens and decision-makers.*" Lynn Steen, past-President of the Mathematics Association of America.

Comments on Statistical Literacy:

"*There are few tasks in education today as urgent as improving the quality of statistical literacy. It is not necessary that every student learn the techniques of a professional statistician, but it is important that every student know enough to become an intelligent and critical consumer of statistical information.*" Dr. David Kelley, author of "*The Art of Reasoning.*"

"*Many universities now have statistical or numerical literacy courses in addition to the traditional introductory statistics course. One lecture explaining the difference between an observational study and a randomized experiment, and the role of confounding variables in the interpretation of observational studies would do more to prepare students for reading the news than a dozen lectures on statistical inference procedures.*" Jessica Utts, The American Statistician, May 2003. P. 74.

"*From my perspective, this teaching of causal inference is the most interesting topic today in statistical education, certainly so at the undergraduate level*" Dr. Donald Rubin, Professor of Statistics, Harvard University.

See also Joel Best's Chronicle article, "*Telling the Truth about Dammed Lies and Statistics,*" at http://chronicle.com/free/v47/i34/34b00701.htm.

"*Misuse of the language of statistics is statistical doublespeak.*" Dennis Haack, author of *Statistical Literacy: A Guide to Interpretation*.