

Planning a Statistical Literacy Program at the College Level: Musings and a Bibliography

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Abstract

Much has been written in recent years on statistical literacy, but what do we mean by “statistical literacy” ? I will take a pragmatic approach and provide resources to help you to define this term for yourself and implement your idea of statistical literacy in the classroom. This paper includes a bibliography of relevant resources. The text provides notes on the bibliography and ruminates on the issues involved. Even if my conclusions differ from yours, the bibliography and discussion may still prove useful in defining, defending and implementing a statistical literacy program.

Planning a statistical literacy program

I will discuss the improvement of statistical literacy in the context of school, particularly in colleges or universities, the context I know best. However, much that I say will be relevant to a potential high school course, or to efforts to enhance statistical literacy by integrating it into the K-12 curriculum.

There are three main steps to improving statistical literacy.

1. Define “statistical literacy”.
2. Gather the resources you need to achieve it.
3. Implement a specific plan.

Defining statistical literacy

We can provisionally define “statistical literacy” as the skills a person needs in order to deal with issues of probability and statistics that arise in everyday life. That is still pretty general (e.g., “Which issues are ‘statistical’ ?”). Recent years have seen many recommendations to improve quantitative and statistical literacy — usually as part of an effort to reform the teaching of mathematics and statistics [10, 22, 24, 25, 26, 27, 44, 45, 46]. Recommendations from the statistical community, to my mind at least, are often colored by the “view from within”. In particular, the list of topics is often skewed toward the content of a traditional introductory statistics course, rather than inspired by an empirical study of what skills are actually needed in real life. In contrast, most of the reformed high school mathematics curricula have done away with the traditional courses entirely. A similarly radical statistical literacy course is the *Chance* course offered by Laurie Snell at Dartmouth (among other people and places). Their way to determine what issues come up in daily life is to have the students read the news. Then topics in probability and statistics are caught and taught as they arise. Hence each offering of *Chance* represents a new sampling of what statistical issues really do come up in everyday life. Whether or not you choose to teach a pure *Chance* course, note that looking to the news is a better guide to real life than looking at the table of contents of a textbook.

I urge you to start your thinking about a definition of “statistical literacy” with the needs of the students

in mind rather than the content of existing courses. The statistics of everyday life are rarely p -values or t -ratios. Instead, we find summaries in paragraphs, in tables, and in charts. Study life, not books, to determine what the students need, then ask how and whether their needs can be met by modifying an existing course. Perhaps the biggest pitfall in designing a literacy course is the temptation to make it a watered-down version of the methods course. The *Chance* course makes it clear that there may not be much overlap between the two courses. Even when there is overlap, the uses the two audiences are likely to make of the material are very different.

To give just one sample of content differences, I strongly suspect that the statistics of everyday life are mostly concerned with categorical data. Consider, for example, the short form for the year 2000 U. S. Census, available at <http://www.census.gov/dmd/www/pdf/d61a.pdf>. Only the age/DOB question gives rise to measurement data. Similarly, the questions asked by the major polling agencies yield almost entirely categorical data. Yet, when we look at an introductory statistics textbook, categorical data are usually only a tiny part of the whole. Most of the coverage is in a chapter on χ^2 which is mostly computations and often optional.

When we look at its content from the perspective of everyday life, we find the traditional introductory course is seriously skewed in this and many other ways. I think the reason for this is that a methods course concentrates on “inference”, that is, determining whether the results we see could be due to random noise. The techniques devised for answering this question are among the major triumphs of statistical science, and have been widely adopted by other sciences. Those sciences now demand that we teach these techniques to their students. However, the techniques are largely technical, and in my own experience in actually doing statistics, the possible effects of noise are drowned out by the effects of bias, inadequate samples, faulty design, and a host of other non-computational issues. It is these latter issues that are at the heart of statistical literacy. The traditional methods course is about the tools of statistics. Continuing that metaphor, it teaches us more about

hammers than houses. A statistical literacy program must teach about houses and leave the hammers to the carpenters. Instead of focusing on the tools, we need to focus on the quantitative issues people face in real life.

The first thing teachers of statistical literacy need is some general guidance on what statistical issues actually *do* come up in everyday life. One resource for seeing where chance is in the news is called *Chance News*. This is a collection by Snell and his associates of references to articles from the news sources they monitor. Their work is currently at www.dartmouth.edu/~chance, but as it is done by volunteers, it may not continue forever. Even if they cease gathering data, we still have the results of many years of past work available to guide us. *Chance* magazine covers similar quantitative current events with a time lag. There are also compilations of past important issues in book form, of which the most famous is *Statistics: A Guide to the Unknown* [47] (new version due in Jan. 2005). *A Mathematician Reads the Newspaper* [33] is another source. The collections by Mosteller *et al.* [30, 31, 32] and Burrill [5] provide much raw data that is from real life, if not always from current news. Zeisel provides summary tables and graphs typical of the kinds encountered in daily life.

Another source of information on needed quantitative skills is our colleagues. Some have thought about this issue already, and can tell us what ended up on their short list of literacy skills. Colleagues in other disciplines can tell us what skills are needed or missing in the courses they currently teach. One caveat here is to avoid crating a list of skills each of which is needed in only one or two specialized areas. These probably belong in those areas rather than in a general statistical literacy program. There follow some suggested topics you might consider adding to your statistical literacy list. The list is based on a blend of my own thinking and the literature. Included are only quantitative reasoning skills that appeared to deal specifically with probability or statistics. Excluded are issues that come up in connection with specific techniques, such as heteroscedasticity and multicollinearity in connection with regression.

Categorical data

I have already mentioned the prevalence of categorical data in daily life. These commonly arise in cross-tabulations and other tables, and as percentages and rates (as in “death rate”, not the rate-of-change of calculus.) Generally, textbooks for the methods course assume students already know how to deal with these (Siegel [42, 43] is a welcome exception.) and proceed directly to inference using χ^2 . In contrast, Jabon and Narasimhan [18] say that, “We have found that students have difficulty interpreting even simple cross tab tables...”, and Schield [37] gives many specific examples. That table reading is not obvious is supported by the interest of information scientists in finding ways to make tables more understandable [23].

There is a connection between rates and conditional probabilities; compare “the unemployment rate among blacks” with “the probability that one is unemployed given that one is black”. Indeed, the former way of saying it is how conditionals normally appear outside the classroom. There is an ongoing discussion in British medical journals [13] of doctors’ and patients’ misunderstandings of medical risks which are often based on (conditional) rates. Here statistical literacy can be a matter of life and death. Note that the issue is not formulae for computing conditional probabilities but rather the interpretation of empirical probabilities.

Graphs

In addition to needing to be able to read tables, students need to be able to read graphs. As with tables, we often overestimate how much they convey to the untrained eye.

Measurement

Even under ideal conditions in the “hard” sciences, repeated measurements of the same quantity give different results. Under less stringent circumstances there are numerous questions about defining what we want to measure and finding a way to measure it. This may involve quantifying something that is

not easily quantified. (A special case of measurement is index numbers.) In any case, we need to be concerned with how accurately the measurements are made, and how well they reflect the quantity of actual interest. Especially important are questions of how small a quantity (or difference) is detectable. It is here that I would informally discuss the fact that small samples are blunt instruments.

Studies

In a first statistical methods course, I consider *data* to be the most important ingredient. The shortest form of Cobb’s recommendations [8] is in their title: *More Data, Less Lecturing*. I submit that, in a statistical literacy course, studies play the role of data in a methods course. That is because raw data for the statistical issues of daily life are rarely available to us. What we have are studies and summaries from those who *do* have the data. I would not expect students in a statistical literacy course to evaluate whether a particular study used the best statistical technique for the data, or carried out the computations correctly. I would want them to ask questions about what kind of study it was (e.g., observational vs. experimental), what variables were included, what variables were controlled or adjusted for, what important variables were *not* controlled or adjusted for, what kinds of bias may have been present, and a host of other questions. I would be inclined to leave lengthy discussion of issues connected with formal inference, such as statistical significance and the power of a test, to the methods course. At this level we could focus on *practical* significance, as few studies lacking statistical significance are published anyway.

Finding resources for teaching statistical literacy

Perhaps the first question is whether there is a textbook that covers the topics that you have chosen as most important. Generally that depends on where you wish to locate yourself along the continuum from a reformed methods course to a *Chance* course. The more you wish to emphasize concepts over calculations the fewer textbook authors who are qualified to

help. (Any mathematics teacher can show students how to plug numbers into formulae.) Even so, we are fortunate that there are probably more good textbooks for a reformed methods course than at any time in history. The following authors have strong credentials in statistics and within the reform movement, and have developed textbooks or other educational materials that exhibit an ability to write clear prose: David Freedman, Gudmund Iversen, David S. Moore, Roxy Peck, Allan J. Rossman, Richard L. Scheaffer, Andrew F. Siegel, Jessica Utts and Paul Velleman. Since I may have left someone deserving out, I should mention two papers that offer guidance in evaluating texts. Cobb [9] gives excellent philosophical guidance even though most of the books he considers are now out of print. Hayden [15] concentrates more on the rapid elimination of unreformed or pseudoreformed books. Even if you find a suitable textbook, you may still need to supplement it in one of the following areas.

Resources for categorical data

Bennett and Briggs [1] provide basic material on using and interpreting simple percents. (This text was used by the DePaul statistical literacy program[18].) For the kinds of tables Minitab calls row-, column- and total-percents, *The Minitab Handbook* [36] or Siegel [42, 43] cover the basics. Zeisel [53] gives many examples of interpreting real tables. Often we want to *compare* percentages or rates. Most introductory methods textbooks give little guidance to doing this with either tables or graphs. Schield [38] gives some guidance for tables. Rossman and Short [35] give excellent guidance to teaching conditional reasoning in the context of tables.

Resources for graphics

There is a much larger literature on graphs [19, 20, 40, 51]. Twyford [48] provides an interesting resource if you are trying to reach artists. Its title might better have been *Visual Communication*. It covers art, mechanical drawing, maps, symbols and many other forms.

Studying studies

Just as data analysis is best learned by working with real data, Statistical literacy is best learned by studying real studies. Tanur *et al.* [47] gives detailed analyses of many real studies. Crossen [11] has the unusual feature of following a number of issues over a stretch of time and a number of studies. However, her book has a “debunking” quality that needs to be balanced with examination of some studies that actually led to useful results. (My experience has been that young people react negatively to books that sound like a parental scolding or warning to “be careful”.) There are many other cautionary books on interpreting statistics in the news [16, 34, 41]. What is harder to find is positive discussions of general issues, such as how to design a study or comparing observational with experimental studies. One source for the latter is the first two chapters of Freedman, Pisani and Purves [12]

Information resources

In discussing quantitative issues we often find we need additional information. (I do not want to say data as we are usually interested in reports and summaries rather than raw data.) Today, the world wide web provides a vast but unstructured resource. *Finding Statistics Online* [2] is a book that provides some guidance. For certain kinds of information we can turn to an almanac, either general as the *World or Information Please* varieties, or specialized as business or sports almanacs, or *The Almanac of the American People* [3]. Sometimes we want the probability of things such as the probability of being struck by lightning. *What the Odds Are* [21] gives many along with vague references (e.g., “Bureau of Labor Statistics”). *Reading the Numbers* [4] provides information on all kinds of everyday measurements, such as hat sizes, pH and paper weights.

Implementation

What do we want?

There is another area in which the *Chance* course can challenge our thinking. It is a separate course

rather than a replacement for a traditional methods-oriented introductory statistics course. Most recommendations from statisticians on improving statistical literacy at the college level concentrate on reforming the existing methods course, but this is not the only option. The canonical statement of consensus on the reform of statistical instruction is by George Cobb. Originally a report on an email discussion group, it appeared as a chapter [7] in a collection on mathematics education, and in summary form in a journal on mathematical education [6] and in a collection of resources for teaching statistics [8]. These repeated replications over a decade suggest that Cobb has captured the spirit of the reform movement. His recommendations are explicitly applied to *all* statistics courses, and Cobb lists two existing statistical literacy courses, one of which (Iversen's at Swarthmore, p.14 of [7]) is explicitly distinct from the methods course. Moore [28] discusses these recommendations in the context of *Statistics Among the Liberal Arts*. He urges instructors to seek their own balance between the liberal arts component and the technical content of statistics. In discussing *What Educated Citizens Should Know About Statistics and Probability*, Utts [49] has a title that suggests a liberal arts emphasis and an abstract that sounds like she is talking about the usual methods course. The body of her paper argues against two separate courses, though in a way that suggests she is concerned that a separate literacy course might become an *alternative* to reforming the traditional methods course. While I can imagine circumstances where that might be a political possibility, I doubt that approach has much support in the statistics community. Clearly, Cobb intends his recommendations to be relevant to *all* statistics courses — perhaps *especially* to the introductory methods course.

We could pursue the debate over whether a separate course is a better approach, but I prefer to look at the choice as ranging over a continuum. At one end we have a traditional methods course, jam packed with all the different techniques the serviced departments demand. At its worst, this course degenerates into a catalog of formulae into which students are drilled in entering inputs and calculating outputs — with little or no understanding of their

meaning. That is not a good thing, but it is not easy to change without reducing coverage of specific tests and procedures. That may take considerable persuasion with serviced departments. Perhaps we can get them to agree to a “reformed” methods course that emphasizes statistical thinking. This is the next region on the continuum. As we move further in the same direction, we spend less time on techniques and more time on concepts. Landmarks along the way might be the innovative introductory textbooks by Freedman, Pisani and Purves [12], Utts [50], and Iversen and Gergen [17]. These books might be used for the methods course at one institution and for a literacy course at another. By now we are not far from David Moore's *Concepts and Controversies* text [29] — which is usually used for a literacy course! Even more separate are the *Chance* course and the course being developed at Augsburg College by Milo Schield [39]. Jabon and Narasimhan [18] describe an interdisciplinary course taught by faculty from many departments. Perhaps the most radical departure from past courses is no course at all! The *Quantitative Reasoning Across a College Curriculum* effort described by Wolfe [52] mimics a writing across the curriculum program and incorporates statistical literacy into courses in other disciplines. What you want to do will depend on the length of the list of statistical literacy desiderata you have generated and local realities of politics and resources. If there should be two courses, there will be questions of overlap, and whether students may obtain credit for both. I prefer to consider two courses with minimal overlap, so that credit could be granted for both, and one might even be a prerequisite for the other. In addition to the issues covered, a literacy course might provide some students with the motivation and incentive to take an elective (or profit from a required) introductory statistical methods course.

What can we get?

Widespread reform must be based on what can be done with typical, existing teachers, perhaps with the aid of a quantity of resources and retraining we can realistically expect to provide. The “new math” movement in the U.S. showed what can happen when

teachers are not prepared for reforms [14]. As an example from today's problem, few teachers have the improvisational skills needed to teach a pure *Chance* course. While such a course provides great immediacy, it requires an instructor who can go into class with no preparation on the issues students might raise that day. I have seen Snell do that at Dartmouth, but I don't think I (or very many others) could repeat his performance. Indeed, most instructors will want to have a textbook and follow it fairly closely. However, even if it cannot be widely implemented, the *Chance* course is so different from traditional courses that it is worth considering, if not as a model to emulate, at least as a challenge to think beyond what we have been doing all along.

In addition to considering the nature of existing teachers, we need also consider the nature of the intended audience. Many of the fears that students bring to a statistics course stem from a lack of facility with formulae and computation. I would like to be able to promise my students no computations beyond basic arithmetic, which they may do with an inexpensive calculator. Starting about thirty years ago, computer software began to be integrated into college statistics courses, and, starting about fifteen years ago, graphing calculators began to be integrated into the high school mathematics curriculum, including (possibly AP) statistics. In my experience the students who find computers less daunting than "hand calculations" (i.e., than a \$2 calculator) are a minority among the audience for this course. Likewise, I find that while many of today's college students own a graphing calculator that they used in high school, among the audience for this course there is little facility with those calculators in the functions they do *not* share with a \$2 calculator. And, mastering those additional functions is no more popular than learning formulae or computer software. So, I personally would favor a low-tech course, though I realize many others may not share that opinion.

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