Graphical Excellence - The Importance of Sound Principles and Practices for Effective Communication

Thomas E. Bradstreet, Ph.D.
Merck Research Labs, BL 3-2,
10 Sentry Parkway,
Blue Bell, PA 19422 U.S.A.
thomas_bradstreet@merck.com

1. INTRODUCTION

Communicating effectively through graphics is a prerequisite skill for both students and working professionals whether they are statisticians or nonstatisticians. Effective graphics show the data; tell the truth; encourage comparison of different pieces of data; pack large amounts of quantitative information in a small region; reveal the data at several levels of detail; provide impact: communicate with clarity, precision, and efficiency; serve a defined purpose: discovery, understanding, and presentation; and are closely integrated with statistical and verbal descriptions of the data (Tufte 1983, 1990; Cleveland 1985; Tukey 1990, 1993).

Currently, the emphasis in statistical education is generally placed on one or more of the following areas: deriving statistical theory; computing statistical methods; or data analysis. Little attention is given to the final presentation of the results and inference from experiments, surveys, and other data collection activities. In most scientific and business disciplines, being able to design, construct, and present clear and perceptively accurate graphical (and tabular) displays is key to effective communication. In modern statistical education, greater emphasis needs to be placed on preparing today's students who will be tomorrow's working professionals, in the science and art of visual perception, graphical construction, and written and oral presentation.

Most of my perspective on this topic has been shaped by my experiences as a consulting statistician in the pharmaceutical industry. And, I received all of my formal academic preparations in the U.S.A. However, I believe that the issues I raise, the examples I provide, and the recommendations I make, generalize to both undergraduate and graduate students in other countries as well as to professionals working in other industries, government, or academia.

In Section 2, I outline some graphical presentation needs of working professionals with examples drawn from the pharmaceutical industry. I outline the graphical needs of students in Section 3. Section 4 presents my proposal for incorporating graphics presentation skills into modern statistical education. I make a few closing remarks in Section 5.

2. GRAPHICAL NEEDS OF WORKING PROFESSIONALS

Many working professionals are responsible for summarizing and communicating the results of experiments, surveys, or other data collection activities through either an oral presentation or a written report. The target audience is comprised mostly of individuals who are not intimately familiar with the details of the experiment or survey; they may be less quantitatively and analytically skilled; they may be more statistically naïve; and they may be either internal or external to the employee's organization.

Internal communications generally document past activities, summarize the progress of ongoing efforts, and support decisions about future initiatives. Employees at all levels of the organization may be in the target audience. For example, a pharmaceutical company decides whether or not to pursue further research on a new drug based upon numerous animal studies, and initial studies in healthy human volunteers and small numbers of patients. The studies' results are

communicated through a series of oral presentations and written reports which are reviewed by a wide range of scientific disciplines and levels of company management.

External communications present the accomplishments of the whole organization and individual employees. Organizational presentations focus on the organization's output, fiscal health, and recruiting efforts. In a pharmaceutical company, a critical step in the approval of a new drug is the worldwide submission of thousands of electronic and/or hard copy pages of a new drug application (NDA). This massive series of documents describes and illustrates the details of the safety and efficacy of the new drug, and it is read by regulatory agencies around the world. A series of oral presentations is given at the regulatory agencies in which the scientifically-oriented employees in the pharmaceutical company guide the regulatory personnel through the highlights of the NDA. Following the drug's approval, there are numerous oral and written marketing initiatives targeted at health organizations, hospitals and physicians.

Individually, working professionals communicate their research through professional conferences and refereed journals. Skillfully designed, thoughtfully constructed, and clearly presented graphics are critical to success at professional conferences as the speakers have a limited amount of time to convey their messages. Statisticians often do a poor job at presenting because we use too few, inappropriate, or poor quality graphics and other visual aids (Sprent 1998; David 1998). Recognizing the importance of the presentations, some statistical societies have embarked upon remedial measures. These include distributing helpful tips on preparing and giving presentations (e.g., Becker and Keller-McNulty 1996), and organizing best paper presentation competitions where graphics and other visual aids are an important part of the evaluation criteria. For example, the Biopharmaceutical Section of the American Statistical Association sponsors a best paper presentation competition at the annual Joint Statistical Meetings where the five evaluation categories are: contribution, organization, verbal delivery, visuals, and handouts.

3. GRAPHICAL NEEDS OF STUDENTS

In addition to preparing for their professional lives in industry, government, or academia, students at all levels need to communicate effectively through graphics. For example, graduate students have doctoral dissertations and masters theses to write and defend, to present at professional meetings, and to publish in refereed journals. At many schools, a senior year honors thesis is either mandatory or optionally available to challenge more motivated students.

A standard graduate program requirement is a comprehensive exam which often includes the graphical summarization of the students' work. Indeed, the Examinations Board of the Royal Statistical Society (RSS) has been greatly concerned at the extremely poor quality of graphs and diagrams submitted in recent years by candidates at all levels of The Society's examinations (Oliver 1998). In an attempt to give guidance to exam candidates, the RSS has formally prepared notes on how to present information in graphs and diagrams (Oliver 1998).

Students may also be involved in collaborative research with faculty members. They may prepare part or all of a presentation, and assist in publication efforts. Both of these activities may be confined to internal presentations and publications, or they may be targeted at external professional conferences and refereed publications.

To gain relevant job experience, some students support themselves financially through summer internships or semester long contract work positions in either the private or government sectors. As part of their activities, the students may make either internal or external presentations, and almost definitely, they will need to construct graphics-rich reports for both internal and external use. And, when seeking a permanent position, students may be asked to give a seminar and provide a sample of their writing skills (see Bradstreet and Heyse 1998). Depending upon the subject matter discipline, the job responsibilities, and the employer, the seminar and writing sample combination can weigh quite heavily on the final employment decision.

4. PROPOSED GRAPHICS EDUCATION

Graphics education should begin with students prior to their undergraduate studies, continue through their academic preparations, and into their professional careers. Further, there needs to be a harmonization of the ideas behind graphics for presentation and graphics for data analysis. Currently, these two groups of ideas are generally treated separately in much of the literature. For example, rather than present data with either a bar graph or a pie chart, most likely a dot chart (Cleveland 1985, 1994) will communicate more effectively. Students and working professionals need to understand that graphical insight follows a continuum from discovery and understanding in data analysis through to clarity and efficiency in final presentation. And, that the non-data-ink and chartjunk laden default presentations of data analysis graphics which are generated by many software packages should be improved to be clear and effective presentation graphics.

To empower students and working professionals to produce effective graphics, we must train them in implementing the basic definitions, strategies, and practical considerations of graphical perception, design, and construction. The world is multidimensional, but most graphical communication is trapped in a two-dimensional "flatland" (Tufte 1990). To successfully communicate in flatland, students and working professionals must understand the perceptual hierarchy of elementary graphical-perception tasks: position along a common scale, position along identical nonaligned scales, length (distance), angle, slope, area, volume, color hue, color saturation, density (amount of black); and related topics such as the aspect ratio (Cleveland 1985). Further perceptual principles are founded in the concepts of data-ink, data-ink ratio, non-data-ink, redundant data-ink, chartjunk, multifunctioning graphical elements, and data density (Tufte 1983).

To achieve perceptual success, students and working professionals must be skilled in manipulating the anatomy of a graph. Parts include data measures and graphing elements; panels and small multiples; superposition and juxtaposition; scale-line rectangle; data rectangle; vertical and horizontal scales; reference lines, inner grid lines and markers; tick marks; data, scale, and tick mark labels; keys; titles, subtitles, legends, and captions. And, they must be able to purposefully orchestrate these graphical components in compliance with graphical perception, construction, and presentation guidelines (see Tufte 1983, 1990; Cleveland 1985, 1994; Kosslyn 1994).

I also recommend that graphics education be highly interactive, as can be delivered through workshop-driven courses (e.g., Bradstreet 1996). Students should be repeatedly challenged to present for critical review and comment, the results of a series of experiments and surveys. Ideally, the students will have designed, conducted, and statistically analyzed the data from some of the experiments and surveys prior to their final graphical presentations.

5. CLOSING REMARKS

Modern statistical education must harmonize the ideas behind graphics for presentation and graphics for data analysis. Through this effort, today's students who will be tomorrow's working professionals in industry, government, and academia, will be better equipped to communicate effectively. As a result, better scientific and business decisions will be made sooner. The impact will be improved products and services delivered to consumers sooner in many fields of application such as the pharmaceutical industry.

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SUMMARY

Communicating effectively through graphics is a prerequisite skill for both students and working professionals whether they are statisticians or nonstatisticians. Graphics education should provide a harmonization of the ideas behind graphics for presentation and graphics for data analysis. Students and working professionals must be trained in implementing the basic definitions, strategies, and practical considerations of graphical perception, design, and construction. And, graphics education should be highly interactive.

RÉSUMÉ

La capacité d'utiliser les graphiques pour communiquer efficacement est essentielle à tous les étudiants et tous les professionnels, s'ils sont statisticiens ou autres. L'enseignement des arts graphiques devrait mettre en harmonie les deux aspects de l'utilisation des graphiques pour la présentation et pour l'analyse de données. Les étudiants et les professionnels doivent apprendre à mettre en pratique les principes, les stratégies, et les considérations pratiques fondamentaux que nécessitent la perception, la conception, et la construction graphiques. L'enseignement des arts graphiques devrait être très interactif.