IMPROVING STATISTICAL LITERACY AMONG CONSULTANTS AND CLIENTS

Patricia L. Busk, University of San Francisco
123 Turquoise Way San Francisco, CA 94131-1639

KEY WORDS: Statistical Education; Statistical Consulting

Changes in the mathematics education for kindergarten through grade 12 in the U.S. schools involve an emphasis on statistics. An important component of the change is the inclusion of data analysis and quantitative reasoning. Recommendations have been made for students in grades 9 to 12 to be able to understand and apply measures of central tendency, variability, and correlation; to communicate outcomes of a statistical experiment; and to reason validly in statistical arguments (Scheaffer, 1990). These changes are intended to make the graduates more knowledgeable in the area of statistics and statistical reasoning. When and if these individuals with the newly acquired skills and experiences become researchers, statistical consultants will find that their clients have a basic understanding of statistics and will be literate statistically. Even when individuals with this new training and educational experiences reach college or graduate school, the statistical literacy of researchers who consult statisticians will not be known empirically.

Abilities (Anderson & Loynes, 1989) and training (Bradley, 1989) of statisticians has received considerable attention in the literature. Guidelines have been put forth for statistical consultants (Boen & Zahn, 1982; Marks, 1989) and their training (Carter, Scheaffer, & Marks, 1986; McCulloch, Boroto, Meeter, Polland, & Zahn, 1985; Zahn, 1982).

What is missing from the literature is information on the statistical literacy of consultants and their clients. The details regarding the training of statistical consultants and the methods that they use to keep current with developments in the field of statistics would be a beginning step in addressing this issue. This paper has two purposes: first, to determine the statistical literacy of clients of statistical consultants and methods that the consultants use to improve the literacy of their clients and, second, to assess the consultants' attempts at keeping abreast of developments in the field and their unmet needs from their graduate training. To address these purposes, a random sample of members of the American Educational Research Association (AERA) Special Interest Group-Educational Statisticians and the Caucus of Women in Statistics of the American Statistical Association (ASA) was surveyed. Individuals in these organizations provide consulting services to a broad audience--academics, school personnel, medical and health-care professionals, and private and public agencies. Their responses should provide insights into the statistical literacy of consultants and clients.

1. METHOD

A questionnaire with 14 items was developed to assess statistical literacy needs of consultants and clients. (A copy of the questionnaire can be obtained by writing to the author.) Five items were demographic questions relating to statistical consulting. All but two of the remaining 9 questions were of an open-ended format.

Seventy-seven members of the Special Interest Group-Educational Statisticians of AERA and 50 members of the Caucus for Women in Statistics of ASA were randomly sampled and sent the literacy survey. Many of the members of the Special Interest Group-Educational Statisticians are also members of the Caucus of Women in Statistics or ASA. Targeted individuals were requested to name a colleague who might be able to provide insights on statistical consulting. An additional 33 surveys were mailed to those individuals named, yielding a total of 160 in the study sample.

Four surveys were returned by the post office with undeliverable addresses. To replace these individuals, four names were randomly sampled from the Caucus for Women in Statistics and mailed a survey. Two of those surveyed were found to be duplicates, which reduced the accessible sample to 158. Two months after the initial mailing, 73 questionnaires were returned

and 6 individuals declined to participate in the survey for a 50% response rate. A second survey was mailed to all nonrespondents. An additional 33 questionnaires were returned, with three of those returning forms indicating that they were not able to respond as they were no longer statistical consultants. In all there were 9 decliners and 104 respondents, for a total response rate of 70% based on an accessible sample of 147. Slightly more members of the Special Interest Group-Educational Statisticians (78%) returned their questionnaires compared to those sampled from the members of the Caucus of Women in Statistics (60%).

Multiple responses were given for all but 4 of the questions (items 1, 2, 5, and 8, which are closed-ended questions). Each multiple response was coded separately, and the total number of such responses was used to determine percentages for each coded category of these items.

Demographic characteristics of the survey respondents are found in Table 1. Two more males (n = 53) responded than females (n =. 51). No differences between male and female statistical consultants were found in their responses to the demographic questions.

Table 1. Demographic Consulting Characteristics of Survey Respondents

About how long have you been providing statistical advice as a consultant? (N= 92)	
Range = 1-35 years	
Mean = 14.15 years	
SD = 7.5 years	
What portion of your time is spent consulting? (N = 104)	
6.7%	Full-time
14.4%	More than half-time
43.3%	Less than half-time
35.6%	Occasionally

Multiple responses were provided for type of client, the advice that is sought, and the type of setting for consulting. These data are given in Table 2. All but one respondent provided consulting for more than one type of client. This individual assisted only health-care providers. Consulting advice is given in more than one type of setting, with 22% of those surveyed providing a second setting for consulting; 7%, three settings; 4%, four settings; and 2%, five settings. No one indicated that the advice that is sought by client is of only one type. Most often clients seek information about design, data analysis, and interpretation of computer output.

Open-ended items were content analyzed and categories developed. Agreement was reached by two coders on all but 5% of the categories. A third coder resolved the discrepancies.

2. RESULTS

In this section, the results from the survey regarding the statistical literacy of clients are presented first and followed by the statistical literacy of the consultants.

2.1 Clients' Statistical Literacy

Responses to the questions regarding literacy of clients and consultants were compared for differences due to length of time consulting (divided into 5 categories--less than 5 years (n=17), 5 to 10 years (n=34), 11 to 15 years (n=21), 16 to 20 years (n=13), and 20 and over (n=18)), type of client, type of setting (investigated in two ways--based on the first response to the question, which was classified as educational institution (n=87) vs. all other types of settings (n=16), and those identified as in education departments (n=33), statistics departments (n=20), and psychology departments (n=7)), and gender. No differences were found for these analyses. Therefore, results are presented based on all respondents.

Statistical consultants commented on the statistical literacy of their clients in five ways: level of understanding about statistics, gender differences in statistical literacy, attempts to advance statistical understanding of those with little or no knowledge, proportion of individuals requesting additional information, and aspects lacking in statistical background of clients.

Level of understanding about statistics of individuals seeking statistical advice was assessed by requesting that respondents estimate the proportion of individuals in each of three categories: with no knowledge, a basic understanding, and advanced knowledge. Greater percentages of respondents estimated below 50% for no knowledge, above 25% for a basic understanding, and below 25% for an advanced knowledge. The estimates were investigated for

Table 2. Survey Responses to Questions Regarding Type of Client, Advice, and Setting

Who constitutes your consulting audience? [For example, students, faculty, health-care providers, lawyers, independent researchers, etc.] (*N* = 270)

28.1% - Students (graduate and undergraduate)
27.8% - Faculty and colleagues
10.7% - Independent researcher
5.2% - School districts/ school district personnel
4.8% - Health-care providers
4.1% - Business and industry
3.7% - Physicians
2.6% - Lawyers
2.2% - State and federal agencies and departments
1.9% - Engineers
1.5% - Statisticians
1.5% - Data analysts and other methodologists
1.5% - Other--foundations, testing agencies, human resources professionals, Navy and Marine Corps
1.5% - Administrators
1.1% - Clinical psychologists
1.1% - MD fellows
0.7% - Consulting company and research firms

What advice are the individuals with whom you consult seeking? [Data analytic techniques, design of research studies, interpretation of computer output, etc.] (N = 343)

27.4% - Data-analytic techniques and issues
26.5% - 'Design of research studies
21.0% - Interpretation of computer output
3.5% - How to write up results--report writing
3.2% - Computer-entry and Data input
3.2% - Use of statistical package
2.9% - Sampling
2.9% - Instrument/Scale/Questionnaire design
1.5% - Conceptualization of research problem
1.5% Data collection
1.5% Development of research questions
1.5% Measurement
1.2% Grant preparation
1.2% Summarize and present data graphically
0.9% Instrumentation
0.3% Modelling

At what type of setting do you provide statistical consulting? (N = 141)

61.7% - Educational institution
12.8% - Private practice
10.6% - Nonprofit organization
9.9% - For-profit organization
3.5% - Governmental agency
1.4% - Other--law firm, random referrals

differences based on' consulting audience, for the proportion asking for more information about statistics, and type of consulting setting. No differences were found for any of these analyses.

Eighty-eight percent reported that there were no gender differences between clients. Most often the statistical consultants reported differences between types of clients (49%) with those in the medical profession designated as the least knowledgeable and the most difficult to give advice. Those in education were compared with individuals in other disciplines or fields and were found to be less knowledgeable, in particular, industry and engineering faculty have a greater statistical literacy than those who in education. A description of differences is provided in the summary of the results, which can be obtained by writing to the author.

When queried about what was lacking in the background of those with whom they consult, statistical consultants reported a variety of weaknesses. The most frequent of which was a lack of understanding of the basic concepts such as variability, randomness, and unit of analysis (22.4%), which was followed by lack of knowledge about appropriate statistical procedures (13.2%) and lack of ability to conceptualize the research process (11.2%). Consultants also pointed to the need for advanced training in multivariate and advanced techniques (9.2%).

How do consultants attempt to improve the statistical literacy of their clients? Most often consultants refer individuals with little or not knowledge to books (30.4%) or work with them one-on-one (25.8%). Additionally consultants attempt to advance the knowledge of their clients

by suggesting courses to take (18.9%) or by referring them to journal articles (15.7%). At some of the facilities where consultants work, there are tutorial programs or private tutors available for their clients to use. A few consultants have handouts or bulletins that they have developed for use with clients needing more information.

All but 2% of the consultants indicated that their clients ask for more information about statistics. Specifically, about 40% of the respondents have 26 to 100% of their clients asking for more information, leaving 30.6% of the respondents indicating requests from clients between 11 and 25% and 27.6% between 1 and 10%. When the percentage of clients asking for additional information was contrasted with level of understanding, no relationship was found between the two items.

2.2 Consultants' Statistical Literacy

What about the statistical literacy of the consultants? They were questioned about how they handle a consulting problem that they do not know how to solve, their educational background, and techniques that they use to acquire knowledge about new statistical procedures.

Most often a client is referred to colleague (34%) with a problem that the consultant does not know how to solve, or the consultant looks through texts himself or herself and reads up on the problem (30.1%). Another approach used to handle a difficult problem is to consult with a colleague about the issue without a referral (21.8%). Rarely will a consultant suggest that the client read a book (7.8%) or journal article (6.3%).

Respondents indicated that they primarily use journal articles (28.5%) and conferences (25.1%) to acquire knowledge about new statistical procedures. Books (17.3%) and discussions with colleagues or interactions with them on projects (12.2%) are two other important sources for gaining information about new approaches in the field of statistics. Workshops (5.8%), especially the ASA Continuing Education Series, and seminars (4.7%) are used by about 10% of the respondents. Other methods include sitting in on courses at other institutions (4.1%), reading information in computer packages (1.7%), and using Bulletin Board systems (0.7%).

Coursework in general (20.3%) and specific courses (accounting for an additional 19%) were specified as being most helpful in the educational background for the individual's preparation for the consulting role (see Table 3 for specific responses). Another 20% indicated that such experiences as statistical consulting while in school, working in a statistics lab, or learning on the job were helpful. Other relevant experiences involve teaching statistical methods courses as a teaching assistant (9.8%), being a research assistant (5.9%), research experience gained by working on real data sets (5.9%), a mentor professor (5.9%), working with an experienced consultant (3.3%), and working as a statistician or programmer (2.6%).

A variety of answers were given to the question about what was missing from the consultant's educational background that would have improved their consulting (see Table 4). Almost a quarter of

Table 3. Percentages of Responses to Question About Consultants' Educational Background

What was most helpful in your educational background for your work as a statistical consultant? (N = 153)

20.3%- Course work	3.3% - Working w exp. consultant
17.6%- Statistical consulting exp/working in stat lab	3.3% - Learning on the job
9.8%- Teaching statistical methods courses as a TA	3.3% - Research methods course
5.9%- Statistical theory courses	2.6% - Stat and programmer work exp
5.9%- Being a research assistant.	2.0% - Communication/Interviewing
5.9%- Work on real data sets--research experience	2.0% - Broad scientific background
5.9%- Mentor professor	2.0% - Very little
4.6%- Courses in experimental design	1.3% - Theoretical linear models course
3.9%- Computer courses	0.7% - Time

the respondents indicated that actual consulting environment or a course in statistical consulting should have been part of their training. Other comments were given with much less -frequency. Only one other response was given about 9% of the time, which was a mathematical statistics course.

3. DISCUSSION

The majority of respondents to the survey regarding statistical literacy were consulting in an educational institution. The departments in the educational institution within which the individuals perform their consulting were varied, representing education, psychology, statistics, biostatistics, health sciences, biometrics, mathematics, and computer sciences. Many of the consultants operated in several settings in addition to the educational one. Views from those consulting in nonprofit and for-profit organizations, governmental agencies, and private practice were represented. Individuals' consulting experience ranged from one year to 35 years, with the majority of respondents having consulted at least 12. years.

Two more males than females responded to the survey. Statistics has traditionally been a field dominated by men. In particular, women represented 28.5% of the members of the AERA Special Interest Group-Educational Statisticians in 1991. One might conclude that female views were overrepresented. There were, however, no statistically significant differences found by gender in the number of years providing statistical advice as a statistical consultant or in the responses to any of the questions on the survey.

The consulting audience ranged from students (both undergraduate and graduate), faculty, and colleagues to engineers, lawyers, independent researchers, and school district personnel, which indicates that a broad spectrum of clients were seeking advice from those answering the survey. Advice ranged from the problem conceptualization, designing research studies, and development of research questions to data-analytic techniques and issues to interpretation of computer output, and report writing.

Given the characteristics of the individuals who responded to the statistical-literacy survey, it can be concluded that an experienced and varied group of consultants were represented in the survey. There were no gender, type of setting, and department affiliation differences in the responses to items on the questionnaire. With a 70% response rate, the trends and patterns in the results would be unlikely to change with additional responses.

Table 4. Percentages of Responses Indicating Missing Components from Consultants' Education (N= 110)

What was missing from your education that you think would have improved your statistical consulting?

24.5%- Actual consulting environment or a course
9.1%- Mathematical Statistics
6.4%- Nothing
5.5%- Problem-solving skills, critical thinking, communication skills
5.5%- "People" skills
4.5%- Reading in journals, critiquing statistical analyses
4.5%- Other--sampling, methods, simulation techniques (bootstrapping, etc.)
3.6%- Linear models
3.6%- Measurement, psychometrics, test use
3.6%- More involvement of faculty in applications instead of theory
3.6%- Time for more studies
2.7%- Experience in statistical consulting
2.7%- Biostats, specialized stars
2.7%- Time series course
2.7%- Multivariate methods
2.7%- Categorical course
2.7%- Experience with stat packages (Minitab)
1.8%- More variety in consulting experience
0.9%- Marketing self to clients
0.9%- Supervisory skills
0.9%- Learning to write technically
0.9%- Politics of academic environment
0.9%- Theoretical foundations
0.9%- Qualitative course
0.9%- Graphical methods
0.9%- Course in psychotherapy

All of the consultants who were surveyed reported that they use one or more techniques to acquire knowledge about new statistical procedures, which indicates that consultants are continuing to improve their statistical literacy. Although journals and books are the primary sources of new knowledge, individuals attend conferences, workshops (especially the ASA Continuing Education Series), and seminars and courses. Therefore, for practicing statisticians to stay abreast of developments in their field, associations should continue to invite papers that focus on new and recent developments in the area. Associations also should offer opportunities to learn firsthand about the advances through workshops and to interact with the individuals who are advancing knowledge in statistics and developing new methods for presenting data.

One of the possible explanations why individuals who consult, whether full-time or part-time, keep current in their field may be because they encounter clients seeking advice about problems that the consultants do not know how to solve, requesting information about a new technique or procedure, or seeking assistance with interpretation of computer output from programs involving new methodology. The majority of consultants responding to the query about problems not within their expertise handled them by looking through texts, reading up on the problem, or consulting with a colleague. If there are a number of clients with the same problem that cannot be solved by these methods, consultants May then attend workshops, seminars, or courses to advance their knowledge.

Statisticians find that course work, statistical consulting experience, and related experiences (i.e., being a research assistant, working as a statistician, etc.) from their educational background prepared them for their work as a statistical consultant When asked what was missing from their education that would have improved their consulting, respondents primarily focused on actual consulting experience and interpersonal skills (e.g., "people" skills--communication, marketing self to clients). There were no differences in what was missing from their education and the years providing statistical advice, portion of time spent consulting, and the type of setting for consulting. Both of these deficits could be satisfied while in graduate school by providing students supervised consulting experiences.

Providing consulting experience as part of educating statistical consultants could be as structured as the programs at Florida State University and Pennsylvania State University; as formal as consulting laboratory experience at the University of California at Berkeley, Wright State University, Michigan State University, and the University of Wisconsin at Madison; or as informal as students collaborating with faculty on their consulting projects. These consulting experiences are not limited to statistics or biostatistics programs but are found in schools of education with quantitative programs, such as those at the University of Wisconsin-Madison and Michigan State University. The Florida State (McCulloch et al., 1985), Pennsylvania State University (Derr & •Rosenberger, 1992), and Wright State programs focus on supervised experience and attend to the interpersonal skills. Florida State provides a didactic and experiential unit on interpersonal relations as part of the preconsulting course, whereas Wright State requires students to read Boen and Zahn (1982) as part of a pretraining session.

The programs at Florida State, Pennsylvania State, University of California at Berkeley, and Wright State are part of the degree program, and course credit is given for the laboratory consulting experience, with students meeting weekly with the faculty instructor. Other consulting experiences are student employment opportunities--University of Wisconsin-Madison and Michigan State University, where students meet individually with faculty as necessary.

The supervision could be structured along three broad lines: (a) formal, (b) informal, and (c) intermediate. At Florida State University, students are videotaped while consulting and attend three different types of meetings a week (McCulloch et al., 1985), which is a formal program. Informal programs are ones where students meet with their supervisor when questions arise, such as at the University of Wisconsin at Madison. Less formal than the Florida State program is the one at Wright State where there are weekly staff meetings with time

spent going over questions and reporting on progress of clients.

Because the opportunity for supervised consulting is a valuable experience for anyone performing statistical consulting, departments of statistics, biostatistics, or education without such units should consider providing such an opportunity. The benefits and structure of a consulting 'laboratory in a research-oriented university had been detailed by Carter et al. (1986) and Calvin. (1982). If the department faculty are reluctant to begin a statistical consulting service to train students, then faculty should provide opportunities for students to gain experience in informal ways. Within a seminar, students could advise individuals working on dissertations or theses about their research designs and data-analysis approaches. In addition, faculty could involve students in their own consulting projects.

Lastly, faculty and consulting statisticians alike may benefit from tips that have been provided by Joiner and Pollack (1982). Although given 10 years ago, their advice is still applicable and can be readily updated.

Turning to the statistical literacy of clients, consultants report the majority of their clients have a basic understanding, followed by a large percentage with no knowledge, and a smaller percentage of individuals with an advanced knowledge. The difference in statistical literacy is not between males and females but rather between disciplines. Consultants report more often that those in the fields of medicine and education are ill-prepared. They also indicated that administrators and school personnel have little statistical literacy.

In terms of what is lacking in the statistical background of the clients, the statisticians most often focused on the basic concepts, knowledge about appropriate statistical procedures, and the ability to conceptualize the research process. These aspects are essential components for an individual to be an effective researcher and for a basic course in research and in statistics. Obviously the researchers who are seeking statistical advice are not• quantitatively literate. They lack the skills necessary to carry out research investigations and evaluate the data collected, which are many of the skills recommended by the Mathematical Sciences Education Board of the National Research Council (Scheaffer, 1990) for students in elementary. and secondary schools.

These methods were reported as lacking from biostatistics in medical schools (Dawson-Saunders, Azen, Greenberg, & Reed, 1987). In the field of education, there is a shift to qualitative research, which has resulted in less emphasis on traditional research and on statistics courses. Even for qualitative researchers, basic courses in the scientific method and statistics are essential for conceptualizing the research process and for reading and analyzing research previously conducted using quantitative methods. Descriptions of such courses have been provided by Brogan and Kutner (1986) and Field (1984). For some researchers, particularly those in the medical or health-care fields, the educational background may be the only way to improve their statistical literacy. Often these individuals are unwilling to take a consultant's advice for further reading or coursework, providing that they have consulted a statistician at all.

Given the educational background of the client, consultants do advance the statistical knowledge of clients in a number of ways. They will refer the client to books, journals, or courses and will work with them one-on-one. With these efforts of the consultants, the statistical literacy of clients should be improved if the client follows through on the recommended readings and courses. Consultants can be assisted in the providing sources to clients through the use of the Current Index to Statistics, which is now available as a software package. Statisticians also might take advantage of the electronic bulletin board services that are available to post and retrieve handouts on statistical topics.

5. SUMMARY

Where are we with respect to the statistical literacy of consultants? As reported by the consultants themselves, they are actively engaged in advancing their statistical literacy and keeping abreast of developments in the field through reading journals, attending professional meetings, and participating in workshops and continuing education sessions. Their efforts must be supported and continued by the statistical professional associations. 'The

consultants cite deficits in their educational background, some of which can be accommodated by providing them consulting experience through a laboratory, by one-on-one faculty assistance, or by collaboration individually with advisors while in graduate school.

Where are we with respect to the statistical literacy of individuals seeking statistical advice? Clients' statistical literacy is improved through the efforts of the consultants either by working with the client one-on-one or by referring them to books and journals. In addition to the efforts of the consultants, a stronger research and statistical background must be provided to those individuals who will be involved in research, particularly in the health-care and educational fields. This education should not have as a goal that the researcher will become a statistician or a data analyst but rather that the researcher will become a client, that is, preparation for the researcher should be task relevant--preparing them to ask relevant questions and to understand statistical advice. Will this preparation be necessary when the effects of changes in mathematics education are realized for future generations of researchers? Individuals will be more familiar with interpretation and statistical reasoning but will still lack specific data-analysis techniques and research skills; consequently, the training of researchers should focus on conceptualizing the research process and on motivating them to seek statistical advice.

REFERENCES

Anderson, C. W., and Loynes, R. M. (1989), "University statistics--what are we trying to teach and how?," in *The second international conference .on teaching statistics, proceedings*, eds. R. Davidson and J. Swift, Victoria, BC: University of Victoria, pp. 317-321.

Boen, J. R., and Zahn, D. A. (1982), *The human side of statistical consulting*, Belmont, CA: Lifetime Learning Publications.

Bradley, R. A. (1989), "Teaching statistics in universities," in *The second international conference on teaching statistics, proceedings*, eds. R. Davidson and J. Swift, Victoria, BC: University of Victoria, pp. 308-316.

Brogan, D., and Kutner, M. H. (1986), "Graduate statistics service course," *The American Statistician*, 40, 252-254.

Carter, R. L., Scheaffer, R. L., and Marks, R. G. (1986), "The role of consulting units in statistics departments," *The American Statistician*, 40, 260-264.

Calvin, L. D. (1982), "Experience with a student consulting service," in *Teaching of statistics and statistical consulting*, eds. J. S. Rustagi and D. A. Wolfe, New York: Academic Press, pp. 311-325.

Dawson-Saunders, B., Azen, S., Greenberg, R. S., and Reed, A. H. (1987),"The instruction of biostatistics in medical schools," *The American Statistician*, 41, 263-26:

Derr, J. A., and Rosenberger, J. L. (1992), "A multi-objective course in statistical consulting education," *1992 Annual Meeting*, Boston: American Statistical Association

Field, C. (1982), "A 'reverse order' elementary statistics course," *The American Statistician*, 38, 117-119.

Joiner, B. L., and Pollack, A. K. (1982), "Practicing statistics or what they forget to say in the classroom," in *Teaching of statistics and statistical consulting*, eds. J. S. Rustagi and D. A. Wolfe, New York: Academic Press, pp. 327-342.

Marks, R. G. (1989), "Teaching statistical consulting to communicate as consultants--an example in biostatistics," in *The second international conference on teaching statistics, proceedings*, eds. R. Davidson and I. Swift, Victoria, BC: University of Victoria, pp. 325328.

McCulloch, C. E., Boroto, D. R., Meeter, D., Polland, R., and Zahn, D. A. (1985), "An expanded approach to educating statistical consultants," *The American Statistician*, 39, 159-167.

Scheaffer, R. L. (1990), "Toward a more quantitatively literate citizenry," *The American Statistician*, 44, 2-3.

Zahn, D. A. (1982), "Teaching statistical consulting: Statistical and non-statistical aspects," in *Teaching of statistics and statistical consulting*, eds. J. S. Rustagi and D. A. Wolfe, New York: Academic Press, pp. 517- • 548.