ON PUTTING STATISTICAL THEORY INTO PRACTICE

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Abstract

Several procedures are advanced for putting statistical theory into practice. The first is to realize the broadness of the field of Statistics as well as what is encompassed. The second is to realize that Statistics is one of the languages of Science, and that statistical procedures represent scientific tools or laboratory equipment for an investigator. Such a realization could add considerably to the teaching of courses in Statistics, in statistical consulting, and in statistical literature. It is suggested that a list of synonyms of statistical procedures used in the many diverse areas be prepared. Some methods of presenting new ideas, concepts, developments, and applications are listed. In this connection, a list of some new statistical journals was prepared. Despite the relatively large number of statistical journals, it is felt that three new journals are needed, viz one on statistical education, one for review and expository articles, and one for extended abstracts and short papers. The problem of narrowness of training and overspecialization of individuals in the Statistics profession needs correction as does the teaching of Statistics courses by nonstatisticians.

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Introduction

Prior to discussing the topic of the title, it is essential that we all agree on what Statistics, the subject, encompasses. For the ensuing discussion, we shall consider Statistics to be concerned with the characterization, the development, and the application of techniques and procedures for

(i) the statistical design of an investigation whether it be an experiment, a survey, an observational, or a model building study,

(ii) the statistical summary of the facts from the investigation, and

(iii) the statistical inferences that are, and that may be, drawn from the facts in the investigation about the parameters in the sampled population.

Whether or not other components are added to the above depends upon a broad view of items (i), (ii), and (iii). For example, the author considers (i) to encompass the definition and description of the population, sampling unit, experimental unit, observational unit, the sampling procedure, measurements and measuring instruments, the experiment design, the treatment design, the sample survey design, the response model or models, sample size (or replicate number), and sequential design, as well as the principles and properties concerned with any of the preceding. Statistics is not one part of the definition, as some of our inference people state; neither is it solely a study of the combinatorial properties of a procedure or design, nor is it confined solely to situations wherein the classical linear model involving homoscedasticity holds. It

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* In the Mimeo Series of the Biometrics Unit, Cornell University.

encompasses all of the above, but is much broader than statistical textbook writers would lead one to believe. It is a much broader and more creative subject than the Snedecor and Feller prototypes and copiers appear to believe. If any of you do not believe that most statistical methods texts copy Snedecor and that most probability books copy Feller, volume I, it is suggested that you become a Book Reviews Editor for a few years.

Likewise, the mathematical derivations and manipulations are often described as "the theoretical part of Statistics". Since Statistics involves much more than Mathematics, mathematical manipulations in themselves may be useless in describing statistical theory. Also, the overemphasis on number manipulation, statistical computing, may contribute little or nothing in explaining statistical theory. Computing aspects of Statistics are easy to teach, require little creativity, and can be understood by most people. Therefore, this aspect of statistical methodology tends to dominate the pages of a methods text and of the lectures of a methods course. A knowledge, the understanding, and the use of all three parts of Statistica would greatly increase the effectiveness of our teaching and statistical writing and would correct the erroneous impression of many statisticians that they are doing "design of experiments" when they perform a statistical analysis or some algebraic derivation for something that has been called a "randomized complete block experiment". Can the reader give a text-book citation wherein the population and sampling procedure for obtaining the experimental units for a "randomized complete blocks design" has been defined? Furthermore, can the reader cite a statistical textbook reference wherein the response equation has been determined rather than defined? Remember the investigator has <u>to determine</u> the real world situation rather than <u>to assume</u> it as the statistician does in his chalkboard world of a classroom.

Statistics as a Tool of the Investigator and as a Scientific Language

In order for the statistician to keep his perspective, especially if he is located in a department of Statistics or Mathematics, he should consider the uses to which new statistical theory can and/or should be applied. The developer of new statistical theory who tries to force or to entice all users of statistical procedures to use "his procedure", can, and often does, contribute to misuses and erroneous inferences. One should, of course, consider all potential uses for a new statistical procedure, but this does not necessarily imply that it should replace all previously used procedures. Quite often new developments in an area (e.g., combinatorial properties of experiment design, asymptotic normal theory, tests of hypotheses, etc.), may have no immediate application for an investigator but may be important in completing statistical theory. This in itself is justifiable, but certainly an entire department's research effort should not be concentrated on one of these areas of research. The broad view of Statistics (i.e., all aspects relative to the application, development, use, and characterization of statistical procedures) is necessary for all statisticians if the field of Statistics is to expand and to be fully accepted by investigators. It is necessary that appropriate, easy to use, and easily understood procedures be developed and be brought to the attention of the investigator. Quite often investigators, and statisticians, in one subject matter area may be unaware of techniques used in other areas. For example, reliability statistical theory quite often does not make use of genetic statistical procedures, medical statistical theory does not make use of statistical procedures for exploiting wild life populations, educational statistics does not make use of biological statistical theory, and so forth. In this connection, a very useful doctoral dissertation would be to review the procedures used in two or more subject matter areas, to compare the terminology used in the different fields, and to bring the theory

in the areas to the same level. The same type of study should be done for areas of Mathematics; for example, fractional factorial theory, coding theory, net theory, graph theory, orthogonal latin square theory, etc. If this were done, the theory in one area could be made useful in another area rather than requiring the development and application to be performed in both areas independently. This procedure has proved fruitful in certain areas in the past. (See, e.g., Farquhar, P., Ph.D. dissertation, 1974, Cornell University, where he was able to considerably advance the theory of multiattribute utility functions by using known fractional factorial theory.) Even in two areas of Statistics, the terminology may be so different that the usefulness of theory in one area may not be recognized as being useful in the other area. An example of this is the so-called "messy data" or "unbalanced data with missing subclasses" and fractional factorial areas. Any n-way classification with one or more missing subclasses becomes a fractional replicate of a complete factorial. Hence, one fruitful way of putting more of statistical theory into practice would be to clean up our terminology or at least to prepare a list of synonyms.

Another item in maintaining one's perspective as a statistician is to realize that statistical procedures represent scientific tools for an investigator in the same manner as a piece of laboratory equipment. Most investigators could care less about the asymptotic or combinatorial properties of a procedure. They want the tool to have high repeatability with a small measurement error for the investigations of the type being carried out. If the tool is so complicated that a statistician has to be hired to use it, the tool with not be used. If the tool is inappropriate because the conditions are not satisfied, it will not be used. Hence, the developer of any new statistical theory, which is planned for application, must consider the situations wherein his procedure is appropriate

and how robust it is. The user needs to be made aware of these properties. Perhaps, if the introduction of every statistical research paper was written so that a director of a research station could understand it, theory would get into practice much more quickly.

The languages of Science are considered to be English (or the national language of a country), Mathematics, Statistics, Chemistry, and perhaps Physics. It is often stated that Mathematics is the language of Science. It takes only a moment's reflection to see that this is an incomplete statement. It is one of the languages, but not the sole language of Science. We often forget that English is one of the languages of Science. Note that it is even being accepted as one of the languages of Science in non-English-speaking countries. It is definitely one of the languages of Statistics, even though some individuals imply that Mathematics is the sole language of Statistics. Likewise, any statistician who considers Statistics to be merely a branch of Applied Mathematics is doing himself and the Field of Statistics an injustice. The realization by all statisticians that Statistics is one of the languages of Science will, in itself, have an effect on how broad the statistician becomes in his training, on how he teaches his courses, on how he conducts himself in statistical consulting, and in his writing of statistical papers and books.

Methods of Putting Statistical Ideas, Applications, Concepts, and Theory into Practice

Four common methods of presenting new ideas in the teaching of Statistics, new statistical theory, new and novel applications of statistical procedures, and statistical concepts and misconceptions are:

(i) classroom lectures and seminars,

(ii) professional meetings,

(iii) special conferences or symposia, and

(iv) publication in a journal, special publication, or textbook.

In recent years there has been a considerable increase in the number of new journals containing some or all of its articles related to Statistics. Some of these are presented in Table 1. Despite the considerable number of new statistical journals it is believed that at least three new types of journals are needed. These are:

(i) a Journal of Statistical Education,

(ii) a Journal of Review and Expository Articles, and

(iii) a Journal of Short Papers and Extended Abstracts in Statistics.

A Journal of Statistical Education is needed because articles found in the following publications would be difficult if not impossible to publish in any of the present Statistics journals, including the new ones listed in Table 1:

1. Statistics in Action, editor, T. J. Sielaff.
2. Federal Statistics, volumes I and II, editors, W. A. Wallis et al.
3. Statistics: A Guide to the Unknown, editors, J. M. Tanur et al.
4. Statistics by Example, F. Mosteller et al.
5. Teacher's Commentary and Solutions for Statistics by Example, M. Zelinka and S. Weisberg.
6. The American Statistician, June 1972, papers by Hogg, Good, and Blyth.
7. Statistics at the School Level, editor, L. Råde.
8. Communications in Statistics, Statistical Education, volume 5, number 10.
9. Evaluation, volume 3, numbers 1 and 2, 1976 (Russell Sage Reports), pages 115-138.

Also, a literature on statistical consulting, expert witness testimonies in legal trials, morals and ethics connected with using statistical procedures, and procedures designed to ensure the privacy of an individual's responses or vita information, is needed. To have a literature there must be a media for publication. Such a journal as the above could answer this need.

The second type of journal needed is one on review and expository articles. The latter type article should, in general, inform the reader of a statistical procedure or property at an elementary level with simple applications. With such articles, a statistician and investigator not familiar with an area could easily obtain the basic concepts and places of application. Of course, an expository sequel to the preceding one would also be in order. The review articles could be just that, but the form depending upon the goal and interests of the author. For example, an article entitled "A review of bioassay theory in the period 1973-1977 inclusive" would be one kind of review article. The writers of doctoral dissertations, together with their thesis advisors, should be able to prepare such articles. Expository and review articles which are well done would be of considerable value to other Ph.D. students in orienting themselves and in selecting thesis topics. The existence of this type of journal would encourage individuals to write such articles simply because there would be a place for them. Presently, a writer of a review or an expository article must be subjected to the interests of an editor and to the usual reviewing processes of a journal. This process discourages authors from preparing articles of the above type, especially when the author does not know which journal would consider his article. All journals profess to desire such articles, but when one is submitted, the harassment and complications of getting the article accepted are too much for all but the most determined. One possible editorial change would be

for an editor to select an author to write a given article, but even here the memories of past experiences with review or expository articles are enough to keep one from accepting. For example, I know that I should write at least three or four expository and review articles but am unwilling to devote so much effort to these projects when I consider the possible hassels from reviewers, editors, and referees. To do a good expository or review article requires a considerable amount of effort, and the prospect of having it all wasted is just too much for most would-be authors.

The third journal possibly needed is one which would publish extended abstracts, two to three pages, which would summarize the results, illustrate possible applications, and perhaps methods of proof, and place the results in the overall statistical setting. The author should attempt to get the reader interested enough so that he would want to read the entire paper, which would be available at cost from the editorial office of the journal. The review and refereeing system for these extended abstracts and short papers would be much simplified in that it could be handled by one or two editors. It could be made fast and efficient. The author would need to justify in his covering letter why the abstract or short paper should be published. Some of this justification should also appear in the introduction. (For more discussion of this type of journal, see S. R. Searle, "On publishing extended abstracts, and reviews", The American Statistician, 27(4):155-157, 1973.) A successful journal of this type could lead to a reduction in the number of statistical journals. The number of journals is quite large (e.g., R. C. Nair, "Statistical journals in Cornell University libraries", BU-486-M in the Mimeo Series of the Biometrics Unit, Cornell University, October 1973, lists 164 journals, and he omitted a number of journals of interest to probabilists.)

The overspecialization in S atistics by masters and doctoral students needs to be corrected if new theory is to be put into practice successfully and quickly. Students trained in departments of Mathematics or the more mathematically inclined departments of Statistics know little or nothing about designing investigations or about statistical methods (including data analysis) for summarizing the results of an investigation. Likewise, students trained in the more "applied-statistics" departments often have insufficient mathematical and mathematical statistics training to read articles in The Annals of Statistics, Biometrika, or JRSS B. Individual specialists in one or two areas are often quite deficient in many other areas of Statistics. This leads to a narrowness in teaching and statistical consulting. There are strong feelings among some statisticians that if one is well-versed in Mathematics and Probability, one is qualified to teach any kind of course in Statistics. There are equally strong feelings among other statisticians and investigators that one cannot teach courses in Statistics without knowing the applications in the subject matter area of the students. There is considerable evidence to indicate that both of these extreme views are incorrect. However, regardless of the teacher's expertise in one or more areas, he must know the material he is teaching as well as the intricacies of the statistical applications of the material. He should know the material in the other Statistics courses in the curriculum in order to better blend his course with the remaining courses. Thus, a re-education of current teachers of Statistics is needed to broaden their areas of competence and effectivenesss of teaching. For example, if one is to judge statistical methods courses by the textbooks used in teaching these courses, one would find a dearth of statistical design (as defined above) and data analytic procedures. Both are necessary items if the quality of research investigations is to be raised. Remember that a large proportion of current

investigators have received only a small portion of the material presented in the G. W. Snedecor and W. G. Cochran textbook entitled 'Statistical Methods'; also, remember that the last chapter in the book is on sampling theory.' Similar statements could be made about introductory probability and statistics courses. The broadening of training for students of Statistics can be accomplished by changes in the curriculum content and requirements, and by post-graduate study. For current instructors, this can be accomplished by study leaves and grants for the express purpose of broadening their outlook and teaching. If these opportunities are not available, personal effort by the individual can accomplish much of the above by attending lectures, doing the problems, and taking the examinations in a course with which he is unfamiliar. One course a year over a period of years could work wonders for the instructor of Statistics.'

Another area that needs considerable attention by the entire Statistics profession is the teaching of courses in Statistics by non-statisticians. These individuals should be replaced as quickly as possible by statisticians who are well-versed in the subject matter involved. The replacement must know what methods are in current usage, and he must not teach mathematical and probablistic procedures which are not and will not be used in a given area. Note that, in general, the nonstatistician teaching these courses will often not be able to read papers presenting new research results in Statistics. Hence, present and new theory will not be put into practice by such individuals. Also, the non-statistician teaching Statistics courses tends to emphasize number manipulations (computing) or symbol manipulation (mathematical) rather than statistical concepts. They tend to teach what they were taught, e.g., significance and hypothesis testing, to the exclusion of other topics and of changes and broadening of statistical concepts. The correction of this problem is a must for the statistical profession, but the method of correction is extremely important if it is to be accomplished.

Journal Name	Year of Origin	Vol.No. in 1977	Nos./ Volume	Name and Address of Editor(s)
Bulletin of Applied Statistics	1974	4	2	G. K. Kanji, Dept. Mathematics and Statistics, Sheffield City Polytechnic, Sheffield, S1 1WB, England, U.K.
Canadian J. of Statistics	1975	V	2	Editor, c/o Dept. Mathematics, McGill Univ., Montreal 101, Quebec, Canada
Communications in Statistics, Series A, Theory and Methods	1972	A6	12-15	D. B. Owen, Dept. Statistics, Southern Methodist Univ., Dallas, Texas, 75275, U.S.A.
Communications in Statistics, Series B, Simulation and Computation	1972	B6	4	D. B. Owen, Dept. Statistics, Southern Methodist Univ., Dallas, Texas, 75275, U.S.A.
J. of Consumer Research	1974	?	?	R. E. Frank, Wharton School - W253, Univ. or Pennsylvania, Philadelphia, Penna., 19174, U.S.A.
J. of Educational Statistics	1976	2	4	M. Novick, 356 Lindquist Center for Measurements, Univ. of Iowa, Iowa City, Iowa, 52242, U.S.A.
J. of Multivariate Analysis	1971	7	4	P. R. Krishnajah, Air Force Flight Dynamics Lab./FBRD, Wright-Patterson AFB, Ohio, 45433, U.S.A.
J. of Multivariate Experimental Personality and Clinical Psychology	1974(?)		4	G. Pierson, Box 248, Bandon, Oregon, 97411, U.S.A.
J. of Statistical Planning and Inference	1977	1	4	J. N. Srivastava, Dept. Statistics, Colorado State Univ., Fort Collins, Colorado, 80523, U.S.A.
International J. of Mathematics and Statistics	1977	1	2	U. D'Ambrosio and P. N. Rathie, IMECC, UNICAMP, Campinos, S.P., Brasil
Scandanavian J. of Statistics, Theory and Applications	1974	4	4	Bengt Rosen, Dept. of Mathematics, Royal Institute of Technology, S-10044, Stockholm 70, Sweden
Selecta Statistica Canadiana	1973	V	4	Editor, c/o Dept. Math., Burke Sci. Bldg., Rm. 110, 1280 Main St.,W., Hamilton, Ontario, L8S-4K1, Canada
South African J. of Statistics	1967	11	2	N. F. Laubscher, Dept. Statistics, Univ. of Port Elizabeth, Port Elizabeth 6000, South Africa
The Mathematical Scientist	1976	2	2	J. Gani, Div. Mathematics and Statistics, CSIRO, P.O.Box 1965, Canberra City, A.C.T. 2601, Australia
Utilitas Mathematica	1972	11 & 12	6	R.S.D. Thomas, P.O.Box 7, Univ. Centre, Univ. of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

Table 1. Year, volume, issues, and editorial address of some new journals devoted in whole or in part to publishing articles in Statistics.