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Miscellanea

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Preparing Mathematical Statisticians for Statistical Agencies

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Abstract: The objective of this paper is to stimulate the academic community that is training mathematical statisticians. It presents the qualifications and skills sought in graduates from universities by a statistical agency, namely Statistics Canada. In major aspects, these have often not been met. In the light of their own experience, the authors put forward suggestions as to how universities might be able to assist in better preparing mathematical statisticians for statistical agencies.

Key words: Statistical training; university; government statisticians.

1. Introduction

This paper is intended to stimulate the academic community in Canada. Over the years the authors have been involved in recruiting graduates in statistics from Canadian universities. They have developed opinions on how statistics graduates of Canadian universities could be better prepared to work at Statistics Canada. This paper presents these opinions after providing background material relevant to the Statistics Canada context.

The paper begins with a brief review of the work of mathematical statisticians at Statistics Canada, especially those hired into the junior or development positions. We highlight what is required to perform the work in a junior position. Next the university recruitment program is outlined to show how attempts are made to recruit graduates that meet these requirements. We look at how our recent candidates and recruits differ from our ideal candidate or recruit. Then suggestions are made on how universities might better prepare mathematical statisticians for professional careers in a statistical office. The suggestions made by the authors are compared with some other countries' ideas and practices. The authors feel that their suggestions on how universities might better prepare students, although prepared in the Canadian statistical context, could also apply to other countries.

Finally, the authors' suggestions are limited to the current situation. As more and more university programs are adapted to better meet the needs of statistical agencies, some of the recommendations contained in this paper

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will become irrelevant. Similarly, as the statistical offices also progress, new requirements should appear and thus new suggestions for university training should emerge.

2. Work of Mathematical Statisticians at Statistics Canada

Statistics Canada employs about 130 mathematical statisticians whose main responsibilities are to provide survey design and methodology support to the many program areas (e.g., Agriculture, Industry, Labour Force Survey, Census of Population and Housing), and to undertake methodology research. These two main functions, namely service and research, are described below. We then highlight various important aspects that are part of, or arise out of, the work, namely computing, teaching, presentation and publication of results, and management.

2.1. Service function

Approximately 90% of the work of survey methodologists at Statistics Canada is in direct support of the program areas. This is statistical work relating to the design, re-design, evaluation, development and testing of sample surveys and censuses, and the use of administrative records or the combination of data from these three sources. Also included is advice on appropriate methods for analyzing complex survey data and consultation on general statistical problems.

Our methodologists are involved in many facets of the survey process, namely general survey planning, survey design (the actual sampling design, dealing with response problems, estimation), questionnaire design, data collection processes and data processing (including their quality control), survey evaluation (aimed at measuring data quality and discovering how processes can be improved) and, on occasion, giving advice on data analysis.

Since most of the recruitment of recent university graduates is into the junior developmental positions, we describe the variety of work performed at this level.

Under the close supervision of a senior methodologist, each methodologist at any given moment is usually working on four to six surveys or survey activities. These may be the design of small surveys or parts of larger ones (e.g., edit and imputation, quality control, or improved estimation).

Each survey or survey activity is generally conducted by a project team. Other members of the team typically include an economist or sociologist representing the subject matter, a systems expert and, if the survey involves field enumeration or other field operations, a regional operations representative.

The survey methodologist has the prime responsibility for ensuring that statistically sound and practical survey methods are used within the constraints (budget, time, staff, technology, and user requirements). Information on these constraints is usually available from other team members based on their knowledge and experience with similar operations. Thus, solutions are arrived at in an iterative fashion using the knowledge and experience of all team members. Based on an initial understanding of the constraints, the methodologist proposes alternative methodologies. The team selects one method and further adapts it to meet the practical and theoretical considerations that surface on closer examination.

For smaller projects, the methodologist is a project team member. For larger projects, his/her supervisor may be on the main project team. This supervisor would generally parcel out some parts of the overall methodology to different methodologists, parts that they should be capable of tackling with some help from time to time. In each case the work will usually involve consultations, meetings and discussions with program, system, and field

specialists.

One should observe that each survey presents new and different challenges and difficulties. There is not usually an "off-the-shelf" or "textbook" solution. Often methods have to be adapted or specially derived.

2.2. Research

Overall, about 10% of the time of survey methodologists is devoted to research and development. Some research is of bureau-wide application and is usually conducted by project teams with several survey methodologists. Other research is of more narrow interest, having emerged from the problems particular to a subject matter division. Both types of research deal with applications and can be tested and developed using data from the area of study.

2.3. Computing

The amount of computer use varies. It involves use of statistical and graphics packages (e.g., SAS) or programs developed internally. Tasks involving computer applications are very much a part of most junior methodologists' work when they join Statistics Canada. Often a program is put together using SAS to pilot a system that is eventually rewritten for large-scale processing on the mainframe. Research also often involves the development of pilot software, simulation and other studies.

2.4. Teaching

Many staff as they progress become involved in teaching statistical and survey courses to other bureau employees.

2.5. Presentation and publication of results

Presentation most typically occurs in meetings to brief project teams, steering committees or managers as well as in written reports to all these levels. Seminars on survey development and research completed are given to audiences with a more general background at Statistics Canada and other federal and provincial departments and agencies.

Technical reports are also prepared on all aspects of survey design and methodology, from planning to publication of survey results, or on particular aspects such as pilot surveys, estimation, quality control, and survey evaluation. Technical papers on survey development and research may appear in the Statistics Canada journal "Survey Methodology" published since 1975. Papers are also submitted to and published in international journals. Presentations of papers are also made to learned societies, to other statistical bureaus and to various Statistics Canada Advisory Committees.

2.6. Management

As a statistician progresses, he/she becomes more and more involved in management. A junior methodologist can expect to be promoted based on demonstrated abilities first to the methodologist level and then to the senior methodologist level (the first supervisory level, which can be reached in three to seven years). The senior methodologist would typically supervise a unit of junior methodologists and occasionally support staff.

Promotion rests on professional expertise and the ability to apply it. Statisticians are expected to provide leadership based on their knowledge and expertise. Thus right from the beginning, a junior statistician may be making statistical proposals for a subtask or a project. Senior methodologists can be project managers and often provide advice on planning steps required in a project. Chiefs and senior methodologists interact with directors and senior staff of divisions in planning future survey methodology activities and in assessing the resources and time required. For ongoing projects, they monitor and control the methodology input as well as direct and provide feedback on progress to the program and survey methodology directors.

It is these management and professional qualities, or at least the potential to develop and exercise them, that are sought in recruits.

3. Characteristics Sought in Recruits

The experienced statistician should have the knowledge, ability, experience and personal qualities to perform most of the above functions. In reality, junior statisticians hired more or less directly from university programs must have the requisite personal qualities as well as certain core knowledge and abilities and the potential for substantial development over a period of time to respond to the needs of a more demanding position.

The basic knowledge requirements sought in recruits for junior levels begin with a solid background in theoretical statistics and sampling theory. The first would normally be gained through courses in probability theory, statistical inference, multivariate and nonparametric analysis, linear models, analysis of variance, experimental design and so forth. For the second at least one course in sampling, with emphasis on practical applications, is essential. Some exposure to basic survey methods (including such topics as questionnaire design, editing and imputation and quality assurance) would also be highly beneficial. Finally, a solid background in computer programming (including some practical experience) is very useful.

In addition to this technical knowledge, the recruit must have the capacity to function as a consultant in the face of real-life problems. This requires the ability to analyze problems logically and to propose and justify workable (and affordable) solutions. Finding such solutions depends on the ability to select from one's acquired theoretical knowledge those methods which are relevant to the problem and to adapt them appropriately within the operational constraints. Finding solutions also depends on knowing when to consult colleagues to benefit from their specialist knowledge or experience.

Justifying these solutions to one's colleagues, clients or supervisors requires the ability to express oneself clearly and persuasively, both orally and in writing. It also requires an aptitude for explaining technical concepts and solutions in terms that a nonspecialist can readily grasp. Equally important, the statistician, as a consultant and/or a (project) team member, must be a good listener, to absorb the relevant facts as well as to establish a good rapport with colleagues. Finally, the person with the potential to be a good applied statistician will be highly motivated, interested in both the problems and the people he or she encounters, and always open to fresh ideas.

An interest in others' points of view and the willingness to dirty one's hands with the really difficult parts of the problem will go a long way to making the statistician an effective member of any project team.

4. The Recruitment Program

The recruitment of mathematical statisticians for Statistics Canada occurs annually and consists of four main phases:

(1) publicity campaign;
(2) screening of applications for interview;
(3) interview and ranking of candidates;
(4) making offers of employment.

The publicity campaign consists of conducting information sessions at Canadian universities. There are three central purposes for this activity:

- to inform students about employment opportunities at Statistics Canada and to provide all the information that a graduating student might need to apply for a position;
- to promote the benefits and the challenges of a career as a statistician and to encourage students to pursue their studies in statistics;
- to acquaint faculty members with the demands placed on practicing statisticians, to

give them an opportunity to discuss subjects of mutual interest, and to encourage them in developing improved training programs in statistics.

We believe that this direct approach not only gives visibility to Statistics Canada as a recruiter in the short run but also increases the quantity and quality of statistics graduates in the long run.

Our screening process is designed to limit interviews to candidates with strong academic training and experience, i.e. those who are likely to be the best equipped to step into the role of survey methodologist. Screening scores are assigned based on the information on the candidate's application following a formal point system. Points are assigned for courses taken in: sampling, mathematical statistics, computer science and other related areas, e.g., numerical analysis. Points for work experience are assigned on the basis of relevance and length. The candidates with the highest scores are called for interviews provided that they have a passing score in sampling and mathematical statistics.

Once a year, interviews, each lasting about an hour, are conducted at the universities by pairs of middle-level statisticians. A common set of questions is used at all universities but the individual candidates may be asked different questions as the set includes alternative and optional questions. We feel that our interviews are more technically demanding than most job interviews and might be considered more in the nature of an "oral examination."

The interview is designed to assess the candidate's knowledge, abilities and personal suitability. A candidate must pass on all three aspects to pass the interview. Some questions are of a theoretical nature, while others deal with practical problems. In this way, both the candidate's knowledge and his/her ability to use it to tackle practical problems can be gauged.

Knowledge is rated in four areas: general statistical theory, sampling, survey methodology and data analysis. Abilities are evaluated in three areas. Firstly, the interviewers look at how well answers are organized and structured. Secondly, they assess how the candidate explores and analyzes a problem, the number of solutions proposed, and their originality and quality. Lastly, they rate communication skills in terms of clarity, conciseness, appropriate use of technical vocabulary and ability to present solutions in layman's terms.

For personal suitability, observations about the candidate's demeanor during the interview are used to assess motivation, enthusiasm and self-confidence.

Based on an overall mark on the interview, each candidate is placed in one of three categories:

A. those who appear to have all the attributes to become excellent statisticians and potentially senior methodologists;
B. those who pass but have some weaknesses;
C. those who fail.

The names of all passing candidates are placed in an inventory, for one year, for use by Statistics Canada and other federal departments in filling vacancies in mathematical statistician and related positions. Interview reports are prepared on all candidates, with more detail provided for those in the first category.

Offers of employment are usually made between January and May and in practice are almost always restricted to candidates who received an A-rating on the interview as the number in this category generally exceeds the number of positions to be filled. The final selection is based on matching the requirements of a particular position with the strengths and preferences of the candidates.

Table 1 gives an idea of the magnitude of the recruitment program for the past four years. In most years, we have hired 10 to 20 of the available candidates.

Table 1. The magnitude of the recruitment program

Year	Applications	Interviewed	A-rated
81/82	196	99	30
82/83	292	122	45
83/84	295	128	44
84/85	267	82	34

5. Characteristics of Candidates

The Canadian experience over the past decade has been of a steadily increasing supply of high-quality graduates in statistics. This favourable position has made the situation highly competitive for those graduates seeking employment in the federal government. Thus, Statistics Canada has become increasingly selective in its recruiting.

To put this in perspective, it is helpful to examine the profile of a typical candidate interviewed in 1984–85 as an indicator of the level of training now expected:

- 2 semester courses in sampling,
- 11 semester courses in other mathematical statistics,
- 3 semester courses in computer science,
- 3 semester courses in other related areas,
- 1 four-month period of relevant experience.

It is quite clear from this profile that a student who has not specialized in statistics has little chance of obtaining an interview.

In hiring survey methodologists, we consider a knowledge of sampling to be very important. We found that, of those interviewed, 90% had taken at least one sampling course. Since some interview questions are specific to sampling and survey methods, candidates without this training were at a serious disadvantage. Given that sampling courses are now widely offered at Canadian universities, many candidates have the required theoretical knowledge of sampling, although they often lack practical experience.

The general level of training in mathematical statistics has risen significantly in recent years. While some candidates with as little as 6 or 7 semester courses were interviewed, such candidates often had compensating relevant experience. The wide range of courses taken by recent graduates shows a shift to training of statisticians rather than mathematicians with some statistics courses. This reflects the fact that some universities have decided to offer a full program in statistics. The result has been that the best-qualified candidates are coming from a small number of universities. Although applications were received from 38 universities and interview candidates were chosen from 21 universities, 5 universities alone provide 61% of all the candidates interviewed.

Computer science courses are considered useful training, since junior methodologists are increasingly required to use computers in their work. Most candidates have taken at least one computing course. Even of those who had no formal courses, most had learned and used at least one programming language and one statistical package as part of other course work.

Experience has become increasingly important for candidates since those who have practical experience have an easier time answering the interview questions. Of the interview candidates, 3 out of 4 had some relevant work experience. Some universities are encouraging practical work experience for their students by providing more opportunities for applied work through co-op programs[2] and statistical consulting services. Nonetheless, "lacks practical experience" was a common comment on unsuccessful candidates.

The degree obtained (B.Sc., M.Sc., or Ph.D.) is not considered in our screening or interviewing of candidates. In 1984–85, the

[2] "Co-op programs" refer to undergraduate or graduate training consisting of a combination of academic and employment terms. It is called co-operative because it entails coordination between universities and employers (industry or government).

distribution by degree of the 80 candidates interviewed was 48 bachelor's degrees, 28 master's and 4 doctorates. On average, candidates with higher degrees had better interview results. Of the 34 candidates receiving "A" ratings on the interview, there were 17 bachelor's, 14 master's and 3 doctorates. In making job offers to otherwise equally rated candidates, there has been a preference for those with higher degrees.

The interview rating of candidates in 1984–85 yielded the following percentages: 46% were rated "A" on knowledge, 45% were rated "A" on abilities and 60% were rated "A" on personal suitability. The better results on personal suitability reflect an assessment of good potential in some candidates who presented themselves well. Even though these candidates did not receive an "A" rating on knowledge and demonstrated ability, we believed that they had the talent to produce high calibre work if given more training and experience. Generally, knowledge and abilities tended to determine the overall interview result, since high ratings on these were seldom accompanied by a low rating on personal suitability.

Despite the fact that all interview candidates had taken several mathematical statistics courses, some were rated as lacking depth of knowledge. This was most evident in a minimal knowledge of survey methods even among those with sampling knowledge.

Problem-solving ability was extremely important. Good candidates expressed their answers in a clear and logical manner and suggested good ideas for solutions. Some candidate, who could think on their feet, showed this ability despite limited practical experience. Those who did poorly often gave superficial answers and could not apply their knowledge to the problems posed. "Lacks self-confidence" was a common assessment of weaker candidates.

Our overall assessment of recent graduates suggests that there is room for improvement. This is recognized by graduates themselves. Those with bachelor's degrees often opt to continue their education and reapply later to our recruitment program.

6. What We Need is Not Always What We Get

This section identifies those areas where students are adequately prepared and those areas in which we would like to see some improvements. Clearly, we cannot expect universities to produce students who correspond exactly to our needs. Universities must fulfill objectives other than simply satisfying the labour market's demands. In addition, Statistics Canada is only one employer and as such cannot speak for all employers of university-trained statisticians.

Nevertheless, there are a few areas in which we feel university-trained students could improve their formal education to be better prepared for the type of work carried out in Statistics Canada. This, we believe, could be done without violating any major objectives of a university education and would be in harmony with the provision of well-rounded post-secondary education specializing in a particular discipline (e.g., statistics).

The perceived advantages for the students would be a smoother transition from academia to employment with the federal government. In addition, insofar as university training has a lasting value, it is hoped that the suggested improvements would produce students who are able to make a more permanent and profound impact on their work environment.

Let us now consider in turn the various desirable characteristics of a statistician employed by Statistics Canada.

We seek candidates with a broad foundation in general statistical theory. The students we interview usually satisfy this requirement very well. In fact, for our purposes students often have too much training in theory. Nu-

merous in-depth courses in esoteric aspects of statistics are not particularly relevant to the type of work carried out in Statistics Canada. Furthermore, there are several important areas of statistics (e.g., experimental design and non-parametric statistics) which are rarely used in our work but where a knowledge of the fundamentals is required.

We are looking for candidates with a strong background in applied statistics and practical experience, especially in the area of sampling. It is important that candidates have some knowledge of, for example, the effect of clustering on sampling precision and cost. Practical aspects of stratification is another example of a very real problem which we face continuously. Students we interview, however, typically have very little formal or practical sampling training. (In the 1984–85 recruitment process, 47% of students who applied and 10% of those interviewed had no sampling experience.) The sampling training that students receive often places too much emphasis on the theory and not enough on the practical aspects. For example, many of our sampling errors stem not from variance-type sources but more from systematic sources of bias. The identification and measurement of these biases is far more important than the search for yet one more variance estimation procedure. However, students are often ill-equipped to find innovative ways of identifying and measuring bias.

We are looking for students with at least some experience of general survey methodology (e.g., questionnaire design). It is our understanding that very few universities in Canada offer such courses, and this can be seen in the students we interview. In most cases, the assumption is that new recruits have no experience in this area and that we have to train them, both through formal courses and through practical hands-on experience. We also need students who have some knowledge of statistical quality control and data quality evaluation methods.

We are looking for students with maturity who can work as members of a multi-disciplinary team, who communicate well, and who have some idea of what project management is and how it operates. The students we interview receive virtually no formal training in these areas. Some are better prepared than others by virtue of, for example, summer employment. A statistician at Statistics Canada does not work in isolation. Individuals are obliged to pool resources to complete many projects. To succeed, the statistician must be extremely adept at working with others, creating good relationships, planning and organizing his/her own time, and in general working in an environment more structured than academia. We find many students have not been adequately prepared for this transition. Both oral and written communication skills need to be developed.

We are looking for students with at least some experience in computer programming, general knowledge of computer hardware, and experience with software, especially statistical packages. It is more often the case that students are well-trained in this area and that the only additional training needed is to acquaint new employees with Statistics Canada's particular environment. However, there are still students who have not worked with the standard statistical packages (SAS, SPSS, BMDP) during their university careers. We would consider such students to be considerably less well prepared than students who have worked at least a little with these packages.

We are looking for students with a strong potential for doing statistical analysis. Statistics Canada is slowly broadening its scope to include more than the simple collection, compilation, and dissemination of descriptive data. However, analysis of data requires skills that we find are in general not well-developed in students we interview. Very often students

have absorbed the rigorous and formal statistical techniques without having appreciated or even understood how these techniques should be applied to extract substantive information from the data. It is one thing to learn the statistical properties of the chi-square statistic, the regression model, and even factor analysis. It is quite another exercise to be confronted with a dataset and to be told to extract its substantive information or even to test a few simple hypotheses.

Finally, we are looking for students with the ability to do research since this is an activity in which Statistics Canada is becoming increasingly involved. As with analysis, research requires a certain level of original and innovative thinking, motivation, and a sense of organization. We find that students we interview are often not well-versed or even not interested in research techniques.

One might argue that Statistics Canada should play a more active role in molding new recruits to its own needs. This is already being done with courses offered in, for example, applied statistics, management techniques, and computer science. However, offering such courses draws resources away from the production and service function that is our principal responsibility, rather than training. Furthermore, the necessity of offering courses in fundamentals (e.g., sampling) results in fewer courses that are more specific and on-the-frontier-of knowledge type which are relevant to, and should be applied in, our work.

Much of this section, and in fact much of the contents of this paper, is based on the assumption that the students we see (i.e., interview) are representative of all students produced by statistics departments in Canadian universities. In other words, our inferences are based only on those students whom we interview. However, we strongly suspect that these students are precisely the ones who are most likely to correspond to our needs.

7. Ideas on How Universities Might Better Prepare Students to be Mathematical Statisticians at Statistics Canada

The previous section has highlighted differences between Statistics Canada's requirements for staffing its mathematical statistician positions and the characteristics of graduates who apply. This section presents ideas on how universities might better prepare students to fill these positions. Six general suggestions are presented. Following each of them, a number of more specific proposals are offered.

7.1. To better adapt the technical statistical courses offered to "outside world" needs:

(a) Give a practical sampling course at the undergraduate level

This course should concentrate on advantages and disadvantages of different sampling methods and not on the derivation of theorems. This proposal is made since some universities provide insufficient or no training in sampling at the undergraduate level.

(b) Offer a survey methods course

This course would cover all the different steps in a survey, present the problems associated with each step (e.g., questionnaire design, mode of data collection and dealing with nonresponse) and would propose solutions to these problems (e.g., follow-up of nonrespondents and/or various types of imputation). This training would put sampling in a better perspective as only one of the numerous concerns of a survey designer.

(c) Give computer courses or courses requiring the use of statistical software packages as part of the compulsory body of courses

The inclusion of such computer courses as compulsory courses would ensure that graduates have some computer training.

It is still possible for students to graduate with a degree in mathematics or statistics without any computer-related training. Some universities have only mathematical or statistical courses as compulsory courses and do not include use of computer packages or languages in these courses. As things stand now, some students may not select as optional courses those that would best prepare them for a professional career in statistics.

(d) Give a course at the undergraduate level on performing research

This course would give guidance on how to approach research, break it into steps, and find techniques that could be used at each step. It would remove the misconception that research is only for geniuses and that findings are the results of brilliance or strokes of luck. Students would then be less frightened by, and more inclined towards, doing research.

(e) Offer a practical course on quality assurance and quality control

This course would distinguish between these two concepts and describe how they can be implemented. Both should be very useful to students, as these issues are becoming increasingly important in industry and government.

(f) Give a course on statistical data analysis

This course would show how to conduct a full and proper analysis on selected data sets by the application of methods studied theoretically in other courses.

7.2. To increase students' exposure to "real-world" problems:

(a) Discuss in class real problems from agencies or industries, not only those from textbooks

Techniques should be seen applied to actual problems that local industries and provincial or national statistical agencies are facing. Often, examples used in class are fictitious or unrealistic or do not apply to the world in which the students will eventually work.

(b) Obtain contracts from agencies or industries and have students working at university on these contracts under the guidance of a professor

This would expose students to applied problems similar to those they would have worked on if they had been hired directly by the contracting agency or industry. This would give them valuable practical experience. In addition, these students could receive credit(s) towards their degree and possibly even be paid under the contract.

(c) Give students co-op job assignments with participating industries or statistical agencies

In this case, students would receive the benefits of recommendation (b) above as well as direct exposure to the working environment. These students would become known to prospective permanent employers. As an example, Statistics Canada provides term employment to university students to work on specific projects under a co-op program. Students generally write up their co-op assignment experience as part of the requirements for course credit.

7.3. To give more importance to communication skills:

(a) Require students to write technical essays

This would help to develop much-needed report writing skills. Technical reports

are basic instruments for presenting the results of any (statistical) project. Students should understand that employers require good writing skills.

(b) Require students to give presentations

Students should realize that oral and presentation skills are extremely important in arousing the interest of others in one's work.

(c) Simulate situations in which students must convince managers about technical issues

These situations would develop the ability to express technical arguments in language that a non-specialist can readily understand. First, one cannot assume that a manager is up-to-date on technical issues. Secondly, they would enhance personal qualities such as persuasiveness and diplomacy, and finally, they would show students how to build and present their arguments.

(d) Grade the form as well as the technical content

This would reward students' efforts in communicating well, and would thus stimulate students to give careful consideration to the presentation of their work. Otherwise, students may not spend the time and effort that these activities demand in the "outside world" where content may be ignored because of poor presentation.

(e) Give a course covering technical and administrative report writing and effective presentation skills

In this course, students would acquire knowledge of and practice in the elements of report writing and oral presentation. They would learn how to make effective presentations using various visual aids.

7.4. To stimulate interest in research:

(a) Seek problems with definite applications

Research projects should not simply be theoretical problems defined in a vacuum, but should address problems currently faced by industries and organizations. Students would not only develop their own understanding of statistics but also contribute to the application of statistics in industries and organizations.

(b) Have real data on which to perform research

When solving practical problems, students should use real data and not base their project on artificial data. This would help to set their research in a "real-world" environment.

(c) Postulate realistic hypotheses

Generally, hypotheses have to be formulated in the course of solving research problems. Students should be taught to postulate realistic hypotheses. It would be good to see more resources and energy spent on research based on usable conceptual frameworks.

(d) Give students the option of replacing full course(s) by research projects at the undergraduate level

Under this proposal, undergraduate students could perform research projects in place of traditional courses. Students would learn more by discovering for themselves rather than by being spoon-fed with information in a traditional course. Not only would technical skills be sharpened, but interest in research would be stimulated.

7.5. To provide some basic management training:

(a) Recommend management training courses as optional courses

This would provide some basic knowledge of the managerial considerations that are an increasing part of the concern of a scientist during his/her career.

7.6. To reward excellence in graduates:

(a) Organize an inter-university competition based on practical problems

An inter-university statistical competition could be staged with questions based on practical problems. Each team would have to develop a solution to be presented orally and in writing to a jury. Scores on each question would take into account the form as well as the technical content of the presentations. The members of the team might be rewarded with grants for further studies, summer or full-time employment or fellowships. The media would be invited to ensure wide publicity. A Statistical Society or Association might be involved in organizing the event and industry and government in providing jury members and/or practical problems.

8. Comparison with Ideas and Practices in Other Countries

Although developed independently, the recommendations reached by the authors seem to correspond quite closely with those in the report of the ASA Section on Statistical Education, Committee on Training of Statisticians for Government (Eldridge et al. (1982)). What follows are recommendations summerized from that report.

(a) Universities with baccalaureate and master's programs in statistics should offer a one- or two-semester course in sampling theory taught by a person who has had actual experience in designing a reasonably complex survey or sampling plan.

(b) Universities with baccalaureate and master's programs in statistics should offer a one- or two-semester course in statistical applications that includes education in design of experiments, quality control and reliability methods, and other specialized statistical procedures, stressing their application to actual data.

(c) Baccalaureate and master's programs in statistics should require education in missing/incomplete data techniques. This type of course should stress imputation and validation techniques in an applied setting.

(d) Universities should require all students specializing in statistics to have demonstrated capabilities in the areas of computer programming and statistical software packages.

(e) All students specializing in statistics should be required to take a one-semester course in technical writing.

(f) All programs in statistics (undergraduate or graduate) should include at least one course in which the student is required to consult with subject-matter specialists. The statistics major must be able to translate the subject-matter specialist's needs into statistical specifications, conduct the work, and then translate the results and implications back into the specialist's language.

The need to introduce the university student to "real-life" problems encountered by government statisticians led to the inclusion in their report of the three following recommendations of the American Statistical Association Conference on transfer of Methodology between Academic and Government Statisticians held in 1978.

(g) Government agencies should foster opportunities for collaboration with aca-

demic statisticians through, for example, employment of consultants, temporary exchanges of personnel with academic institutions, and study leaves for senior and junior staff members.

(h) Government statistical offices should develop materials describing vexing problems they face. Government statistical offices should also develop data packages that simulate practical governmental applications, as case studies. These materials can be used as training materials in universities.

(i) Government statistical offices should develop procedures for increasing access of university researchers to government statistics so that appropriate research can be undertaken.

There is a remarkable degree of overlap between the recommendations of the ASA committee and those of the authors. The principal differences are our inclusion of undergraduate courses on how to conduct research, statistical data analysis and management while the ASA committee in its recommendations (g), (h) and (i) focuses more on initiatives that should be taken by government agencies than on those by universities.

We should also like to make a brief comparison with the training and development of British government statisticians described by Orchard (1985), who notes the technical and communication skills required and the need to keep up-to-date with developments in informatics. Concerning communication skills, the point is made that future clients (graduate entry administrators) have spent a lot of time studying subjects which sharpen their skills in writing and speaking whereas statistician recruits have on the whole spent the last three years immersed in mathematics or something similar. As a consequence, it has been decided that future Assistant Statisticians, the new recruits, will attend the same British government developmental courses as Administration Trainees. The statisticians are expected to obtain equally high levels of expertise in communication as the administrators. Here the overlap with the authors' recommendations is especially notable with respect to the concern for communication skills development. However, the British solution is different, namely government training, while we have suggested the development and practice of communication skills as part of a statistics degree program.

The published material we have reviewed seems to support the general applicability of our recommendations. For example, we cite the development of an Applied Statistics course at the University of Sao Paulo (Peres and Morettin (1985)) and the expanded approach to educating statistical consultants taken at Florida State University (McCullogh et al. (1985)). Both anticipate some of our recommendations, with that at Florida State giving more emphasis to the process of consultation. These particular developments seem to indicate that our recommendations may be of interest to universities in other countries when they review their statistics degree course requirements.

9. Conclusions

While we recognize that some of our suggestions have already been put into practice in one form or another, they do point to some possible improvements within the framework of traditional university teaching in Canada and perhaps in other countries. The authors believe that following up on these general suggestions, if not the specific proposals, would help to better prepare graduates to be mathematical statisticians in both government and industry.

We hope we have been successful in expressing the needs of a statistical agency and stimulating a continuing dialogue among statisti-

cians in universities, statistical offices and societies. We do, however, see the universities bearing the largest responsibility for following up to create new or modified training programs.

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