Curriculum Guidelines for
Bachelor of Science Degrees in Statistical Science:
A Preliminary Proposal

G. Rex Bryce, Brigham Young University
Robert Gould, University of California at Los Angelus
William I. Notz, Ohio State University
Roxy L. Peck, California Polytechnic State University

Usually the name Statistics does not appear in either the list of undergraduate departments or that of undergraduate major from which entering students choose. Statistics is thus not seen as a discipline, nor as a possible career . . . Statistics has completely missed the opportunities for recruitment that occur during freshman college enrollment. The availability of undergraduate degree programs would remedy this. *Paul D. Minton (1983)*

1. INTRODUCTION

On May 25, 1999 a committee of ten representatives from academia, industry, and government met to consider what might be done to foster the growth of undergraduate education in statistical science. (*Amstat News*, 1999) Academic representatives included both large universities with active statistics departments and smaller four year institutions with only one or two statisticians. The non-academic representatives were from the pharmaceutical and automotive industries and from the National Science Foundation.

An important result of that meeting was the proposal for an Undergraduate Statistics Education Initiative (USEI) to be sponsored by the American Statistical Association (ASA). The vision and mission statements for the USEI are:

The Vision of the USEI is to have:

- Many opportunities for students to avail themselves of sound undergraduate educational programs in quantitative reasoning.
- Students receive a broad quantitative foundation for further study in specialized disciplines.
- Increased quantitative literacy within the modern workforce.

The Mission of the USEI is to

Expand and improve undergraduate statistical education through:

- Organizing symposia and workshops to create guidelines for programs.
- Marketing the potential for, programs in, and products of statistical education.
- Supporting the continuing development and delivery of modern statistics curricula.

Among the specific recommendations of the committee was the need to develop curriculum guidelines for bachelor's degrees in statistical science. Pursuant to this recommendation a workshop, partially supported by a grant from the National Science Foundation was held on April 28-29, 2000 in Alexandria, VA. There were 17 representatives from larger universities with separate statistics departments, 18 representatives from smaller institutions without statistics departments and five individuals from industry in the workshop.

An objective of the workshop was to develop preliminary guidelines for the topics that should be included in a modern bachelor's degree program in statistical science for institutions that could offer such degrees. An equally important objective was to develop preliminary guidelines for the topics that should be included in modern undergraduate programs/tracks in statistical science for institutions that do not offer a degree program.

The first day of the workshop was focused on curriculum guidelines for undergraduate degrees with four independent teams working simultaneously. On the second day of the workshop five new teams were organized. Two of the new teams discussed directions an individual with an undergraduate degree could take after graduation, two teams discussed the possible content of concentrations and minors in statistics, and one focused on recommendations for a degree in a liberal arts college.

Two writing teams were chosen from the participants in the workshop. The pre-workshop intent was to divide the writing on the basis of institution size, which was thought to be a surrogate for degrees versus concentrations/minors. However, during the workshop it became clear that institutional size was an inappropriate marker and that division along the lines of degree versus concentrations/minors would not accurately reflect the results of the workshop. After some discussion it was decided that a more appropriate division would be between institutions who wish to award Bachelor of Arts degrees and those who could offer Bachelor of Science degrees. Either institution type might offer a concentration of minor instead of or in addition to a degree. The Bachelor of Arts degree might be offered in a statistics department but more typically would be offered by mathematics departments in liberal arts colleges with several statisticians on the faculty. The Bachelor of Science degree would be offered primarily, though not exclusively, by statistics departments. Each of these kinds of programs have their strengths and in many ways are complementary. Each can learn from the other. Thus, the reader of this paper is encouraged to read the companion paper entitled, "Curriculum Guidelines for Bachelor of Arts Degrees in Statistical Science: A Preliminary Report," to obtain a full appreciation for the discussions at the workshop.

The authors gratefully acknowledge the efforts of all of the participants of the workshop without whose enthusiastic work neither article would have been possible. Scheaffer (2000) gives more details on the workshop and provides a list of the participants and their institutions.

2. HISTORICAL BACKGROUND

The quote at the beginning of this paper is taken from Minton's (1983) paper entitled "The Visibility of Statistics as a Discipline." In that paper he reported that the Council of Graduate Schools declared a "discipline" to exist when it "has achieved (a) A theory and body of literature; (b) A significant number of professionals working essentially in the field; (c) More than a few professional journals regularly publishing new advances in the subject; and (d) A significant market demand for its services." Clearly, statistics satisfied the requirements of this definition in the early part of the 20th century. Yet, as Minton (1983) points out in the leading quote above, statistics is not recognized as a discipline nor as a potential career by incoming freshman because of the dearth of undergraduate programs in our colleges and universities. For those interested in earlier history of this problem, O'Fallon (2000) gives some references dating back over a century.

Donald W. Marquardt (1987) urged "widespread study" of Minton's (1983) paper and used his ASA Presidential address in 1986 to argue for the same conclusion. After pointing out that the "marketing" program in statistics was based on producing "a small number of people trained at the graduate level," he goes on to say:

> "What is different about the marketing approach in such fields as engineering or business compared with statistics? The biggest single thing that is different is that these fields have created a large bachelor's-level base of people. What does this accomplish?
>
> - The field becomes legitimized and visible as a career and as a category of people available to be hired into standard jobs.
> - Employers become aware of the field.
> - The brightest and best from the bachelor's program become available as candidates for graduate training.
> - The field can grow in stature and importance in society because there can be enough statisticians to achieve visibility and influence as a discipline."

He continues,

> "the concept that applied statisticians must always be trained or experienced in another field *before* studying statistics, and the concept that statistics is inherently a graduate-level subject are inventions that fitted the era when widespread application of statistical methodology was only a futuristic vision, occurring at the dawn of the computer age in a period of heavy research funding. All of these characteristics have gradually changed. *It is time to adopt some new cultural norms that are more in tune with the external and internal problems that statistics now faces."* (Emphasis added.)

It is clear from the context of the last sentence above that Marquardt meant that to be fully recognized as a discipline in the way that engineering and business are, we must develop viable baccalaureate programs in statistics.

At the same general time that the above comments were being published the Executive Committee of ASA's Section on Statistical Education appointed a Committee on Guidelines for Undergraduate Statistics Curricula. Pirie (1986a, 1986b) published reports on the early work of the committee. The reports recommended topics that were to be covered and the number of semester credit hours under six general headings. The headings and semester hours associated with each were as follows:

- Introductory Statistical Methods (6 semester hours)
- Statistical Theory (6 semester hours)
- Advanced Applications (6 semester hours)
- Upper Division Electives (9 semester hours)
- Computer Skills (9 semester hours)
- Mathematics (18 semester hours)

The upper division electives includes both theory and methods topics from which a student could choose. Recommended computer skills included programming in a higher level language and in-depth experience in using a major statistical package.

During the data gathering phase of the committee's work a survey was sent "to every department in the U.S. and Canada that could be identified as possibly offering undergraduate degrees in statistics." (Pirie, 1986a) One of the questions asked was relative to the possibility of a future accreditation program for undergraduate degree programs. Among those responding to the survey the idea of an accreditation program received surprisingly strong support with 65% of respondents favoring the development of an accreditation program. The Southern Regional Committee on Statistics had several discussions on the idea of accreditation from 1987 through 1990 (Randles, 1998). However, nothing seems to have come from those discussions.

During the 1991 Joint Statistical Meetings in Atlanta, Georgia the Committee on Guidelines for Undergraduate Statistics Curricula met again in both closed and open sessions. The objective of the meetings was to seek further input on some minor modifications to the guidelines and to finalize a proposal to be given to the ASA Board of Directors to seek their support for formalizing the guidelines. The meetings were held, but the Executive Committee of the ASA Section on Statistical Education, which by then consisted of different individuals than those who had appointed the committee, voted not to present the report to the ASA Board which effectively killed the initiative. Due to the lack of support the whole effort was abandoned (Pirie, 2000).

There was little added to the picture until the end of the decade of the '90's. The February 1999 issue of *The American Statistician* published a special section entitled "Undergraduate Statistics: What Should Change?" The lead papers in the section by Higgins (1999) and Hogg (1999) were followed by four discussants and replies. Hogg's paper suggests a general philosophy to use for guidance in improving statistics programs – Continuous Quality Improvement (CQI). Higgins proposes some very concrete changes to the direction of an undergraduate degree in statistics, or as he suggests a "data specialist."

In the discussions Newton (1999) questions whether an undergraduate degree could be constructed within the current practical constraints to accomplish Higgins' (1999) proposals and have enough interested students who could get jobs. Yet, he goes on to point out that with some changes such a program could be developed at Texas A&M. Cobb (1999) approaches the discussion from the perspective of faculty member in a small four-year liberal arts institution. In that context he says, "the future of statistics depends to a great extent on how successfully statisticians can be at accepting and enlisting the cooperation of mathematicians." Bryce (1999) calls for a paradigm shift for statistical education. He states, "the current focus on graduate education and the attitude that one must have a bachelor's degree in another field before seeking a degree in statistics must change to recognize a bachelor's degree in Statistics as a viable, although not unique, entry into the discipline." Groeneveld (1999) also recognizes the need for working cooperatively with mathematicians and points out that there are a variety of ways which the proposals of Higgins (1999) can be accomplished in a typical undergraduate program.

3. THE CURRENT SITUATION

Although there is a perception that statistics is a graduate discipline, many institutions have developed viable undergraduate major programs in statistics. The ASA web site Directory of Colleges and Universities Offering Degree Programs in Statistics includes 83 U.S. institutions that offer a BS or BA degree in statistics. This number does not include those offering a degree in mathematics with an emphasis in statistics. The U.S. Department of Labor, in its *Occupational Outlook Handbook*, reports that about 80 colleges and universities offered bachelor's degrees in statistics in 1998. Also reported were the number of colleges and universities offering graduate programs in statistics, with approximately 100 offering master's degree programs and only about 60 offering doctoral degree programs. Many will find it surprising that more universities now offer a bachelor's degree program in statistics than offer a Ph.D. degree program.

Although most undergraduate programs in statistics are small (see Table 1 below), increased exposure to statistics in the K-12 curriculum and, in particular, the rapid growth in the high school Advanced Placement Statistics Program, are generating increased interest in the field of statistics among high school students. The number of students taking the Advanced Placement exam in statistics has more than quadrupled from 7500 in 1997 to over 33,000 in 2000, and in the four years since the inception of the AP Statistics course, many programs (BYU, Cal Poly, San Luis Obispo, and others) have seen striking increases in Freshmen enrollments in statistics bachelor's degree programs.

The curriculum of statistics bachelor's degree programs varies considerably from one institution to another. The results of a survey of 14 colleges and universities offering a bachelor's degree in statistics were described in a presentation at the USEI workshop described in Section 1 of this paper.

Table 1
Bachelor's Degrees in Statistics Awarded in 1996-1997

Number of Degrees Awarded	Number of Institutions
Less than 5	40
5 - 9	28
10 -14	5
15 -19	6
20 or more	4

The number of semester-equivalent courses in statistics required ranged from 6 to 11, the number of semester mathematics courses required ranged from 2 to 5, and the number of semester courses in computing ranged from 1 to 2. A consequence of this variability in curriculum is that some programs include both more breadth and depth than others. Some programs are consistent with the original recommendations of the Committee on Guidelines for Undergraduate Statistics Curricula described in Section 2, whereas others offer much less ambitious programs.

Three things – the perception of statistics as a graduate discipline, the growing number of students graduating with a bachelor's degree in statistics, and the variability in degree requirements from program to program – have combined to create some confusion among potential employers of bachelor's level statisticians. Many employers have discovered that graduates of strong BA/BS programs possess skills that make them valuable entry-level employees. A review of *Amstat News*, Amstat Online, and the web sites of companies advertising in *Amstat News*, found a number of employers (such as Mayo Clinic, Cleveland Clinic, Environmental Risk Analysis, GMAC, Census Bureau, Bureau of Labor Statistics, and others) advertising bachelor's level jobs with varied titles such as data coordinator, risk management analyst, SAS programer, senior medical writer, quality analyst, and, of course, statistician. These ads shared an emphasis on the ability to analyze data, interpret results, review trends, write reports, manage data bases, and program in SAS. On the other hand, there were many posted job advertisements, including those for SAS programmers, that listed a MS degree as a requirement. In fact, it is not uncommon to find nearly identical advertisements for entry level jobs with similar companies, with one requiring a bachelor's degree and the other a master's degree.

So, in spite of the fact that there are a growing number of undergraduate programs in statistics and what appears to be increased interest in statistics on the part of undergraduate students, there is a wide disparity in the curriculum at various institutions and confusion on the part of employers as to the skills and abilities that can be expected of a bachelor's level statistician. ASA recommendations for an undergraduate curriculum in statistics would surely help to diminish inconsistency and alleviate confusion.

4. CURRICULUM RECOMMENDATIONS

The recommendations in this section evolved as follows. Prior to the workshop five small teams were appointed from the participants to correspond via email and develop a preliminary list of curriculum topics for five general topic areas – statistics, non-mathematics based skills, computations, mathematics, and substantive area skills. The results of these preliminary discussions were presented on the morning of the first day of the workshop. In the afternoon of the first day, participants were divided into four independent teams. Each consisted of individuals from larger institutions with separate statistics departments, smaller institutions without statistics departments, and industry. This insured that diverse viewpoints were represented. Each team was asked to formulate curriculum guidelines for undergraduate degrees in statistics using the results of the preliminary discussions as a starting point. We now summarize the recommendations of these teams.

4.1 General Considerations

Before beginning to formulate curriculum guidelines for undergraduate programs, the teams considered a number of issues. First, what do statisticians do? They analyze data for important problems and develop methodologies for such analyses. These analyses may include the use of mathematical and/or probability modeling and will likely require the use of statistical and other software. They also formulate and interpret quantitative arguments. Often this is done in collaboration with researchers from a variety of disciplines. It is helpful to think about what skills are needed to carry out these tasks.

Second, what are possible career paths for an individual with an undergraduate degree in statistical science? Such an individual may seek employment upon completion of the degree or may pursue graduate study. Those seeking employment may be required to do a variety of tasks, such as standard statistical analyses, statistical programming, or data management. Any undergraduate curriculum should recognize that different career paths exist and may wish to offer multiple tracks. For example, a special track for "data scientists" placing greater emphasis on computing skills is worth considering, and recognizes that there is a growing demand for graduates with these skills.

Third, although statistics requires mathematics for the development of its underlying theory, statistics is distinct from mathematics and uses many non-mathematical skills. Thus the curriculum *must* be more than a sequence of mathematics courses. Faculty trained in statistics should be involved in developing an undergraduate curriculum in statistical science at any particular institution. For the undergraduate the focus should be on data analysis skills rather than on statistical theory, although some theoretical development should be required.

Finally, resources (including faculty) vary greatly from institution to institution. Thus recommendations should be flexible enough to allow schools with limited resources to implement an undergraduate curriculum.

Two approaches to formulating curriculum guidelines emerged. One was to consider core skills that students should obtain as part of an undergraduate curriculum in statistical science. The other was to consider topics that should be included in any such curriculum. The teams were asked explicitly not to think in terms of specific courses. These are complementary and the distinction between skills and topics is not sharp. An advantage of formulating the curriculum in terms of skills is flexibility. There are a variety of ways to equip students with skills. A single course may include many of the skills suggested. Some may be covered iteratively in a sequence of courses at increasingly sophisticated levels. For example, students may obtain the necessary computer skills over a sequence of statistics courses. Integrating skills throughout the curriculum exposes students to statistical ideas in a variety of contexts and helps prevent students from seeing statistics as a collection of unrelated methods.

4.2 Core Skills

In what follows, we give core skills that were identified as important. In some cases, the list of skills suggested lacks some specificity. In such cases, we also identify particular topics that should be part of the curriculum.

<u>Skills in statistical science: mathematics based</u>. Statisticians analyze data and interpret their analyses. Students need to be able to summarize and describe data, conduct graphical analyses, carry out formal statistical procedures. They need to understand statistical concepts such as variability, sources of variability, probability, independence, and correlation. How does one make a case for causality? How are statistical tests to be interpreted? What are the limits to statistical analyses? Students also need to understand mathematical and statistical modeling.

Core topics should include statistical theory (probability, distributions of random variables, estimation, and hypothesis testing), graphical data analysis methods, regression (simple, multiple, logistic, diagnostics, etc.), planned experimentation (randomization, replication, blocking, etc. analysis of variance, fixed and random effects, diagnostics, etc.). There were differing opinions as to what topics should be included in a modern course in statistical theory. This is further discussed in section 5.

<u>Skills in statistical science: non-mathematics based</u>. Non-mathematics based statistical skills are the ones most likely to be neglected in a statistician's education. Yet, it is these skills that most clearly set the statistician apart from mathematicians. Statisticians interact with individuals from a variety of disciplines. The most obvious essential skills for a statistician in such interactions are communication skills. These include the ability to write clearly, speak well, and use appropriate media in presentations. Such communications should include delivery to both technical and non-technical audiences. Teamwork and collaboration with other disciplines are also an integral part of what a statistician does. Opportunities to practice these skills should be included in a variety of venues in an undergraduate program. In practice the statistician is also called upon to manage data collection processes. This requires skill at organizing and managing projects and understanding how problems are formulated. Fundamental to the success of the statistician in all problem solving is the general concepts of statistical thinking – all work occurs in a process, all processes have variability, reducing variability leads to improvement.

A recurring topic in this area was the importance of some kind of experience. Internships, capstone style classes (Spurrier, 2000), and consulting were all mentioned as possible avenues to obtain such experience. Of course, communication of results is critical to the work of a statistician. Thus presentation skills including the use of presentation software, oral presentations, and writing effective reports are topics that should be addressed in some form. See Higgins (1999) for a detailed discussion of this area.

Computational skills. Statisticians routinely work with computers. A variety of computer skills are therefore necessary. Undergraduates should be familiar with word processing, spreadsheets, web use, email, and perhaps presentation software such as PowerPoint. To be able to write programs, students minimally need the ability to break down a problem into the logical components necessary to solve it algorithmically. Additional skills should include familiarity with a standard statistical software package, with various aspects of statistical computing (resampling, algorithms, creating graphical displays), and with various aspects of handling and managing data.

Topics should include managing data (data collection from primary and secondary sources, databases, data integrity, data preparation, documentation, data manipulation, and dealing with missing data), using statistical software (recognized statistical packages and focused purpose packages), and programming concepts. In addition, students should have a basic understanding of different operating systems including file structures, data transfer, etc., along with some exposure to issues of numerical accuracy that can impact statistical analyses.

Mathematical foundations. In order to understand statistical theory, certain mathematical skills are necessary. Minimally, these should include calculus (differentiation and integration) through multivariable calculus and applied linear algebra with an emphasis on matrix manipulations. Hopefully, such courses will include exposure to rigorous methods of proof. Some additional mathematics is beneficial for those intending to pursue graduate study and, as one participant pointed out, "you can never have too much mathematics."

Substantive area skills. To communicate with researchers from other disciplines, one must be able to interpret results in context. Thus, it is strongly recommended that the undergraduate curriculum include the equivalent of a minor or concentration in another substantive application area.

4.3 Other Recommendations

Some teams made suggestions for specific courses and ways to implement recommendations. For example, at least one team recommended that students be required to take a course from the communications department or from a faculty member with expertise in oral, written, and media presentations. Another recommendation was that focused study in a substantive area of statistics or coherent collection of applied courses is desirable. Substantive areas might include, survey sampling, industrial design, quality control, time series, survival analysis, multivariate methods, categorical data analysis, classification and clustering, or nonparametric methods. There was also considerable discussion around the idea that some of the skills such as computing and communications be integrated throughout the curriculum through projects or other means.

Lacking in the above discussion are specific recommendations regarding depth of coverage. For example, should students know a high level programming language or is a knowledge of basic programming concepts sufficient? Exactly what topics in mathematical statistics, probability, regression, analysis of variance, etc. should be covered? We leave these decisions to the discretion of individual programs or as topics for further discussion.

4.4 A Statistics Minor or Concentration.

During the second day of the workshop, participants were again divided into teams and given specific tasks. Two of these teams were asked to address the issue of a statistics minor or concentration. The following recommendations were made.

The core of a minor or concentration should consist of a course in general statistical methodology, a course in applied regression (including multiple regression), and a course from some non-exhaustive list (for example, a list such as mathematical statistics, time series, design of experiments, or Bayesian methods). Exposure to professional statistical software should be a component of both a minor and concentration.

In addition, the minor should require one or two additional courses and a concentration three or four. These might include a statistics elective, a course in probability, a discipline-based course beyond general methodology, a course in database management, or a capstone experience. Statistics electives could be grouped according to the majors of students pursuing a minor or concentration. For example, electives for students from engineering might include a course in the design and analysis of experiments or a course in quality control. For students from the social sciences, a course in sampling or categorical data analysis would be appropriate. For students from business, one might recommend a course in time series, sampling, or categorical analysis. Biology students, might consider a course in bioinformatics, statistical genetics, or applied multivariate analysis.

To be accessible to students from a broad range of backgrounds, it was recommended that a minor or concentration not require mathematical statistics. However, mathematically prepared students should be encouraged to take a course in mathematical statistics.

5. ADDITIONAL ISSUES

In this section we examine in more detail some of the issues raised in Section 4. Many other issues were discussed at the meeting, especially in the breakout sessions. While all of these were not captured some of the more important ones are summarized below. There was no attempt made to resolve some of these issues. They are given here in the hopes that as further discussions take place interested individuals will get involved.

5.1 Data Analysis

There was unanimous agreement on the need for the undergraduate statistics curriculum to include a heavy emphasis on data analysis. (And, as discussed in a later paragraph, perhaps more weight should be given to the "data" than the "analysis.") This emphasis reflects modern statistical practice, but also helps position students for careers either in industry or graduate school. Students with a solid background in data analysis should have experience with a variety of problems and gain a wide variety of skills. They should have experience with "messy" data and with cleaning and downloading data. They should acquire some consulting skills, such as defining problems based on a researcher's needs, communicating and presenting results, and providing straight-forward and relevant analyses. By emphasizing data analysis, students will gain experience in problem solving and will gain respect for the interdisciplinary nature of statistics.

5.2 Mathematical Statistics

Statistical theory is an important part of the curriculum, and is particularly important for those students headed for graduate school. However, many workshop participants expressed concern that the "traditional" mathematical statistics course needs to be re-considered. While there was no consensus on what, exactly, the ideal statistical theory course should be, many felt that the traditional course, with its emphasis on large sample size approximations and lists of distributions, did not reflect modern statistical practice. A modern statistical theory course might, for example, include more work on computer intensive methods and non-parametric modeling. The statistical theory course is, for many students, the introduction to statistics, and in this role the course should provide students with an overview of statistics and statistical thinking at least as strong as that provided in many non-mathematical introductory statistics courses. (For example, Freedman, Pisani, and Purves, 1998.) Clearly, this is a topic that needs more discussion and should be taken up in a future workshop.

5.3 Electives

The curriculum guidelines given in section 4 were deliberately general. It is understood that departments and institutions will fill in details that take advantage of local strengths, the needs of students, and the demands of the local economy. However, students' future plans and current desires will determine, to some extent, the degree of specialization that is desirable in an undergraduate statistics degree. Clearly the core skills listed in section 4.2 are the basis for any undergraduate degree in statistics. However, in addition to these core skills and the related topics identified in section 4.2, what electives should be available to students who wish to focus on a specific career plan?

To address this question, on the second day of the workshop two of the five teams were asked to discuss possible post undergraduate degree directions. Each team considered one of two groups of students: those planning to attend graduate school and those planning to work in industry, where we interpret “industry” very broadly to include any non academic employment. Not only do these two groups have different needs, but within each group needs will vary depending on which type of industry the student will work in or whether the student intends to get a Masters degree or a Ph.D. Very few institutions will have the resources to be all things to all students, but this list will be helpful, we hope, in illustrating the variety of statistical careers and the resources which should be provided to help students succeed in these careers.

Preparation for graduate school. In addition to the core skills enumerated in section 4.2, for students planning on attending graduate school, additional mathematics is always desirable. In particular, students intending to work towards a Ph.D. should include a real analysis and/or a probability course and a mathematical statistics sequence. These are minimal requirements; "desirable" requirements would include strengthening communication skills (particularly for Master's students but also for Ph.D. students, many of whom will serve as teaching assistants or work in a consulting center), and computing skills (for Master's students this should be more than just programming), and as much additional statistics and mathematics as possible.

Preparation for Employment. For students intending to work in the marketplace the core skills in section 4.2 are the basis. Students intending a professional career should also include a have experience working with databases. Beyond this core, students might specialize further depending on the industry in which they plan to work. Such specialization may place unsupportable demands on a department. For example, it is unlikely that many institutions can tailor four separate programs for the four industries mentioned below, but quite possibly many of the topics can be grouped into a small number of courses, and so, for example, the difference between a student preparing for a business career and a student preparing to work in government might just be a single course.

- *Small organization (manufacturing/engineering)*
  Course work should include quality control, design of experiments and analysis of variance. Time series, and reliability would also be beneficial where possible.

- *Medical*
  Course work including SAS programming, survival analysis (with clinical trial language), categorical data analysis, and analysis of variance.

- *Business and Management*
  Course work might include sampling and surveys, multivariate analysis, quality control, and time series.

- *Government*
  Courses in sampling and surveys, bootstrapping, multivariate analysis, and "extra-statistical issues" such as privacy issues and legal requirements would be beneficial.

5.4 Marketability

One of the more serious concerns discussed at the workshop was about the viability of a statistics degree in the marketplace. The degree must be marketable to industry, who will hire the students, and also to other statisticians, who must feel that graduates of the program are capable of doing "real" statistics. Many industries have found undergraduates with statistics degrees to be valuable and effective employees (See, for example, O'Fallon, 2000). It is hoped that these guidelines will assist in marketing the degree to industry by identifying the skills that a statistics graduate can be expected to have.

Convincing other statisticians, however, could be more difficult. A few in the group felt that statistics is sufficiently complex that in truth it can be mastered only after graduate level training. Whatever it is that undergraduate statisticians might be doing, goes the reasoning, it is not statistics as most practicing statisticians think of it. However, a majority of the workshop participants felt that what is needed is a broader conception of statistics, a conception that includes data management and computer skills that assist in managing, exploring and describing data. The terms "data scientist" or "data specialist" were proposed as perhaps more accurate descriptions of what should be desired in an undergraduate statistics degree. Data specialists would be concerned with the "front end" of a data analysis project: designing and managing data collection, designing and managing data bases, manipulating and transforming data, performing exploratory and "basic" analyses (Higgins, 1999). Data scientists (or specialists) might share some coursework with computer science majors, but where a computer scientist studies compilers and assembly language, a data scientist studies data analysis and statistics.

In grappling with the problem of marketing the degree to other statisticians, it is important to keep in mind that few undergraduate degrees in the sciences prepare their students to do "real" work in their field. Some students will continue their studies in graduate school, and others will apply their undergraduate experience to a variety of related and (perhaps surprisingly) unrelated professional activities. Engineering, business, and in recent years computer science, have been the exception, rather than the rule, by producing undergraduates with a well-defined and immediately applicable skill set. Preparing undergraduate "data specialists" will provide the work force with workers with greatly needed skills, and will help achieve Marquardt's goals, as given in Section 2.

We note that at many institutions (particularly liberal arts colleges), the statistics degree must also be marketed to mathematicians. As noted in section 1, a second document entitled, "Curriculum Guidelines for Bachelor of Arts Degrees in Statistical Science: A Preliminary Proposal" has been prepared, which addresses the issues involved in offering statistics degrees, minors or concentrations within mathematics departments.

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