GUIDELINES FOR UNDERGRADUATE MINORS AND CONCENTRATIONS IN STATISTICAL SCIENCE

Ann Cannon, Cornell College

Brad Hartlaub, Kenyon College

Robin Lock, St. Lawrence University

William Notz, Ohio State University

Mary Parker, Austin Community College

Key Words: Undergraduate programs; Major programs; Minor programs; Statistical science.

ABSTRACT

Representatives from academia, industry, and government met in May 1999 and in April 2000 at the ASA Headquarters to discuss issues concerning undergraduate education in statistical science. One outcome of these meetings was the symposium entitled

"Improving the Workforce of the Future: Opportunities in Undergraduate Education," held August 12-13, 2000, in Indianapolis, IN. Among the topics discussed in the meetings and at the symposium were guidelines for minor programs in statistical science. This article summarizes the results of these discussions.

1. INTRODUCTION

The recommendations in this document arose from a series of three meetings on undergraduate education in statistical science. The first occurred on May 25, 1999. Representatives from academia (both large and small programs), industry (both the pharmaceutical and automotive industries), and government (the National Science Foundation) met to consider what might be done to foster the growth of undergraduate education in statistical science (Amstat News, 1999a). A result of that meeting was the proposal for an Undergraduate Statistics Education Initiative (USEI) to be sponsored by the American Statistical Association (ASA). Among the recommendations was the need to develop curriculum guidelines for undergraduate programs in statistical science.

The second meeting was a response to these recommendations and consisted of a workshop held on April 28 – 29, 2000 in Alexandria, VA. This was partially supported by the National Science Foundation and consisted of 17 representatives from larger universities with separate statistics departments, 18 representatives from smaller institutions without statistics departments, and five individuals from industry. Scheaffer

(2000) gives details on the workshop and provides a list of the participants and their institutions.

A primary objective of the workshop was to develop preliminary guidelines for the topics that should be included in a modern bachelors degree program in statistical science for institutions that could offer such degrees. However, participants also considered preliminary guidelines for the topics that should be included in a minor or concentration in statistics, because it was believed these would be of interest both to institutions that offer a bachelors degree as well as to institutions that do not. An important goal in developing guidelines was to avoid being overly prescriptive. This was intended to provide flexibility so that institutions with limited resources might be able to develop degree programs. Discussion began by considering the minimal content that a statistics minor or concentration should contain. Recommendations were then made to insure that the minor or concentration would be accessible to students from a diverse set of backgrounds and to insure that even departments with limited resources could implement them.

Recommendations from the workshop are presented in two papers. Tarpey, Acuna, Cobb, and DeVeaux (2001) consider curriculum guidelines for institutions offering a Bachelor of Arts degree. Recommendations for institutions awarding a Bachelor of Science degree can be found in Bryce, Gould, Notz, and Peck (2001). Both papers should be consulted to obtain a full appreciation for the discussions at the workshop as well as background information.

These papers, along with several other papers relating to undergraduate education in statistics, were presented at the third meeting, a symposium entitled, "Improving the Workforce of the Future: Opportunities in Undergraduate Statistics Education," held August 12 and 13, 2000 in Indianapolis, Indiana. During the symposium, there was considerable discussion about and interest in the statistics minor or concentration (henceforth simply referred to as a minor). Many departments that do not have the resources to offer a major in statistics would like to offer a minor. As a consequence of the level of interest, a writing team was formed to report on the minor in statistics based on the discussion and questions arising at the symposium. This paper is the result of that effort.

2. GUIDELINES FOR A MINOR IN STATISTICS

Initial drafts of Tarpey, et al. (2001) and Bryce, et al. (2001) included guidelines for minors in statistics. In both, the guidelines were modest in scope and similar in their details. The drafts were available on the web prior to the symposium in Indianapolis and participants were encouraged to read them. The recommendations in Tarpey, et al. (2001) are reproduced below.

A minor in statistics is designed to encourage students studying in another discipline to gain a deeper understanding of the field of statistics than might be gained from just one or two introductory courses. Colleges and universities are encouraged to set up minors in statistics so that, depending on the situation, students either have an opportunity for focused study in statistics without completing the major, or they have some opportunity if the college or university has no statistics major. We recommend that colleges and universities follow their own school guidelines with respect to the number and types of courses required, and the name of the group of courses (e.g. concentration, minor, or track). It is particularly beneficial for a first course to be available to freshmen (or at least sophomore) students and for additional courses to be available immediately after. Students who have an opportunity to explore their interest in statistics fairly early in their college career will be more likely to find time for additional courses. What follows is the description of a minor as we understand it.

The number of courses required for a minor may vary, typically from five to seven, depending on individual institutions. Since students will be undertaking the coursework for this minor in addition to requirements for a major in another area, the recommended requirements focus on courses in statistics, without including other courses in mathematics or computer science. Although some of the possible statistics electives might have mathematical prerequisites, a student should be able to complete a statistics minor without taking a calculus course. Note that courses from several departments might be allowed to count toward a statistics minor; although care must be taken that the content of each of the courses differs substantially from the others.

By a concentration, track, or program in statistics, we mean a collection of courses within the student's major department (such as mathematics) that demonstrates a special focus in the field of statistics. We assume that additional courses from the discipline would be used to complete the major.

Curriculum for a Minor/Concentration in Statistics

1. Core Statistics Topics (2 courses)

A sequence of two courses (for example, an introductory statistics course and an applied regression course) structured to cover the core topics of data production, inference, and applied modeling should be included. These topics and possible courses are described more fully in the discussion of majors. Courses in a student's major discipline that overlap substantially with either course in the core sequence may be substituted.

2. Electives (3 to 5 courses - depending on individual institutions)

Courses include any that would qualify as electives for the major in statistics, probability, and, in the case of minors, courses in other disciplines (for example, econometrics) that have a substantial statistical component distinct from the introductory material in the core sequence.

3. ISSUES ARISING FROM THE SYMPOSIUM

At the symposium, there was considerable interest in and enthusiasm about a minor in statistics. An impromptu survey of the approximately 150 attendees showed the following.

• Will your department institute a minor before a major? 35 responded yes.

• Do you need more specific guidelines for minor? 1 responded yes.

• Does your institution have a minor without a major? 42 responded yes

For many of the institutions represented at the symposium, the discussions about a minor in statistics were probably more relevant than those concerning a major.

During the floor discussion, many questions were raised and comments expressed. Carolyn Morgan (Hampton University) recorded these and a copy of her notes is available from the authors. A few major themes emerged and we attempt to address these below as a series of questions and answers. However, there was no fundamental disagreement with the guidelines presented in section 2 from Tarpey, et al. (2001). We therefore refer to these as simply "the guidelines" in the remainder of this paper.

The guidelines recommend a minimum of five courses: two core courses and three electives. For departments with limited resources, it may be impossible to offer enough courses on a regular basis to meet even this modest goal. Any suggestions?

Departments need not provide all courses for the minor themselves. Methodology courses offered in other departments (for example, Psychology) may be suitable for fulfilling the requirements for a minor. Capstone courses and individual studies courses (for example, a course in case studies) can also be considered.

Moore (2001) points out (using data from Loftsgaarden, Rung, and Watkins 1997) that in recent years enrollments in mathematics have been decreasing, but enrollments in statistics courses have been increasing. Also, the number of students taking the advanced placement exam in statistics has been increasing steadily over the last several years.

Implementation of a minor may therefore increase demand for and enrollments in upper level courses. This might be an argument for devoting additional resources (or a reallocation of resources) to a statistics minor.

As some courses in a minor should be upper-division courses, two-year colleges will not be able to offer a minor. However, courses taken at a two-year college may qualify for transfer credit towards a minor. Two-year colleges are encouraged to design their introductory statistics course so that it may serve as the initial course for a minor. Some two-year colleges may have faculty members with appropriate experience and training to develop and teach a good applied regression course with substantial data analysis. If there are particular institutions to which many students transfer after two years, it may make sense to design courses to closely match those required for a minor at these institutions.

What if the requirements for a minor at my institution are less than those in the guidelines?

The guidelines distinguish between a minor, a concentration, and a track with the recommendation that colleges and universities follow institutional guidelines regarding the name of the program, the number of course required, and the types of courses required. If the program at an institution requires fewer courses than those recommended in the guidelines, these requirements would supersede the recommendations. However, if fewer than five courses are required, we recommend that requirements be structured to

guarantee that there is an adequate breadth of coverage of statistics. This might be achieved by requiring a good course in applied regression as a core course.

Can you provide any guidance about specific courses that should be part of a statistics minor?

Other than suggestions about core courses, in developing guidelines we attempted to avoid being prescriptive. For those looking for explicit guidance concerning courses, we suggest that they examine the requirements of existing programs. To facilitate this, we requested information about the programs of a number of institutions. We have placed the information we received, along with a current version of guidelines for a minor, online at http://www.ma.utexas.edu/users/parker/minors/. For further information, one may wish to contact one of the institutions listed. Of course any of the authors of this paper would be willing to provide guidance.

The guidelines do not explicitly mention any requirements concerning statistical software or programming. However, we do recommend that students be exposed to some statistical software in the introductory course and certainly in any applied modeling course. We do not recommend that either a structured programming course or a statistical programming course be required, although such courses would be appropriate as electives. Because resources vary from institution to institution, we make no recommendations regarding particular software packages, but encourage departments to choose packages that are well regarded by the statistical community. Software should

allow students to solve interesting problems and one should be sure that the features that students use will give correct results. There are a number of good packages to choose from, differing in the variety of statistical analyses they can perform and price. At one end of the spectrum is a package like SAS. A number of participants at the symposium recommended SAS because of its widespread use in practice. Students preparing for a career in statistics would benefit from familiarity with SAS. However, SAS is expensive and small schools may not be able to afford it. A less comprehensive package may be a better choice for introductory courses or if students are expected to purchase copies of the software. *The American Statistician* carries reviews of packages and articles on statistical computing, and is a good source for further information.

The guidelines recommend that it be possible to complete a minor without taking calculus. Does that mean that no course that is part of the minor should have a calculus prerequisite?

We are not recommending that all the courses that can be used to fulfill the requirements for a minor be accessible to students without having calculus. Nor are we recommending that the minor be accessible to students with poor mathematical skills. Certainly a mathematical statistics course will require calculus as will any probability course that covers continuous random variables. And good mathematical skills are needed to be successful in any statistics course. We also recognize that the mathematics prerequisites will vary from course to course. We simply want to encourage departments not to make

calculus a requirement for a minor, and to have some sequence of courses that satisfy the requirements for a minor and do not have a calculus prerequisite.

Who do you see as the audience for a minor?

The guidelines recommend that requirements for a minor be constructed so that a student can complete a minor without taking calculus. The purpose of this recommendation is to make the minor accessible to as broad an audience as possible. We believe students in many majors not having a calculus requirement (the social sciences and journalism, for example) would benefit from training in statistics beyond a first course. A minor could be an attractive option to such students and some suggestions for targeting particular areas are the following.

a. Offer electives that would be particularly attractive to students from certain majors. For example, courses in data analysis and statistical software might be attractive electives for computer science majors with an interest in data mining. Electives in design of experiments or statistical process control should be attractive to engineers. Electives in survey sampling and categorical data analysis might attract minors from business or the social sciences.

b. Form interdisciplinary committees to make suggestions (and perhaps advise) students from a particular major about options for a minor in statistics. Faculty on such committees are in a position to recommend the minor to students in their major.

Larger departments may be able to provide a more extensive collection of electives than smaller departments. In such cases, departments may wish to consider a variety of minors, targeted to students in particular disciplines. Appropriate courses might be determined in consultation with faculty in these disciplines.

What do you see as the purpose of a statistics minor? How can we attract students to such a minor?

It is important to keep in mind that the basic purpose of any minor is simply to expose students to another discipline outside of their major. Thus, the requirements for a minor should be modest and a minor program in statistical science should not have as its primary objective preparation for a career in statistics. Nevertheless, anecdotal evidence suggests that engineering and business students with a minor in statistics are attractive to industry. Students that have obtained a minor in statistics are attractive to graduate programs, including graduate programs in statistics. Data concerning the employment record (one year after the degree, five years after the degree, etc.) would be useful information and might strengthen the case for the value of a minor in statistical science.

4. SUMMARY

We have presented a set of guidelines for a minor in statistical science that are the result of a series of meetings on undergraduate education in statistical science. We have

attempted to summarize the process that produced the guidelines and some of the questions regarding them.

The guidelines should be regarded as recommendations. They have not been approved or adopted by an official body. In developing them, we have tried to avoid being overly prescriptive, thus increasing the chances that even departments with limited resources can develop a minor program that meets the guidelines. Our hope is that this will be useful to departments that are seeking guidance concerning a minor in statistical science.

There are a number of specific issues that we have not addressed, but which would be important in the development of any specific program. These include the following.

• There is considerable support for the inclusion of a heavy emphasis on data analysis in the undergraduate curriculum. This reflects modern practice and highlights the interdisciplinary nature of statistics. Should a similar emphasis be part of the minor program?

• A good applied regression course is an excellent candidate for one of the core courses. What constitutes a "good" course? What might such a course look like? What textbooks might be recommended?

• Although it should not be required, a course in mathematical statistics and statistical theory could be an elective in the minor. In light of modern trends in statistics, what should an up-to-date undergraduate course in mathematical statistics look like?

• Is it reasonable to develop a statistics minor in departments lacking anyone with formal training in the discipline?

None of these issues were addressed in any detail in any of the meetings on the undergraduate curriculum in statistical science, but none of these issues are new. The interested reader is directed to Higgins (1999), Hogg (1999), and the discussions following these two papers as starting points for more information.

6. REFERENCES

Bryce, G. Rex, Gould, Robert, Notz, William I., and Peck, Roxy, L. (2001), "Curriculum Guidelines for Bachelor of Science Degrees in Statistical Science," *The American Statistician*, 55, pp. 7 – 13.

Higgins, J. J. (1999), "Nonmathematical Statistics: A New Direction for the Undergraduate Discipline," *The American Statistician*, 53, pp. 1 - 6.

Hogg, R. V. (1999), "Let's Use CQI in Our Statistics Programs," *The American Statistician*, 53, pp. 7 – 14.

Loftsgaarden, D. O., Rung, D.C., and Watkins, A. E. (1997), *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences: Fall 1995 CBMS Survey*, MAA Notes, Number 2, Washington, CD: Mathematical Association of America.

Moore, D. S. (2001), "Undergraduate Programs and the Future of Academic Statistics," *The American Statistician*, 55, pp. 1 – 6.

Scheaffer, Dick (2000), "NSF-Funded Workshop Points the Way to Undergraduate Symposium," *Amstat News*, June 2000, 276, pp. 18 - 19.

Tarpey, Thaddeus, C. Acuna, G. Cobb, R. DeVeaux (2001), "Curriculum Guidelines for Bachelor of Arts Degrees in Statistical Science," Submitted to *The Journal of Statistical Education*.