Undergraduate Statistics Education: An Introduction and Review of Selected Literature

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Abstract

A recent symposium on “Improving the Work Force of the Future: Opportunities in Undergraduate Statistics Education” was held to focus attention on the importance of undergraduate statistics education. The symposium and the approval of curriculum guidelines for undergraduate degrees by the Board of Directors of the American Statistical Association have done much to define the current state of undergraduate education in statistics and suggest directions for improvement. This article summarizes the activities leading up to the symposium and provides a brief summary of six papers from the symposium that have been published. The article concludes with a discussion of some of the outstanding issues that remain to be addressed.

1. Introduction

For over 100 years leaders in the statistics profession have expressed concern about the state of undergraduate education in statistics both in the United States and the United Kingdom (see the discussions and references in O’Fallon (2000) and Bryce, Gould, Notz, and Peck (2001)). In the United States there have been specific calls to increase the number and quality of undergraduate programs in institutions of higher learning (Minton 1983; Marquardt 1987). It is only recently that these calls have been acknowledged by a large enough cross section of statisticians to begin to have some impact. This article is a review of some of the recent activities attempting to respond to those admonitions. As a tangible measure of those activities, a brief summary of six papers on some important aspects of undergraduate statistics education is included. These papers came out of a broad based effort to gain consensus concerning undergraduate statistics education among a fairly large group of stakeholders. Finally, a brief review of some of the outstanding issues that remain is given.
The author’s personal involvement with this issue began in 1994 with his appointment as chair of the Department of Statistics at Brigham Young University. The department is widely recognized as having one of the largest and best undergraduate programs in the U.S. The department awards 30 to 40 bachelor’s degrees each year. Naturally, the department is concerned about placing those students who do not go on immediately for graduate study in gainful employment. In 1998 the author was invited to give the luncheon address at the spring meeting of the Delaware Chapter of the American Statistical Association (ASA) held to honor the memory of Donald W. Marquardt, specifically addressing the topic, “Developing Tomorrow’s Statisticians.” The topic seemed tailor made to discuss the role of undergraduate degrees in statistics as a part of the larger picture of developing future statisticians.

During the research in preparation for that address the above referenced papers by Minton and Marquardt were found. This led to an examination of the whole issue of education in statistics at all levels, not just at the undergraduate level. Because of the enthusiastic encouragement of J. Stuart Hunter (personal communication, 1998) following the delivery of the address, the author became heavily involved in an effort to treat some of the important issues relative to undergraduate education in statistics. Part of that involvement was in The American Statistician session at the 1998 Joint Statistical Meetings (JSM) entitled, “Undergraduate Statistics Education: What Should Change?” The two papers that resulted from that session were subsequently published in The American Statistician (Higgins 1999; Hogg 1999), along with contributions from various discussants and replies from the authors.

2. The Undergraduate Statistics Educations Initiative

In his published article Hogg (1999, p. 13) calls on the “ASA to organize a high-level conference” to improve undergraduate programs. Bob Hogg, Dick Scheaffer, and the author became the organizing committee for a planning meeting that ultimately led to a workshop and a symposium focused on fostering the growth of undergraduate education in statistics (Amstat News 1999a). From that planning meeting in May 1999 the ASA’s Undergraduate Statistics Education Initiative (USEI) was launched (Amstat News 1999b).

The vision of the USEI is to

- create opportunities for students to avail themselves of sound undergraduate educational programs in quantitative reasoning,
- give a broad quantitative foundation for further study in specialized disciplines, and
- increase quantitative literacy within the modern workforce.

The mission defined for the USEI is to

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

There is a clear need for interested parties to continue work on the mission of the USEI. To date only the first of these mission objectives has been addressed. As will be made clear in the last section of this article, much more work remains to be done.

3. The Symposium and Its Products

In the May 1999 meeting initial plans were laid for a symposium on “Improving the Work Force of the
Future: Opportunities in Undergraduate Statistics Education” to be held in conjunction with the JSM in August 2000 (Amstat News 1999b). Writing teams were selected and assigned to write a series of position papers. The position papers were to make a case for more and stronger undergraduate programs, to give ideas on creatively marketing such programs, to provide curriculum guidelines for programs, to examine the needs of industry and government for bachelor’s level statisticians, and to examine current efforts to improve the first course in statistics. The intervening time between the May 1999 planning meeting and the August 2000 symposium was to be used to prepare position papers to be presented at the symposium.

Because of the potential impact of guidelines for curriculum, a small group met at the 1999 JSM to plan a workshop to develop an acceptable set of guidelines. The workshop, jointly funded by the National Science Foundation and the ASA, was held in April 2000 (Scheaffer 2000). The 40 participants invited to attend the workshop were approximately evenly split between large universities with statistics departments and small liberal arts colleges, with a small number of participants from industry (see Scheaffer 2000 for a list of participants and their affiliations).

The symposium was held on August 12 and 13, 2000 in Indianapolis IN. Because the symposium was not an official part of the JSM and required a separate registration, a special effort was made to encourage attendance (Amstat News 2000). The attendance at the symposium was excellent, despite the necessity of arriving a day before the start of the JSM.

A keynote address and six position papers were presented during the symposium. The papers were posted on the ASA Web site before the symposium and participants were encouraged to read them and be prepared to discuss them during the symposium. Discussion times were scheduled after each presentation. The discussions were often quite animated and excellent suggestions were made. Many of the suggestions were used to improve the manuscripts. Three of the manuscripts were published in the The American Statistician in February 2001. The remaining three are included in this issue of the Journal of Statistical Education. A brief summary of the six papers follows.

Undergraduate Programs and the Future of Academic Statistics, Moore (2001)

This paper was the keynote address at the symposium. Moore argues that while the discipline of statistics is culturally healthy, our place in academia is endangered. He contrasts this with mathematics, which is organizationally strong but insular with declining enrollments in some areas. In order to secure the future, statisticians will need to increase the visibility of statistics in undergraduate education beyond the typical introductory methods course. A brief look at the “market” for statistics suggests increasing opportunities for undergraduate statistics education in certain “leading” disciplines that use more statistics and require less mathematics. The disciplines Moore defines as “laggard” are typically technical in nature and require more mathematics and less statistics. Thus, he concludes that the two disciplines need each other and by working together, both disciplines can benefit.

Advice from Prospective Employers on Training BS Statisticians, Ritter, Starbuck, and Hogg (2001)

This paper should be required reading for both those who offer undergraduate degrees in statistics and those seeking an undergraduate degree. The authors and contributors to this paper are statisticians from a variety of nonacademic institutions. Although the number of contributors is not large, a consistent picture of employers’ needs emerges. Issues of job titles, job requirements, and candidate qualifications are discussed. Advice to educators is also provided. One clear message from the contributors is that the ability to communicate effectively is as important to the success of a bachelor’s level statistician as knowledge of
the principle statistical methods in a given field.

First Courses in Statistical Science: The Status of Educational Reform Efforts, Garfield, Hogg, Schau, and Whittinghill (2002)

Nearly everyone’s introduction to the discipline of statistics is through some version of “Stat 101.” Unfortunately, that introduction tends not to be a happy one, and thus, few desire a second course or make subsequent use of what they have been exposed to. This paper reports the authors’ efforts to understand the impact of attempts to reform the introductory course in statistics. While the authors conclude that such courses should build strong positive attitudes toward statistics and reinforce students’ use of statistics in the real world, their data show that a consensus has not been reached as to how to accomplish that goal. It is clear from the broad based survey discussed by the authors that major changes are being made and will continue to be made in the introductory course. The common theme of these changes seems to be to focus more on concepts, big ideas, and data analysis and interpretation and less on computation, formulas, and theory.

Curriculum Guidelines for Bachelor of Science Degrees in Statistical Science, Bryce, Gould, Notz, and Peck (2001)

This paper starts with some historical background concerning the efforts to strengthen undergraduate programs in statistics. After noting the variability in degree requirements among different institutions, the authors set forth recommendations for curricula for BS degrees in statistics. The recommendations are organized with respect to required skills in statistical science (mathematical and nonmathematical), computational skills, mathematical foundations, and substantive area skills. Since students may have different career goals after the undergraduate degree, consideration is given to preparation for employment in a variety of areas, as well as preparation for graduate school.

Curriculum Guidelines for Bachelor of Arts Degrees in Statistical Science, Tarpey, Acuna, Cobb, and De Veaux (2002)

This paper is a companion to the paper by Bryce, et al. (2001), and should be read in conjunction with that paper. It gives those who are in research universities a useful perspective on an area of higher education of which they may be totally unaware. It proposes guidelines for a bachelor of arts degree in statistical science for liberal arts colleges and other institutions where statistics is taught in departments of mathematics. The recommendations include five mathematics courses, a statistical core (five courses covering data production, applied modeling, statistical theory, and synthesis), statistical electives, and an area of application. The authors also include an appendix with guidelines for minors or concentrations in statistics.

Guidelines for Undergraduate Minors and Concentrations in Statistical Science, Cannon, Hartlaub, Lock, Notz, and Parker (2002)

The guidelines given in this paper are basically the same as given in the paper above by Tarpey, et al. (2002). The added value in this paper is the discussion of six questions concerning practical issues around creating and offering a minor in statistical science. The discussions will be particularly useful to those small institutions that are struggling with limited resources. The discussions range from comments concerning the requirements for a minor to the audience and purpose of a minor in statistical science.
Collectively, these papers give a good summary of the current state of undergraduate statistics education and suggest directions that, if pursued in conjunction with the ASA undergraduate curriculum guidelines discussed below, will reduce the variation in undergraduate programs and provide a standard against which programs may be judged. By reducing the variation in undergraduate programs, employers should have a better understanding of what to expect from a bachelors level statistician and hopefully, be more willing to consider them for employment in places they may have previously hired masters level people.

4. The ASA Undergraduate Curriculum Guidelines

Following the symposium a small group of volunteers developed a set of curriculum guidelines based on the papers by Bryce, et al. (2001), Tarpey, et al. (2002) and Cannon, et al. (2002) with the intent of submitting them to the ASA Board of Directors for formal approval. After many iterations between members of the small group a draft of the guidelines was given to the ASA Section on Statistical Education for their consideration. The draft was disseminated to members of the section for their comments and suggestions for improvement. After careful consideration and some modifications, the chair of the Section on Statistical Education submitted the draft guidelines to the ASA board for their approval (Amstat News, 2001a).

On December 2, 2000 the ASA Board of Directors formally endorsed the Curriculum Guidelines for Undergraduate Programs in Statistical Science with the statement,

“The American Statistical Association endorses the value of undergraduate programs in statistical science, both for statistical science majors and for students in other majors seeking a minor or concentration.”

The guidelines can be found in Amstat News (2001b) or on the ASA Web site at www.amstat.org/education/Curriculum_Guidelines.html.

The papers by Bryce, et al. (2001), Tarpey, et al. (2002) and Cannon, et al. (2002) should be especially helpful in understanding the rationale behind the Curriculum Guidelines for Undergraduate Programs in Statistical Science. In addition to the general guidelines provided in theses sources, Higgins (1999) gives some very specific recommendations as to what a modern program in undergraduate statistics should include. He suggests specific courses that would meet the needs of an undergraduate statistics major and set the discipline of statistics apart from mathematics.

5. The Mission of the Undergraduate Statistics Education Initiative Revisited

The first objective in the USEI mission statement is “to organize symposia and workshops to create guidelines for [undergraduate statistics] programs.” With the approval of the curriculum guidelines by the ASA Board of Directors this objective has largely been met. It may be that changes to the guidelines will need to be made in the future to respond to changes in the discipline, new approaches to the curriculum, or new learning technologies. But, for the near future the current document should serve as an excellent guide for institutions wanting to improve current programs or start new ones.

However, in the six papers summarized above as well as in the papers by Higgins (1999) and Hogg (1999), the various authors raise many issues that will require the continued effort of the ASA and its membership, if we are to put undergraduate statistics education on a solid foundation. Interestingly, the issues raised by these authors fall easily under one or the other of the two remaining objectives in the
USEI mission statement

Moore (2001, p. 6) speaks of the necessity to sell our discipline and asks, “Can we sell our ideas to the institutional majority? Can we sell realistic proposals to mathematics departments? Can we sell our graduates to employers?” Higgins (1999) wonders how to establish programs where none exist. Hogg (1999) asks about the role of the ASA in strengthening the professional status of the bachelors level statistician and how we can improve our product (both the individual student and our teaching) and the marketing of it. Bryce et al. (2001) wonder how and to whom we market undergraduate programs, and Cannon et al. (2002) raise the question of who our audience is. All of these questions and issues fall under the second objective of the USEI mission, “to market the potential for, programs in, and products of statistics education.”

The third objective of the USEI mission is to “support the continuing development and delivery of modern statistical curricula.” Higgins (1999) focuses a major portion of his article on the importance of communications skills and proposes that much more attention needs to be paid to this important issue, an idea with which Ritter, et al. (2001) clearly agree. Both Moore (2001) and Tarpey, et al. (2002) stress the importance of working more closely with mathematics departments where the majority of introductory level statistics is taught. Bryce, et al. (2001) and Cannon, et al. (2002) raise concerns about the nature of a first course in statistical theory and Cannon, et al. (2002) wonder what constitutes a good course in regression analysis. Garfield, et al. (2002) are concerned with how statistical thinking or statistical reasoning is taught and how the learning of students is assessed in these fundamental areas.

It is clear that the Undergraduate Statistics Education Initiative has much to accomplish before it can be declared a success and retired. A major concern at this point is that because of our success with the first mission objective, the ASA and its membership will lose interest and move on to other things. Someone needs to step forward and provide leadership to continue to pursue the mission of the USEI so that its vision can be realized. A single individual or even a group of interested individuals cannot accomplish much in the ASA without the support and sanction of some official part of the organization. Thus, it appears that the logical entity to carry this effort forward is the Section on Statistical Education with full support from those in the ASA office charged with fostering the growth and maintaining the health of our profession.

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The initial planning meeting for the symposium was attended by ten willing workers from a variety of institutions (Amstat News 1999a). Forty representatives from academia, industry, and government participated in the curriculum workshop (Scheaffer 2000). I am most appreciative of their enthusiastic work and for the over 150 people who attended the symposium and contributed to the discussions and subsequent improvements of the resulting papers. Each of these people have contributed in some way or another to the success that has been enjoyed thus far in working on the mission of the USEI.
Finally, it is a pleasure to acknowledge the writing teams who pulled the inputs from these various sources together into coherent and informative papers. These papers have done much to help our understanding of where we are with respect to undergraduate statistics education.

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