SUSTAINING PROGRESS IN STATISTICS EDUCATION IN THE UNITED STATES THROUGH AN ANALYSIS OF THE PAST 30 YEARS OF ADVANCEMENT

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This comprehensive account of statistics education in the USA describes the changes in the American Statistical Association's (ASA) statistics education efforts during the past 30 years. These changes include the creation of committees that support the work of statistics educators in mathematics departments in four-year colleges and universities, in two-year colleges, and in schools, along with ASA recommendations on course requirements for undergraduate statistics majors and guidelines for assessment and instruction in statistics education in kindergarten through secondary school and in the first-year of college (the GAISE reports). The paper concludes with continuing and new challenges, along with future opportunities, for statistics educators in the United States and other countries.

EARLY HISTORY OF STATISTICAL EDUCATION IN THE USA

Before the 1890s, statistics, in the form of data collection and summaries, were used primarily by government statisticians and historians. In the early years of the 20th century, the ASA was dominated by applied statistics, primarily for government and business. By 1934, mathematical statisticians left ASA to create the Institute for Mathematical Statistics (Harshbargar, 1976). World War II stimulated the development of statistical methods for quality control in war industries. The University of Chicago (1949), the University of North Carolina (1946), and Stanford (1948) already had statistics departments by the late 1940's and served as models for the programs at Harvard (1957) and Michigan (1960) (Agresti & Meng, 2013). Textbooks for the applied statistician available at the time included Fisher's *Statistical Methods for Research Workers* (1925) and Snedecor's *Statistical Methods* (1938) and books for statistics students followed shortly. Hogg and Craig's *Introduction to Mathematical Statistics* was published in 1959. In 1960-61, Mosteller, Rourke, and Thomas prepared a series of books, including *Probability with Statistical Applications*, for secondary schools and for use in their course on NBC's national television network series, Continental Classroom (Mosteller et al., 2010) Snedecor and Cochran's sixth edition of *Statistical Methods* came out in 1967, and Dixon & Massey's *Introduction to Statistical Analysis* was published in 1969. The ASA's Section on Statistical Training was founded in 1947 and became the Section on Statistics Education in 1974. The section primarily served statisticians teaching mathematical statistics at large universities.

THIRTY YEARS OF ADVANCEMENT

Foundations for Changes in Statistics Education in the USA

Although statistics had been taught as an undergraduate course in colleges prior to World War I, it wasn't until the 1970's that statistics education became a focus for research. In 1982 the first International Conference on Teaching Statistics (ICOTS) was held at the University of Sheffield in Sheffield, England. The stated goal of the conference was "to improve the quality of statistics teaching on a world-wide basis." ICOTS conferences have been held at 4-year intervals since that time (http://icots.net/). Also in the early 1980's the Joint ASA/NCTM Committee initiated a Quantitative Literacy (QL) program that included the teaching of data analysis, simulation, survey sampling, and probability for secondary school and first-year college students. In 1987, Mrudula Gnanadesikan, James Landwehr, Richard Schaeffer, Jim Swift, Ann Watkins, and others developed The Quantitative Literacy Series published by Dale Seymour for the QL Workshops. In 1989, the National Council of Teachers of Mathematics (NCTM) published the first edition of its Principles and Standards for School Mathematics and this document included sections on data analysis and probability at each grade band.

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Developments in Teaching Statistics in Liberal Arts Colleges

In April, 1987, the Second Conference on the Teaching of Statistics at Oneonta was held at the State University of New York at Oneonta (Nouri, 1987). Earlier that year, Rosemary Roberts and Tom Moore began conversations about approaches to teaching introductory statistics at the undergraduate level. Their discussions, continued at Oneonta, expanded to include another 20 participants, and led to the formation of SLAW (Statistics in the Liberal Arts Workshop) in the summer of 1987 (Moore, 1999). SLAW has had a large influence on the development of teaching statistics at the undergraduate level since its beginnings.

In 1990, George Cobb, one of the original members of SLAW, started the Joint ASA/ MAA Committee on Undergraduate Statistics. The committee meets twice a year, once at the Joint Statistics Meetings, in July or August, and once at the Joint Mathematics Meetings in January. Its primary focus has been on issues in the teaching of statistics at the undergraduate level, including work to improve the MAA CUPM Curriculum Guide to reflect the concerns and needs of statisticians in departments of mathematics.

In 1992, the MAA invited Cobb to submit an NSF proposal on "Statistical Thinking and Teaching Statistics" (STATS) that supported a series of week-long workshops to teach basic statistics and new methods in teaching statistics to mathematicians who taught statistics but were not trained in statistics. The workshops consisted of lecture/discussions and individual statistical investigations carried out by participants. (Hall and Rowell, 2008)

In 1994, SLAW began planning the PR/ISM conference, Planning Regional Isolated Statisticians Meetings that convened in October, 1995, in Chaska, MN. The goals of the conference included introducing isolated statisticians to each other, demonstrating the value of small conferences for sharing teaching concerns, and encouraging regional groups of isolated statisticians to form and continue to meet. Today, the New England Isolated Statisticians group is a large and vibrant group that meets annually, but other groups started in the late 1990's met only sporadically.

Developments in the ASA Structure and in the Statistical Education Section

Concurrent with the developments in SLAW, Stat-Ed Section members began actively promoting the importance of statistics education. The accomplishments of the section included the development of an informative website (http://www.amstat.org/committees/isostat/isostat.html) and the establishment of the two awards for the best contributed paper at the Joint Statistical Meetings and for teaching innovation.

The ASA Board of Directors recognized the importance of statistics education for the profession by creating a Director of Education position and began promoting statistics education at the Kindergarten through Grade 12 (K-12), undergraduate, and graduate levels. It also greatly expanded its continuing education programs. The Association supported the on-line *Journal of Statistics Education* that greatly expanded the number and types of articles presented in the Teaching Corner of *The American Statistician*. ASA now funds an international statistician to study in the United States and the Meeting-Within-A-Meeting teacher workshops for K-12 instructors at the Joint Statistical Meeting. The Director of Statistics Education arranges webinars for K-12 teachers throughout the academic year and posts lesson plans for teaching statistics in K-12 (STEW). The webinars and lesson plans are available to all who visit the website (http://www.amstat.org/education/onlineresources.cfm).

Guidelines for Statistics Programs and for Introductory Courses

Additionally, the ASA supported the development of two curriculum guidelines, one for undergraduate programs and another for master's degree programs. Descriptions of these guidelines can be found on the ASA website (http://www.amstat.org/education/curriculumguidelines.cfm).

In 2000 the Association supported the Undergraduate Statistics Education Initiative (USEI) (Bryce, 2002), which led to another ASA Strategic Initiative that supported writing the Guidelines for Assessment and Instruction in Statistics Education (GAISE). The GAISE project created recommendations for introductory statistics course content at the college level and for statistics education in primary and secondary schools (http://www.amstat.org/education/gaise/). The GAISE College Report recommended: 1) Emphasize statistical literacy and develop statistical thinking, 2)

Use real data, 3) Stress conceptual understanding, rather than mere knowledge of procedures, 4) Foster active learning in the classroom, 5) Use technology for developing conceptual understanding and for analyzing data, and 6) Use assessments to improve and evaluate student learning.

Another ASA strategic initiative led to the creation of the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE), "whose mission is to support and advance undergraduate statistics education, in four target areas: resources, professional development, outreach, and research" (https://www.causeweb.org/). A grant from the National Science Foundation supports CAUSE's informative website. Since 2002 CAUSE has organized the United States Conference on Teaching Statistics (ICOTS), every other year. In 2012, it organized its first eCOTS, an electronic conference on teaching statistics. The Consortium regularly presents workshops and webinars for statistics educators.

Developments in Statistics Education Outside ASA that Furthered ASA Initiatives

Concurrent with the growth of statistics education initiatives within the ASA, The College Board, with the support of David Moore and later Richard Schaeffer and other ASA members, developed the Advanced Placement (AP) Examination in Statistics (http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/2151.html). The first examination was held in 1997 and 7500 students took the test. The numbers of students taking the exam now tops 150,000 annually. Many colleges give credit to students who earn a score of 3 or better (out of 5) on the AP exam in statistics. These AP students are entering college in large numbers, looking for more advanced statistics courses in their first year of college, and thus building pressure on colleges to offer a wider variety of more advanced statistics at the undergraduate level.

Following the development of the AP program in statistics, the College Board produced The College Board Standards for College Success: Mathematics and Statistics (College Board, 2006). This document addressed mathematics and statistics education in middle school (grades 6 – 8) and in high school (grades 9 - 12). The College Board recommendations for statistics education align closely with the ASA's GAISE report recommendations for intermediate and more advanced students.

Shortly after the College Board Standards were published the National Governors Association (NGA) and the Council of Chief State School Officers (CCSSO) led the development of the Common Core State Standards for Mathematical Practice (CCSSM) CCSSM at: (http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf). The CCSSM outlines the standards for mathematics content in K-12th grade and includes standards for statistics beginning in the 6th grade. Forty-five states, the District of Columbia, four territories, and the Department of Defense Education Activity have adopted these standards.

Additional Organizations that Promote Statistics Education

Three additional organizations promoted statistics education during the last 30 years, all of which have influenced statistics education in the United States. The first of these began in 1986 when George Easton, Harry Roberts, and George Tiao, professors at the University of Chicago Business School, organized the first Making Statistics More Effective in Schools of Business (MSMESB) conference (Love & Hildebrand, 2002). The importance of this development should not be underestimated. Approximately twenty percent of all undergraduate degrees earned in US colleges and universities are in the field of business administration, and all business schools require students to take, at a minimum, an introductory statistics course. The ten key MSMESB recommendations are: 1) Practice What We Preach: Remember Our Customers, 2) Use Projects, 3) Students Need to Use Technology Well, 4) Lecture Less, 5) Focus on Useful Tools, 6) Focus on Statistical Thinking, 7) Encourage Collaboration, 8) Use Case Studies, 9) Use Real Data, and 10) Presentation of Ideas Matters. Readers may note how similar these recommendations are to the recommendations of the ASA's GAISE College Report. The MSMESB conferences continue as interest groups within both the ASA and the Decision Science Institute.

In 1993 the first scientific meeting of the International Association for Statistical Education (IASE) was held in Perugia, Italy (http://iase-web.org/). The IASE is the International Statistics Institute's (ISI) equivalent of the ASA's Statistical Education Section. Its current activities include

organizing the International Conferences on Teaching Statistics, housing online IASE and ISI conference proceedings, producing the Statistics Education Research Journal (SERJ), and coordinating the International Statistical Literacy Project.

Finally, in 2001 Mathematical Association of America (MAA) approved its second special interest group, the MAA Special Interest Group on Statistics Education (SIGMAA Stat-Ed) (http://sigmaa.maa.org/stat-ed/). Many of its activities are similar to those of the ASA Stat-Ed Section. It organizes sessions and workshops at the Joint Mathematics Meetings (JMM) and at MathFest, presents an award for the best JMM contributed paper in statistics, and honors an individual with the Robert V. Hogg Award for Excellence in Teaching Introductory Statistics.

CONCLUSION

Statistics education in the United States has made great advances in the past 30 years. More students take statistics in K-12, undergraduate, graduate, and continuing education. Numerous challenges remain. These include finding effective ways to communicate best practices to the widest possible audience, promote recommendations such as those in the GAISE reports, and get these recommendations adopted in schools and colleges. Reduced funding for education at all levels presents further challenges and results in larger class sizes, heavier teaching loads for faculty, and slower adoption of new textbooks. We see at least three new challenges for statistics educators: 1) The impact of the CCSSM standards, 2) The introduction of "Big Data" into the curriculum, and 3) The assessment of the effectiveness of strikingly different methods of delivery, such as MOOs. These challenges must be addressed so that statistics remains an important component of education in the 21st-century and a desired profession.

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