

The Discipline of Statistics Education¹

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The Growing Importance of Statistics

No one will debate the fact that quantitative information is everywhere and numerical data are increasingly presented with the intention of adding credibility to advertisements, arguments, or advice. Most would also agree that being able to properly evaluate such evidence and data-based claims are important skills that all citizens should have, and therefore, that all students should learn as part of their education. It is not surprising therefore that statistics instruction at all educational levels is gaining more students and drawing more attention.

The study of statistics provides students with tools and ideas to use in order to react intelligently to quantitative information in the world around them. Reflecting this need to improve students' ability to think statistically, statistics and statistical reasoning are becoming part of the mainstream school curriculum in many countries. For example, more statistical content is being mandated in the K–12 mathematics curriculum (Australian Education Council, 1994; Curriculum Corporation, 2006; Department for Education and Employment, 1999; Ministry of Education, 1992; National Council of Teachers for Mathematics, 2000). Additionally, as more and more departments realize the importance of statistical thinking in their own disciplines, enrollments in statistics courses at the college level continue to grow (Scheaffer & Stasney, 2004). Moore (1998) suggested that statistics should be viewed as one of the liberal arts because statistics involves distinctive and powerful ways of thinking: “Statistics is a general intellectual method that applies wherever data, variation, and chance appear. It is a fundamental method because data, variation, and chance are omnipresent in modern life” (p. 134).

The Challenge of Learning and Teaching Statistics

Despite the increase in statistics instruction at all educational levels, historically the discipline and methods of statistics have been viewed by many students as a difficult topic which is unpleasant to learn. Statisticians often joke about the negative comments they hear when others learn of their profession. It is not uncommon for people to recount tales of statistics as the worst course they took in college. Many research studies over the past several decades indicate that most students and adults do not think statistically about important issues that affect their lives (Garfield & Ben-Zvi, in press). Researchers in psychology and education have documented the many consistent errors that students and adults make when trying to reason about data and chance in real world problems and contexts. In their attempts to make the subject meaningful and motivating for students,

¹ Excerpted from J. B. Garfield and D. Ben-Zvi (2007). *Developing students' statistical reasoning: connecting research and teaching practice*. Emeryville, CA: Key College Publishing (in press).

many teachers have included more authentic activities and the use of new technological tools in their instruction. However, despite the attempts of many devoted teachers who love their discipline and want to make the statistics course an enjoyable learning experience for students, the image of statistics as a hard and dreaded subject is hard to dislodge. Currently, researchers and statistics educators are trying to understand the challenges and overcome the difficulties in learning and teaching this subject so that improved instructional methods and materials, enhanced technology and alternative assessment methods may be used with students learning statistics at the pre-college and college level.

Ben-Zvi and Garfield (2004) list some of the reasons that have been identified to explain why statistics is a challenging subject to learn and teach. Firstly, many statistical ideas and rules are complex, difficult, and/or counterintuitive. It is therefore difficult to motivate students to engage in the hard work of learning statistics. Secondly, many students have difficulty with the underlying mathematics (such as fractions, decimals, proportional reasoning, algebraic formulas), and that interferes with learning the related statistical concepts. A third reason is that the context in many statistical problems may mislead the students, causing them to rely on their experiences and often faulty intuitions to produce an answer, rather than select an appropriate statistical procedure and rely on data-based evidence. Finally, students equate statistics with mathematics and expect the focus to be on numbers, computations, formulas, and only one right answer. They are uncomfortable with the messiness of data, the different possible interpretations based on different assumptions, and the extensive use of writing, collaboration and communication skills. This is also true of many mathematics teachers who find themselves teaching statistics.

The Development of the Field of Statistics Education

Statistics education is an emerging field that grew out of different disciplines and is currently establishing itself as a unique field of study. The two main disciplines from which statistics education grew are statistics and mathematics education. As early as 1944 the American Statistical Association (ASA) developed the Section on Training of Statisticians (Mason, McKenzie, & Ruberg, 1990) that later (1973) became the Section on Statistical Education. The International Statistical Institute (ISI) similarly formed an education committee in 1948. The early focus in the statistics world was on training statisticians, but this later broadened to include training, or education, at all levels. In the 1960s an interest emerged in the mathematics education field about teaching students at the pre-college level how to use and analyze data. In 1967 a joint committee was formed between the American Statistical Association (ASA) and the National Council of Teachers of Mathematics (NCTM) on Curriculum in Statistics and Probability for grades K–12.

In the early 1970s many instructional materials began to be developed in the USA and in other countries to present statistical ideas in interesting and engaging ways, e.g., the series of books *Statistics by Example*, by Mosteller, Rourke and Thomas (1973) and Mosteller, Kruskal, Pieters, and Rising (1973a–d), and *Statistics: A Guide to the*

Unknown by Tanur, Mosteller, Kruskal, Link, Pieters, Rising and Lehmann (1972), which was recently updated (Peck, Casella, Cobb, Hoerl, Nolan, Starbuck, & Stern, 2006).

In the late 1970s the ISI created a task force on teaching statistics at school level (Gani, 1979), which published a report, *Teaching Statistics in Schools throughout the World* (Barnett, 1982). This report surveyed how and where statistics was being taught, with the aim of making suggestions as to how to improve and expand the teaching of this important subject. Although there seemed to be an interest in many countries in including statistics in the K–12 curriculum, this report illustrated a lack of coordinated efforts, appropriate instructional materials, and adequate teacher training.

By the 1980s the message was strong and clear: Statistics needed to be incorporated in pre-college education and needed to be improved at the postsecondary level. Conferences on teaching statistics began to be offered, and a growing group of educators began to focus their efforts and scholarship on improving statistics education. The first *International Conference on Teaching Statistics* (ICOTS) was held in 1986 and this conference has been held in a different part of the world every four years since that date (e.g., ICOTS-7, 2006, see <http://www.maths.otago.ac.nz/icots7/icots7.php>; ICOTS-8, 2010, see <http://icots8.org/>).

In the early 1990s a working group headed by George Cobb produced guidelines for teaching statistics at the college level (Cobb, 1992) to be referred to as the new guidelines for teaching introductory statistics. They included the following recommendations: 1) emphasize statistical thinking, 2) more data and concepts, less theory and fewer recipes, and 3) foster active learning. The three recommendations were intended to apply quite broadly, whether or not a course had a calculus prerequisite, and regardless of the extent to which students are expected to learn specific statistical methods. Moore (1997) described these recommendations in terms of changes in content (more data analysis, less probability), pedagogy (fewer lectures, more active learning), and technology (for data analysis and simulations).

By the end of the 1990s there was an increasingly strong call for statistics education to focus more on statistical literacy, reasoning, and thinking. One of the main arguments presented is that traditional approaches to teaching statistics focus on skills, procedures, and computations, which do not lead students to reason or think statistically. In their landmark paper published in the *International Statistical Review*, which included numerous commentaries by leading statisticians and statistics educators, Wild and Pfannkuch (1999) provided an empirically-based comprehensive description of the processes involved in the statisticians' practice of data-based enquiry from problem formulation to conclusions. Building on the interest in this topic, *The International Research Forums on Statistical Reasoning, Thinking, and Literacy* (SRTL) began in 1999 to foster current and innovative research studies that examine the nature and development of statistical literacy, reasoning, and thinking, and to explore the challenge posed to educators at all levels— and to develop these desired learning goals for students. The SRTL Forums offer scientific gatherings every two years and related publications (for more information see <http://srtl.stat.auckland.ac.nz>).

In 2005 the Board of Directors for the American Statistical Association endorsed two reports that included recommendations for statistics education, one that focused on

Pre-K to 12, and one that focused on the introductory college course (The GAISE Reports, Franklin & Garfield, 2006). The first report offered detailed guidelines for carefully developing the important ideas of statistics over the entire pre-college curriculum, complementing the NCTM standards but offering many more details. The college report offered a set of six guidelines for teaching the introductory college statistics course (see <http://www.amstat.org/Education/gaise/GAISECollege.htm>). These guidelines suggest that the desired result of all introductory statistics courses is to produce statistically educated students, which means that students should develop statistical literacy and the ability to think statistically. They also describe student desired learning goals in an introductory course that represent what such a student should know and understand. To achieve these learning goals, the following recommendations are offered: 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 analyzing data, and 6) use assessments to improve and evaluate student learning.

One of the important indicators of a new discipline is scientific publications devoted to that topic. At the current time, there are four journals. *Teaching Statistics*, which was first published in 1979, and the *Journal of Statistics Education*, first published in 1993, were developed to focus on the teaching of statistics. While more recently the *Statistical Education Research Journal* (first published in 2002) was established to exclusively publish research in statistics education. In addition, there is a new journal devoted to statistics education – *Technology Innovations in Statistics Education* – that reports on studies of the use of technology to improve statistics learning at all levels, from kindergarten to graduate school and professional development.

Collaborations among Statisticians and Mathematics Educators

Some of the major advances in the field of statistics education have resulted from collaborations between statisticians and mathematics educators. For example, the *Quantitative Literacy Project* (QLP) was a decade-long joint project of the American Statistical Association (ASA) and the National Council of Teachers of Mathematics (NCTM) that developed exemplary materials for secondary students to learn data analysis and probability. The QLP first produced materials in 1986 (Landwehr & Watkins, 1986). Although these materials were designed for students in middle and high school, the activities were equally appropriate for college statistics classes, and many instructors began to incorporate these activities into their classes. Because most college textbooks did not have activities featuring real data sets with guidelines for helping students explore and write about their understanding, as the QLP materials provided, additional resources continued to be developed. Indeed, the QLP affected the nature of activities in many college classes in the late 1980s and 1990s and led to the *Activity Based Statistics* project, also headed by Scheaffer, designed to promote the use of high quality, well structured activities in class to promote student learning (Scheaffer, Gnanadesikan, Watkins & Witmer, 2004; Scheaffer, Watkins, Witmer & Gnanadesikan, 2004).

Members of these two disciplines have also worked together on developing the *Advanced Placement* (AP) statistics course, offered first at 1997, a college level introductory statistics course taught to high school students, part of the College Board Advanced Placement Program (see http://www.collegeboard.com/student/testing/ap/sub_stats.html?stats). Currently hundreds of high school mathematics teachers and college statistics teachers meet each summer to grade together the open-ended items on the AP Statistics exam, and have opportunities to discuss teaching and share ideas and resources.

More recent efforts to connect mathematics educators and statisticians to improve the statistical preparation of mathematics teachers include the ASA *TEAMS* project (see Franklin, 2006). A current joint study of the International Congress on Mathematics Instruction (ICMI) and the International Association for Statistical Education (IASE) is also focused on teaching and teacher education (see http://www.ugr.es/~icmi/iase_study).

Statistics versus Mathematics

Although statistics education grew out of statistics and mathematics education, statisticians have worked hard to convince others that statistics is actually a separate discipline from mathematics. Rossman, Chance and Medina (2006) describe statistics as a mathematical science that uses mathematics but is a separate discipline, “the science of gaining insight from data.” Although data may seem like numbers, Cobb and Moore (1997) argue that data are numbers with a context. And unlike mathematics, where the context obscures the underlying structure, in statistics, context provides meaning for the numbers and data cannot be meaningfully analyzed without paying careful consideration to their context: how they were collected and what they represent.

Rossman et al. (2006) point out many other key differences between mathematics and statistics, concluding that the two disciplines involve different types of reasoning and intellectual skills. It is reported that students often react differently to learning mathematics than learning statistics, and that the preparation of teachers of statistics requires different experiences than those that prepare a person to teach mathematics, such as analyzing real data, dealing with the messiness and variability of data, understanding the role of checking conditions to determine if assumptions are reasonable when solving a statistical problem, and becoming familiar with statistical software.

How different is statistical thinking from mathematical thinking? The following example illustrates the difference. A statistical problem in the area of bivariate data might ask students to determine the equation for a regression line, specifying the slope and intercept for the line of best fit. This looks similar to an algebra problem: numbers and formulas are used to generate the equation of a line. In many statistics classes taught by mathematicians, the problem might end at this stage. However, if statistical reasoning and thinking are to be developed, students would be asked questions about the context of the data and they would be asked to describe and interpret the relationship between the variables, determining whether simple linear regression is an appropriate procedure and model for these data. This type of reasoning and thinking is quite different from the mathematical reasoning and thinking required to calculate the slope and intercept using algebraic formulas. In fact, in many classes, students may not be asked to calculate the

quantities from formulas, but rather rely on technology to produce the numbers. The focus shifts to asking students to interpret the values in context (e.g., from interpreting the slope as rise over run to predicting change in response for unit-change in explanatory variable).

In his comparison of mathematical and statistical reasoning, delMas (2004) explains that while these two forms of reasoning appear similar, there are some differences that lead to different types of errors. He posits that statistical reasoning must become an explicit goal of instruction if it is to be nourished and developed. He also suggests that experiences in the statistics classroom focus less on the learning of computations and procedures and more on activities that help students develop a deeper understanding of stochastic processes and ideas. One way to do this is to ground learning in physical and visual activities to help students develop an understanding of abstract concepts and reasoning. In order to promote statistical reasoning, Moore (1998) recommends that students must experience firsthand the process of data collection and data exploration. These experiences should include discussions of how data are produced, how and why appropriate statistical summaries are selected, and how conclusions can be drawn and supported (delMas, 2002). Students also need extensive experience with recognizing implications and drawing conclusions in order to develop statistical thinking. (We believe future teachers of statistics should have these experiences as well). Recommendations such as those by Moore (1998) have led to more modern or “reformed” secondary and tertiary-level statistics courses that are less like mathematics course and more like an applied science.

The Future of Statistics Education

We anticipate continued growth and visibility of the field of statistics education as more research is conducted, more connections are made between research and teaching, and more changes are made in the teaching of statistics at all educational levels. There are increasingly more valuable and accessible resources such as curricula, publications, professional journals, innovative technology, organizations and conferences (see Garfield & Ben-Zvi, in press). As the insights from new research grow, and efforts to connect the research to teaching practice continue, we anticipate many advancements in the field, which will improve the educational experience of students who study statistics, overturn the much maligned image of this important subject, and set goals for future research and curricular development.

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