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Guest Editorial…
Common Core State Standards and the Future of Teacher Preparation in Statistics

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In our data-centric world, statistics are everywhere and statistical literacy is essential. For example, what is "margin of error" in a political poll? Is the finding from a study of a new cancer drug "statistically significant"? According to American Statistical Association's (ASA) Pre-K-12 GAISE Framework Report, "Every high-school and college graduate should be able to use sound statistical reasoning to intelligently cope with the requirements of citizenship, employment, and family and to be prepared for a healthy and productive life." (Franklin, et.al, 2007, p.1). A statistically literate citizen is proficient in basic numeracy involving data interpretation (e.g., rates, percentages, charts, and tables). A statistically literate citizen understands the strengths of the scientific process and can critically analyze media reports of scientific findings by knowing the appropriate questions to ask about the study's design and conclusions.

First, a bit of perspective. The roots of Statistics as a subject are not in Mathematics but in other areas such as agriculture, social science, and astronomy. (Box, 1985; Stigler, 1990) If we trace Statistics back to its origins, the field was created to fill a need to solve real problems. I view Statistics as helping bring Mathematics into the practical world of useful applications. Statistics and Mathematics are mutually supportive. It seems that what happened in the teaching of Statistics is, at some point, the mathematics of statistics often overshadowed its problem-solving roots.

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Historically, the teaching of Statistics at the college level has primarily been in Mathematics departments, with the courses typically being very formula-oriented, with little emphasis placed on learning concepts or on the interpretation of findings. (Moore, 1993) In such courses, communication skills have not generally been emphasized. They have been focused on computations and not on statistical reasoning (i.e., understanding how to quantify variability and interpret data in a context). The lack of accessible technology was a significant contributor to this situation, with the result being that Statistics courses have often been taught as a laundry list of topics where students depended on rote memorization rather than conceptual understanding.

However, times have changed. We are now able to teach statistical topics and reasoning skills in K-12 (as well as at the college level) using technology and problem-solving-oriented activities that in years past we could not due to the formal higher level mathematics needed. Technology allows us to focus on analyzing data from real studies, often with large data sets, and to rely on simulation in the place of mathematical theory to understand why and how statistical methods work. Technology also allows the exploration and visualization of the data. The focus of instructional time can be spent interpreting graphical and numerical representations and understanding key statistical concepts, such as margin of error and statistical significance.

How did Statistics become part of the K-12 curriculum? Statistical reasoning was promoted for inclusion in the K-12 Math curriculum as early as the 1960s (Moore, 1993), but in the 1980s we began seeing a formal movement toward quantitative literacy in K-12 with the National Council of Teachers of Mathematics (NCTM) standards in 1989. This set the stage for a successful Advanced Placement Statistics program to be developed in the early 1990s. The notion of teaching Statistics at the K-12 level gained national attention with the revision of the NCTM standards in 2000 and the publication of the ASA Pre-K-12 GAISE Framework in 2007. (NCTM, 2000; Franklin, et.al, 2007) The recently approved K-12 Common Core State Standards (CCSS) in Mathematics (adopted by approximately 46 states, including Georgia) promotes statistical reasoning skills at the middle and secondary level (CCSS, 2010). The CCSS in Mathematics gives Statistics and Probability a prominent role (alongside Algebra and

Geometry) at grades 6-12. The Statistics standards emphasize conceptual understanding and present us with the great opportunity of "statistical literacy for all." Given that almost all of the states have adopted CCSS, Statistics standards should finally be taught nationwide. Since a national assessment including statistics items will be required in 2014, it should be a guarantee that Statistics will be included in the Math curriculum for grades 6-12. The Statistics standards for grades 6-8 are located at: http://www.corestandards.org/Math/Content/SP The Statistics standards for high school are located at: http://www.corestandards.org/Math (Click on High School: Statistics and Probability).

As one views these standards, one's first reaction may be: "Amazing - this sounds similar to the course description for Advanced Placement Statistics or a college-level introductory course. Is this really what ALL students are expected to master by the time they leave high school?" Yes, the core foundation and concepts of the AP Statistics and college introductory Statistics course are now standards in the national CCSS – an event I believe is long overdue, as well as exciting. Also, the Statistics standards in the CCSS are intended to introduce basic statistical concepts at a more intuitive level than what should be taught in an AP or college Statistics course.

However, with great opportunities come great challenges. I would like to focus on a critical challenge to the successful implementation of the Statistics standards: Preparing K-12 teachers to deliver the statistical content in the CCSS, both at the pre-service and in-service level.

The Conference Board of the Mathematical Sciences (CBMS) identified the statistical preparation of teachers as an area of concern in their recent publication of the Mathematics Education of Teachers 2 (MET2) document (CBMS, 2012). Although advances have been made in recent years at select teacher-preparation programs (including here at the University of Georgia), the inclusion of Statistics in the teacher preparation curriculum has not been a high priority. Most of our current K-12 teachers have either never taken a formal Statistics course or the statistical training they received occurred in the traditional formula-oriented courses (CBMS, 2001; CBMS, 2012). I am especially concerned about in-service teachers at grades 6-8. The writers of the CCSS made the decision to eliminate Statistics from the K-5 curriculum. The ASA and the writers of the Pre-K-12 GAISE Framework strongly advocated maintaining Statistics in the K-5 curriculum. However, as a result of the CCSS writers' decision, grades 6-8 are now packed with the students' first real exposure to Statistics. Thus, teachers in these grades are being asked to teach many unfamiliar statistical topics. Thus, how do we equip K-12 teachers with the necessary tools and knowledge in Statistics to help their students develop into competent consumers of statistical information? This includes not only advancing teachers' content and the pedagogical knowledge needed in teaching the statistics content students are expected to learn, but also in preparing students with strategies for handling the statistical concepts that they will encounter in the future.

The Pre-K-12 GAISE Framework, the document endorsed and published by the ASA (and which heavily influenced the Statistics standards in CCSS), presents the Statistics curriculum for grades Pre-K-12 as a cohesive and coherent curriculum strand. GAISE identifies three developmental levels for learning Statistics in the schools (Levels A, B, and C), and emphasizes that students must progress through these levels in order to develop sound statistical reasoning skills. Levels A and B are roughly equivalent to grades 6-8 in CCSS, while Level C is high school. GAISE also describes a conceptual structure for statistics education as a two-dimensional framework model, with one dimension defined by the statistical problem solving process (Formulate a question that can be addressed with data, Design and implement a plan for collecting data, Analyze the data, and Interpret the data), and the second dimension being comprised of the three developmental levels. Few Mathematics teachers in the United States are adequately prepared to teach Statistics at K-12 as promoted by this GAISE Framework model and CCSS. Most of these teachers are struggling with fundamental notions of teaching, learning, and the nature of Statistics as a discipline. Based on my experiences in working with both pre-service and in-service Mathematics teachers, I have found they express the inability to apply statistical knowledge to different contexts (where context is essential to statistical reasoning) and intimidation at not being able to predict and answer students' questions. The typical teacher concern I hear is about their lack of confidence in teaching the Statistics standards and being able to interpret the intent of the statistics standards. They feel that they lack both statistical content and pedagogical knowledge.

Based on educational research and my anecdotal experiences as a Statistics educator working with teacher preparation for K-12, I suggest the following recommendations:

1. The GAISE Framework should be used as a vital resource in guiding the statistical preparation of K-12 teachers. The statistical preparation of teachers must include learning experiences based on concepts from more than one developmental level (as promoted by GAISE), if we expect teachers to teach with understanding.
2. Statistics courses should be developed in a manner such that content and pedagogy are integrated. The Statistics and Mathematics Education departments at the University of Georgia have collaborated since 1998 to successfully develop and teach this type of specialized course for the elementary and high school levels. Deborah Ball (2003), in her work on the Mathematical Knowledge needed for Teaching, argued that teachers need to know more than what we expect educated members of society to know, and that the knowledge for teaching mathematics is not the same as the mathematical knowledge required for other mathematical based professions. These principles apply to statistical content and pedagogy. We can't begin to prepare our teachers adequately for teaching Statistics by simply requiring a general introductory college Statistics course. The MET 2 report (CBMS, 2012) recommends that high school teachers take a one-semester course in introductory Statistics emphasizing data analysis following the Pre-K-12 GAISE Framework philosophy, as well as a one-semester course in statistical methods including both bivariate categorical and measurement data, exponential and quadratic models, study design, randomization procedures for data production, and inference. The report also emphasizes that good teaching practice must be part of any course taught for prospective teachers. The MET 2 report recommends that middle school teachers should have course content similar to the two courses described for high

school teachers, with more emphasis on appropriate pedagogical practice for middle school.

3. It is essential to develop collaborations at teacher-preparation colleges between Mathematics educators and Statistics educators / statisticians so that the course work for K-12 teachers emphasizes stronger conceptual knowledge of Statistics and the essential ideas of statistical thinking and problem solving. This recommended course curriculum also applies to professional development courses and workshops for current teachers.
4. State departments of education and school administrators must provide professional development opportunities specific to Statistics content and pedagogy and provide support and encouragement for teachers to attend. There then should be follow-up to the professional development, with continual support provided at the local school level.
5. State departments of education and national organizations such as ASA, NCTM, Association of Mathematics Teacher Educators (AMTE), and Mathematics Association of America (MAA) should work together to facilitate the uniform development of resources, assessments, and the structure of professional development in Statistics. ASA and NCTM have published several excellent books (located at their respective websites) to support the implementation of the Statistics standards at all levels of K-12. These resources should become part of the courses in professional development and teacher preparation in Statistics. The soon-to-be published NCTM Essential Understanding Books on Data Analysis and Statistics for Grades 6-8 and Grades 9-12 were specifically written as resources for teacher preparation.
6. Statistics educators should provide leadership in the development of assessment items for the national tests that focus on statistical concepts and reasoning, not merely procedural understanding (heretofore, this has been the typical type of statistical assessment on high stakes tests). A key to the CCSS statistics standards being interpreted correctly by teachers is making the statistical assessment match the spirit of the standards. Teachers will teach the content to match the assessment. Currently, a national team

of Statistics and Mathematics educators are developing assessment items in the spirit of the Pre-K-12 GAISE Framework. More information on "The Levels of Conceptual Understanding in Statistics (LOCUS) project", (Jacobbe, et.al, 2011) sponsored by the National Science Foundation, may be found at the following website: http://education.ufl.edu/locus. There are three goals of the LOCUS assessments: (a) to provide a model for assessment developers to consider when constructing high stakes assessments; (b) for teachers to use as formative assessment to inform their teaching of Statistics; and (c) for researchers to utilize as an assessment to measure growth in statistical understanding due to an intervention.

In addition to the above recommendations, I've embraced the philosophy that a teacher's beliefs about Statistics may be more important (at least initially) than a teacher's knowledge about Statistics, insofar as these beliefs relate to helping students develop a healthy acceptance and understanding about the necessity of statistical literacy. Even when a teacher is uncomfortable with teaching the Statistics content, if the teacher believes that developing statistical reasoning skills is important for the student, he or she will be more likely to engage in practices that enable him/her to become a more effective teacher.

In summary, we have traditionally expected our students to learn statistical skills by enrolling in one college-level Statistics course. We simply ignored the fact that most students had never been given the opportunity to mentally develop and cultivate statistical thinking skills at the elementary, middle, and high school levels. As a result, most students were not exposed to statistical topics until college, if at all. Even students exposed at college often did not develop the ability to reason statistically. In our data-centric world, sound statistical reasoning skills are needed by all students, regardless of whether they attend school beyond high school. The critical component for the successful implementation of the Statistics standards and statistical literacy for all students in K-12 is the statistical preparation of our teachers. These teachers are key to disseminating the principle that statistical literacy is essential for all citizens. Teacher preparation in Statistics must become a priority for our teacher preparation colleges and for professional development.

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