A CURRICULUM FRAMEWORK FOR
PREK-12 STATISTICS EDUCATION

Executive Summary

The Ultimate Goal: Statistical Literacy

Every morning the newspaper or other media confront us with statistical information on topics which range from the economy to education, from movies to sports, from food to medicine, from public opinion to social behavior; such information informs decisions in our personal lives and enables us to meet our responsibilities as citizens. Our lives are governed by numbers. Every high school graduate should be able to use sound statistical reasoning in order to cope intelligently with the requirements of citizenship, employment and family, and to be prepared for a healthy, happy and productive life.

Public opinion polls are the most visible examples of a statistical application that has an impact on our lives. A citizen informed by polls needs to understand that the results were determined from a sample of the population under study, that the reliability of the results depends on how the sample was selected, and that the results are subject to sampling error.

The U.S. Census was established in 1790 to provide an official count of the population for the purpose of allocating representatives to the congress. The roles of the Census Bureau and other Federal departments have greatly expanded to include the collection of a broad spectrum of socio-economic data about agriculture, health, education, environment and commerce that are used to determine priorities for government policy.

Statistics inform our personal choices. Products that we purchase have a statistical history. Our investment choices are guided by a plethora of statistical information. The Nielsen ratings decide which shows are available on television. If we consider changing jobs and moving to another community, then our decision can be informed by statistics about cost of living, crime rate, and educational quality.

At work we may be confronted by quantitative information on market demands or sales forecasts. Teachers may be confronted with educational statistics concerning student performance. Law enforcement professionals depend on crime statistics. Individuals who are prepared to use statistical thinking in their careers will have the opportunity to advance to more rewarding and challenging positions. A statistically competent work force will allow the United States to be more competitive in the global market place.

Life expectancy in the USA almost doubled during the 20th century and this increase in life spans is the consequence of science. Science has enabled us to improve medical care and procedures, food production, and the detection and prevention of epidemics. Statistics plays a prominent role in this progress**;** medical scientists must understand the statistical results of their experiments.

The Case for Statistics Education

Over the past quarter century, statistics has become a key component of the K-12 mathematics curriculum. This grass-roots effort was given sanction by the National Council of Teachers of Mathematics (NCTM) when their *Curriculum and Evaluation Standards for School Mathematics* were published in 1989 included Data Analysis and Probability as one of the five content strands. The NCTM *Standards* became the basis for reform of mathematics curricula in many states, and has led to the acceptance of statistics as an important part of mathematics education. The National Assessment of Educational Progress (NAEP) has developed around these NCTM *Standards*, with statistics questions playing an increasingly prominent role. A recent study entitled *Ready or Not: Creating a High School Diploma That Counts* from the American Diploma Project recommends data analysis and statistics as "must have" competencies for high school graduates.

The main objective of this document is to provide a conceptual *Framework* for K-12 statistics education. The foundation for this *Framework* rests on the NCTM *Principles and Standards for School Mathematics.* The *Framework* is intended to support and complement the objectives of the NCTM *Principles and Standards,* not to supplant them. This *Framework* provides a conceptual and developmental structure for statistics education that presents a coherent model for the overall curriculum.

The Difference between Statistics and Mathematics

"Statistics is a methodological discipline. It exists not for itself but rather to offer to other fields of study a coherent set of ideas and tools for dealing with data. The need for such a discipline arises from the *omnipresence of variability*". Cobb and Moore

It is this focus on *variability in data* that sets statistics apart from mathematics. There are many different sources of variability in data. Repeated measurements on the same individual may vary. Variability is inherent in nature because individuals are different. Comparing natural variability to the variability induced by other factors forms the heart of modern statistics. Statisticians often use a sample to represent a population but they realize that two samples from the same population may give different representations.

"The focus on variability naturally gives statistics a particular content that sets it apart from mathematics itself and from other mathematical sciences, but there is more than just content that distinguishes statistical thinking from mathematics. Statistics requires a different *kind* of thinking, because *data are not just numbers, they are numbers with a context".* Cobb and Moore

Investors might use a plot of the Dow Jones Industrial Average (DJIA) over a ten-year period; it is the variability of stock prices that draws their attention. This stock index may go up or down over some intervals of time, may fall or rise sharply over a short period But strip away the context and there remains a graph of very little interest or mathematical content!

Probability is an important part of any mathematical education. It is also an essential tool in statistics. The use of probability as a mathematical model and the use of probability as a tool in statistics employ not only different approaches, but also different kinds of reasoning. Two important uses of "randomization" in statistical work occur in sampling and experimental design. When sampling we "select at random" and in experiments we "randomly assign" individuals to different treatments". Randomization leads to chance variability in outcomes that can be described with probability models. When randomness is present, the statistician wants to know if the observed result is due to chance, or something else.

The evidence that statistics is different from mathematics is not presented to argue that mathematics is not important to statistics education or that statistics education should not be a part of mathematics education. To the contrary, statistics education becomes increasingly mathematical as the level of understanding goes up.

The Framework

The Role of Variability in the Problem Solving Process

Statistical problem solving is an investigative process that involves four components:
(1) Question formulation, (2) Data collection, (3) Data analysis, (2) Interpretation.
An understanding of variability is crucial for the practice of this process.

The formulation of a statistics question requires an understanding of the difference between a question that anticipates a deterministic answer and a question that anticipates an answer based on data that vary. The anticipation of variability is the basis for understanding this distinction.

Data collection designs must acknowledge variability in data and frequently are intended to reduce variability. The understanding of data collection designs that acknowledge differences is required for effective collection of data.

The main purpose of statistical analysis is to give an accounting of the variability in the data. Accounting for variability with the use of distributions is the key idea in the analysis of data.

Statistical interpretations are made in the presence of variability and must allow for it. Looking beyond the data to make generalizations must allow for variability in the data.

Maturing over Levels

The mature statistician understands the role of variability in the statistical problem solving process. The beginning student cannot be expected to make all of these linkages. They require years of experience as well as training. The *Framework* uses three developmental levels, A, B, and C. Although these three levels may parallel grade levels, they are based on development, not age.

The *Framework* Model

A conceptual structure for statistics education is provided in a two-dimensional model. One dimension is defined by the problem-solving process components plus the nature of the variability considered and how we focus on variability. The second dimension is comprised of the three developmental levels. The model is presented in the form a matrix. Each of the first four rows describes a process component as it develops across levels. The fifth row indicates the nature of the variability considered at a given level. Reading down a column will describe a complete problem investigation for a particular level along with the nature of the variability considered.

Organization of this Document

The complete report is in two parts. The first part provides an overview of the goals and need for statistics education, a thorough discussion of the differences between statistics and mathematics, and a detailed presentation of the *Framework* Model. The second part is an appendix that presents descriptions of learning activities at each of the three developmental levels; these provide examples for teachers of the types of activities that should be used in the classroom to effectively promote statistical literacy.