The ASA-NCTM Quantitative Literacy Project : An Overview

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1. Background and current setting

> "As the economy adapts to information-age needs, workers in every sector ... must learn to interpret intelligently computer-controlled processes. Most jobs require analytical rather than merely mechanical skills, so most students need more mathematical power in school as preparation for routine jobs. Similarly the extensive use of graphical, financial, and statistical data in daily newspapers and in public policy discussions compels a higher standard of quantitative literacy for effective participation in a democratic society.
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> Citizens who cannot properly interpret quantitative data are, in this day and age, functionally illiterate." (*Reshaping School Mathematics*, Mathematical Sciences Education Board, 1990)

The technological society of today is dependent upon the collection and interpretation of numerical data for virtually all of its decision making processes. Sample surveys measure the consumer price index and the unemployment rate which, in turn, trigger critical economic decisions affecting all residents of the nation. Surveys determine what products are marketed in retail stores and what programmes are shown on television. Clinical trials determine the effectiveness of new drugs and whether or not they are allowed on the market. Statistical process control improves manufacturing processes so that American industry can remain viable in a competitive world. These are but a few of the ways data collection and analysis play key roles in the lives of everyone. Everyone, then, must understand something about data collection and interpretation if they are to make informed decisions on economics, jobs, politics, health and even entertainment. It is vitally important that the students of today be taught data analysis skills before they become the workers and leaders of tomorrow.

In addition to being important in their own right, data analysis skills help build connections between mathematics and other subjects in the school curriculum and to the world outside of the classroom. Such connections are essential if the students are to comprehend the importance of mathematics and the role it plays in virtually all aspects of life. Data on animal speeds or genetics interest students in biology, data on distances to and motions of the stars and planets interest students in the physical sciences, data on demographics and voting patterns interest students in the social sciences, data on industrial quality and productivity interest students in business and economics, data on the prices of stereos or cars or clothing interest anyone who wants to make rational personal decisions. These connections can change student attitudes about mathematics and its usefulness as a tool in practical problem solving.

While broadening the students' perception of mathematics, working with data can provide the motivation for studying traditional topics in mathematics and can build student skills and understanding of concepts. What are the chances of winning a ball game or that a disease will spread beyond control? Can the adult height of a five-year-old child be accurately predicted? Do tall people run faster? Which brand of batteries will last longest in a CD player? Beginning with a real problem of interest to them, students collect data to investigate the problem and may end up using straight lines, logarithms, or polar coordinates to find a good model for their data. A simple question of chance may lead students into the study of sequences - outside of a calculus class! Such situations lead to the study of real mathematics that is both relevant and interesting. Along the way, data collection and summarisation can hone basic skills at the same time that data interpretation and model building can develop higher order thinking skills.

Many studies of the 1980s, including the Mathematical Sciences Education Board report quoted above, recognise the importance of and lack of attention to statistics in the Americal educational system. In particular, the National Research Council's report *Every-body Counts* builds a case for a restructured mathematics curriculum that emphasises practical applications close to the experiences of the students, most of which would be data oriented. This report points out that a transition must be made from preoccupation with routine skills to "developing broad-based mathematical power", as in "using tables, graphs, spreadsheets, and statistical techniques to organise, interpret and present numerical information". Another transition from "emphasis on tools ... to greater emphasis on topics that are relevant to students' present and future needs" lists probability, exploratory data analysis, and model building as key components. This increased emphasis on the practical aspects of mathematics can change attitudes about mathematics. "Only in America do adults openly proclaim their ignorance of mathematics as if it were some sort of merit badge."

The National Council of Teachers of Mathematics (NCTM) recently released their Curriculum and Evaluation Standards, which have a carefully delineated strand in statistics throughout the curriculum and an emphasis upon modelling from data in other areas such as algebra and functions. The data analysis tone of the Standards can be seen in the following quote:

> "In this age of information and technology, an ever-increasing need exists to understand how information is processed and translated into usable knowledge. Because of society's expanding use of data for prediction and

> decision making, it is important that students develop an understanding of the concepts and processes used in analysing data."

That the emphasis on data analysis should be woven through the mathematics curriculum and connected to other components of the curriculum is seen in the following:

> "This standard should not be viewed as advocating, or even prescribing, a statistics course; rather, it describes topics that should be integrated with other mathematics topics and disciplines."

The NSF-funded Quantitative Literacy Project (QLP), a joint project of the American Statistical Association (ASA) and the National Council of Teachers of Mathematics (NCTM), served as the basis from which the strand in statistics was developed for the Standards. The QLP provides curriculum materials in certain areas of data exploration, probability, and inference, in a style that makes the material accessible to teachers and students, and provides a model framework for in-service programmes to enhance the skills of teachers in the area of statistics and probability. More specific information on certain aspects of the QLP will be provided below.

2. QL curriculum materials and workshops

The curriculum units developed by the QLP explore elementary topics in data analysis, probability, simulation, and survey sampling, with new units being planned for exploring measurements and planning experiments. The approach is to use real data of interest to the students and simulations of real events to show how to use statistical ideas to extract useful information from numbers. Many of the statistical tools are graphical and reflect the latest thinking among practicing statisticians. Teachers using these materials are provided with opportunities to make heavy use of hands-on activities, group discussion, student projects, and report writing. A brief summary of the current QL publications follows:

(i) *Exploring Data:* This book is an introduction to data analysis. Students learn how to make various kinds of graphs, how to select the most appropriate plots for a given set of data, and how to examine the plots in order to describe the data, detect patterns, and make conjectures. (Grades 7-12)

(ii) *Exploring Probability:* This book is designed to give students a working knowledge of basic probability through using counting skills and some knowledge of fractions. The approach emphasises student experimentation and estimation of probabilities using relative frequency, not through counting supposedly equally likely possibilities. Students progress from using spinners, coins, and dice to understanding basic empirical and theoretical probability. (Grades 6-9)

(iii) *The Art and Techniques of Simulation:* This book should follow *Exploring Probability* and is intended for students in grades 7-12. It introduces students to methods for exploring and understanding the behaviour of complex processes and systems through experiments that simulate actual situations. Using a basic simulation model, the activities are designed to demonstrate real-life applications

of probability and statistics and encourage analytical reasoning.

(iv) *Exploring Surveys and Information from Samples:* This unit covers more advanced materials than the other three units and is intended for average or above average students in grades 10-12. Ideally it should follow the other three QL units. However, it does contain some review materials so it can be used by advanced students who have not studied the other units. The purpose of this book is to teach the statistical ideas underlying sample surveys and to give students enough information that they can make informed opinions about the widespread use of polls and other surveys.

The QL in-service workshop model requires teachers to attend a one-week institute in the summer, followed by at least twelve hours of follow-up work during the school year. This model has now been used about 12 times since the summer of 1988, and seems to be effective. Each summer institute hosts around 40 teachers from one geographic region and enlists the cooperation and support of local supervisors, professors of mathematics education, and statisticians. The statisticians, who volunteer through local chapters of ASA, not only help with the summer institutes, but are also instrumental in hosting and leading follow-up activities during the school year. These statisticians give advice on student projects, sources of data, and methods of data analysis, and provide teachers and students with opportunities for field trips. The in-service programme not only provides enhancement of the teachers' statistical skills, but also builds a local support group for the teaching of statistics, with cooperation from schools, colleges, and industry, so that the programme can succeed and grow.

3. Continuation of the QL effort

The QLP has raised the awareness of statistics as an appropriate topic for inclusion in the K-12 education of students, and has provided some ideas on how to teach statistics effectively. Seeing the need for a continuing effort in the area of statistical education, ASA has established a Centre for Statistical Education (CSE) to disseminate materials developed under the QLP, expand in-service education for teachers, promote project and poster competitions for students, develop new materials, serve as a clearing-house for information on statistical education, and promote statistical education in the schools through joint efforts in mathematics, science, and social science. With regard to the latter, one newly formed task force is studying the role of statistics in the science curriculum with a view toward improving the design of laboratory experiments and the analysis of laboratory data. This group is working with the National Science Teachers Association. Another task force, working with the National Council for the Social Studies, is studying the use of data and data analysis in the social studies curriculum of the schools. Of course, strong ties with NCTM still remain and the ASA-NCTM Joint Committee will be leading new efforts to fund in-service workshops for teachers and to develop the materials necessary to make statistics a regular part of the taught curriculum. One such activity is discussed in the following section.

4. A special emphasis in mathematics

Historically, integrating data analysis into the mathematics curriculum has not been a common practice and has not been part of the education of mathematics teachers. The materials and in-service workshops of the QLP have been well received by teachers, and most of the teachers leave the workshop fully intending to teach the material to their students. However, virtually all of them say that it takes great effort on their part to find a way to fit statistical ideas into the taught curriculum, given the traditional nature of that curriculum, and some never do succeed. Clearly, teachers need curriculum materials that have data analysis concepts embedded within them if the goals of NCTM, MSEB and others for a truly relevant mathematics curriculum are to become a reality.

With that in mind, the CSE has set out to develop a data-driven curriculum strand in mathematics for grades 9 through 12 in the form of curricular modules tied to a detailed scope and sequence plan. It will draw upon existing projects that produce material on statistics for the schools for conceptual ideas and examples, but will build a plan that is comprehensive in mathematical and statistical content, detailed and sound in pedagogy, and flexible in use. The intention is to help the spirit of the Standards take on concrete form for the teachers, so they can effectively and efficiently use the materials which contain new motivation for mathematics and which present mathematics from a different perspective. The data analysis modules will build modern statistical concepts and practical motivation into the four topics in the mathematics curriculum designated to receive increased attention by the Standards, namely, algebra, geometry, trigonometry and functions, and do so in such a way that the modules can be used in a variety of curricular settings ranging from the traditional algebra-geometry-algebra to the integrated math I-math II-math III. A tentative outline for these modules is now being developed.

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