Quantitative Literacy - Implementation Through Teacher Inservice

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1. Introduction

The need for mathematically literate students who can function in a technology driven society plus the demonstrated lack of success of the current mathematics curriculum have paved the way for major reform efforts in mathematics in the United States. Recognising the link between mathematical literacy and statistical literacy, *Everybody Counts*, a publication of the Mathematics Sciences Education Board, is typical when it advocates that statistics should be a primary component of a revised curriculum. The National Council of Teachers of Mathematics *Curriculum and Evaluation Standards for School Mathematics*, released in 1989, has content strands on statistics and probability for all grade levels. Working with real data, all students are expected to understand the concept of sampling, design experiments, construct and draw inferences from data summarised numerically and graphically, and make predictions using curve fitting. The focus in the probability strand is on empirical probability and on simulation techniques to represent and solve problems involving uncertainty.

Since 1967 the American Statistical Association/National Council of Teachers of Mathematics Joint Committee on the Curriculum in Statistics and Probability has promoted statistics education in the United States. Under the direction of the committee a three-year Quantitative Literacy Project, funded in 1984 by the National Science Foundation, produced materials to teach exploratory data analysis, probability, simulation techniques and an introduction to the process of inference through sampling and surveys (see References). Workshops conducted by the Quantitative Literacy staff prepared over 500 teachers to begin using the materials in their classrooms. Quantitative Literacy I succeeded in raising the consciousness of teachers and supervisors on the importance of including statistics in the curriculum as well as laying the foundation for the statistical content to be included in the NCTM Standards. The next step was to provide materials and mechanisms for making statistics an integral, planned component of the mathematics curriculum.

Working for this goal the second Quantitative Literacy Project : Leadership Training for Master Teachers, funded by the National Science Foundation in 1987, focused on indepth professional development activities for teachers. Six workshops were held for 240 teachers at selected sites during the summers of 1988-89. Related efforts by other organisations include a series of mini-institutes held each summer at approximately 8 to 10 sites sponsored by the Woodrow Wilson National Fellowship Foundation, a nonprofit, private organisation which supports a variety of educational endeavours in the United States. The National Science Foundation has also funded a three-year national programme for teaching statistics at the University of Illinois. In addition, there are currently professional development programmes involving quantitative literacy in over one-third of the states in the United States. A newsletter, *The Statistics Teacher Network*, published through the Joint Committee, serves as a focal point for information about professional development activities as well as updates on material and software development.

2. Inservice workshops

The main focus of the second Quantitative Literacy Project was to provide secondary teachers with a week-long workshop on the quantitative literacy materials and on techniques to use in teaching those materials. The participants modelled the roles of students and the staff the role of the teacher, using techniques that could be transported to a secondary school classroom. One unique aspect of the workshops was the involvement of professional statisticians contacted through the local ASA chapters who served as speakers, provided on-site visits and were role models for those interested in statistics as a profession. Another key element was to involve participants in planning, designing and carrying out a project with the guidance of one of the statisticians.

For many of the presentations the sessions were divided by grade level into teachers of grades 7, 8 and 9 (approximately ages 12 to 14) and those of grades 10, 11 and 12 (approximately ages 15 to 18). This allows the staff to directly address the different needs and backgrounds of teachers from those levels. One noticeable difference is that teachers of grades 7, 8 and 9 are interested in developing the basic notions of probability, while upper level teachers are more concerned with the process of formal inference.

During the school year following the workshop, the participants attended a total of twelve hours of follow-up sessions. These sessions were held after school, on Saturdays, or on release time during the school day. Teachers critiqued their classroom experiences, asked questions of the staff, and planned lessons for more units. Whenever possible, the resource statisticians hosted the follow-up sessions to give teachers experience in relating the topics to real uses in business and industry.

To facilitate teaching statistics in the schools, the project, when completed, will provide detailed curriculum guidelines to show clearly what topics should be taught at each grade level and how the topics build one upon another. The final framework will contain a set of principles which form the philosophy of quantitative literacy, a set of core curricular objectives which should be a part of the content for every student at every level, and a set of specific objectives for individual grade level clusters, including examples and references to appropriate supplementary materials. The principles which

constitute the philosophy of the Quantitative Literacy Project are given below.

3. Principles for teaching statistics

The focus in teaching statistics should be to foster student belief about the positive use of statistics and probability in making choices and decisions. In particular:

(i) Activities for students should be active not passive, asking questions about something in the students' environment and finding quantitative ways to answer the question.
(ii) The emphasis in all work with statistics should be on the analysis and the communication of this analysis in contrast to a focus on a single correct answer.
(iii) Different approaches and solutions for a problem should be discussed and evaluated with opportunities provided for student reflection.
(iv) Real data and hands-on experience in working with data should be used whenever possible.
(v) Exploration and experimentation with simple counting and graphing techniques should precede formal algorithms and formulas.
(vi) Good examples should be used to build intuition rather than using probability paradoxes and statistics to deceive.
(vii) Student projects should be an integral part of any work in statistics.
(viii) Statistics should be a vehicle to make connections within mathematics and to form interdisciplinary links for students.
(ix) Technology should be used to facilitate analysis and interpretation.
(x) A variety of approaches should be used for student assessment: reports, projects, journals, student-generated tests, as well as traditional methods.

4. Implementation issues

With limited time spent working under supervision in the workshops, many teachers understand the process but not the spirit involved in the materials and techniques. They expect that a hierarchy of skills exist and must be learned: "What comes after box plots?" is a common question. They often miss the point of the analysis and focus on mastery of the tool, not recognising that the same basic set of tools can be applied with different levels of sophistication to many different sets of data. They don't recognise that an analysis of one set of data in several different ways can reveal different characteristics. The shift from exact answers to approximations and the emphasis on words such as compare, contrast, and describe, are significant changes in the way most teachers deal with numbers.

Students and teachers are not critical of the data they are given, perpetuating the myth that numbers are factual and rarely disputed unless computed incorrectly. For example, consider the following data taken from the *World Almanac*.

TABLE 1
Speed of animals (in km/hr)

antelope	98	giraffe	51
bear	48	greyhound	62
cat	48	horse	76
cheetah	110	human	43
chicken	14	lion	80
coyote	68	pig	18
deer	56	rabbit	56
elephant	40	turkey	24
elk	72	warthog	49
fox	51	zebra	64
jackal	56		

Students are to organise the data, possibly with a stem-and-leaf plot, and write a paragraph about the speeds of animals from the plot. Both students and teachers immediately begin to process the numbers: neither stop to internalise the data and decide what the numbers really mean. In the United States the metric system is not widely accepted by the public, and both students and teachers ignore the fact that 43 km/hr is an unusually fast speed for a human. After some calculation, they recognise that this must be a sprint speed, an important fact missing in the information about the data.

Teachers must help students learn to write about their results: they tend to say "Some of the animals went slower than the rest" or "Lots of animals are fast" without quantifying their statements and without referring to the data. They also tend to describe the obvious and have to be taught to look for patterns.

Most mathematics teachers summarise data without reference to the context: the mean is 56.38095, and the standard deviation is 22.925295. Answer books, even in relatively new texts, do the same. The inclusion of all of the decimal places is often a source of confusion. The more places the "better" the number is an implied precept. For most people, an approximate number in the original dimension is more than adequate: for the scientist, the use of significant figures is important. Teachers must recognise that neither audience will value those added digits. In order to effectively communicate, students must be taught to make sense using their numbers and to remember their audience. "The average speed of the animals in the list is about 56 km/hr with a variation of about 23 km/hr either way. This means that a typical animal from the list might run between 33 km/hr to 79 km/hr." The summary is easily understood and nonthreatening. Teachers must remember they cannot afford to only address those who already have a "number" sense.

Many teachers value numerical summaries and relegate words and pictures to a "lower" level of learning. In recording the results of a simulation, teachers often use a form similar to Table 2(a). Yet most students, especially those who are not numerical thinkers, will confuse the two columns and will really not be sure which number represents what. Table 2(b) provides a graphical way to visualise the information and helps establish a connection between the abstract numerical summary and the situation.

TABLE 2(a)

Outcome	Frequency
0	2
1	3
2	5
3	11
4	8
5	4
6	1
7	1

TABLE 2(b)

Outcome		Frequency
0	xx	2
1	xxx	3
2	xxxxx	5
3	xxxxxxxxxxx	11
4	xxxxxxxx	8
5	xxxx	4
6	x	1
7	x	1

A significant component in working with statistics is the use of calculators and computers. Many teachers are not comfortable with computers and need time and guidance as they begin. The disk which accompanies the Quantitative Literacy Materials is used by the teachers to explore simulations on the computer and is an excellent vehicle for analysing concepts such as the variability in a statistic caused by different sample sizes. Data Insights by Sunburst is an example of a software package which is easy to use and enables teachers to focus on analysing the graphs rather than on constructing them. Statistical calculators are readily available and make analysis of real data possible, with students able to concentrate on the meaning of the result rather than on the process of calculation. Graphing calculators provide excellent opportunities for every student to explore the effect of different scales on a histogram, the difference between the mean and the median, to generate their own random numbers for a simulation, to experiment with several possible models for a set of data, and to move easily from the graphic to the symbolic expressions. Without experience and background, teachers do not feel "in control" and in most cases will not introduce that aspect of the programme into their classroom. Materials for using the graphing calculators will be available in late 1990.

The traditional classroom environment is not appropriate for teaching statistics and probability with these new techniques. The teachers have trouble adjusting to "mathematics" in which a numerical answer is not the goal, in which there can be several correct results, and justification of a choice is an essential part of the answer. Mathematics teachers have little experience in leading discussions, in working with students in an open-ended atmosphere, or in setting up experiments. Without guidance and direction, teachers will focus on the graph rather than the interpretation, on the calculation rather than what it says about the data. In the fourth National Assessment of Educational Progress (NAEP) administered in 1986, although most seventh and eleventh grade students could calculate the mean, less than 40% of the seventh graders and about 50% of the eleventh graders knew that the average of two numbers must be halfway between the two numbers.

Classroom management changes. Students work much better in groups where they can exchange ideas. Individual assignments are not always appropriate. Most teachers are accustomed to a four step lesson plan: homework correction, lecture on new material, practice and assignment. Students then leave class with a well-ordered set of

problems for homework. The structure of a statistics class is not as predictable. One set of homework exercises may take three days as students actually work their way through a problem or an experiment. The answers cannot be read in ten minutes but must be discussed; often new avenues are suggested by the students which must be explored in the middle of a lesson. The bell may ring before the teacher has time to pull ideas together and to make an appropriate homework assignment.

Student work cannot be graded simply on the number correct: paragraphs must be written and judged. Students are not used to writing sentences in mathematics; mathematics teachers are not used to judging answers in written form. Teachers accustomed to grading 94%-100% as an "A" cannot grade a question comparing two sets of data the same way. New ways to evaluate student progress are needed when the objective is to write a description or find a new insight in a set of data.

A primary goal of the workshops is to give teachers confidence to try something different. To achieve this, all of the above issues must be addressed either formally or informally during inservice sessions. Many of the issues become real only during the follow-up sessions after teachers have experienced them. The teachers who have worked with the Quantitative Literacy materials, however, are enthusiastic. In evaluating the original project, teachers who were surveyed were highly favourable toward the materials, believed they were important, interesting and could be learned by the students. Those involved in the second project are equally as enthusiastic and have truly begun to change their curriculum to include statistics, often in imaginative ways. The average rating for every component of the programme was between 4 and 5 on a 5 point scale. Despite the difficulties in adjusting to new materials and new methods, teachers recognise the improvement in the attitude of the students and in the quality of the learning that is taking place in their classrooms.

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