

Teacher Statistical Education Models

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1. Introduction

The inclusion of statistics and probability in the mathematics curriculum in secondary schools in the United States is now regarded as a necessity. While imparting these skills to all our high school graduates implies an increased level of mathematical training in general, it implies in particular that statistics and probability become part of the normal high school curriculum, probably, although not limited to, the mathematics curriculum.

Teachers, by and large, have either had no statistics courses, or those they have had have been regarded as obstacles in their programmes. It is curiously easy to find teachers (as well as other college graduates) who look back on a statistics course as containing totally incomprehensible material punctuated by impressive and less than meaningful formulas in large numbers. Those of us who dare admit to teaching statistics for some time bear the burden of not having explained ourselves. We have failed to tell our students what our subject is about and we have also failed, I think, to impart the vitality and wide range of applications of statistics. Hence teachers, for whom the subject matter may be new, must be educated in the correct way or we may be doomed to repeat our less than admirable past.

For the most part in the United States ideas about teaching statistics are not included in teacher education programmes, so various independently-funded programmes have taken up the opportunity. The major one of these is the national Quantitative Literacy Programme, directed by the American Statistical Association/National Council of Teachers of Mathematics Joint Committee on the Curriculum in Statistics and Probability. The committee has trained teachers throughout the United States in programmes probably numbering in the hundreds now. Most of these programmes have occurred in the last five years. Four books, known as the Quantitative Literacy Series, have been published for high school use. These "QL" books are: *Exploring Data*, *Exploring Probability*, *The Art and Techniques of Simulation*, and *Exploring Surveys and Information from Samples*.

2. The Indiana Quantitative Literacy Project, 1985-1986

In 1985, the Indiana State Department of Education, responding to the need for statistically literate teachers in Indiana, funded the Indiana Quantitative Literacy Programme. Thirty secondary teachers of mathematics were invited to attend.

Applicants were required to provide information on their teaching experience, write a short statement on why they were interested in the programme, and be supported by a principal or other supervisor. A consequence of these restrictions was that the resulting group was qualified and highly motivated to attend.

This programme divided the training in statistics and probability into two parts. For two and one-half days in October the teachers met at Rose-Hulman Institute of Technology. The emphasis in the programme was on the four QL texts. Work was done by means of participatory lectures, the teachers working in groups on specific problems after some brief introduction to the material. In addition, talks were given on the importance of statistics in industry and the place of statistics and probability in the mathematics curriculum. Instruction was given by teachers, both from secondary schools and universities, who had experience with the national QL project, and about half a day was spent on each of the four texts. A set of computer programs to accompany the texts had been written, and instruction was given in the use of these programs.

A key feature of this programme was that teachers agreed before their acceptance to use the material during that academic year in their classrooms. The April portion, consisting of two days, was devoted largely to hearing reports from teachers about the effectiveness of the material. This was truly educational, both for the participants and the programme leaders. A wide variety of approaches were reported, with varying degrees of success. The teachers learned that teaching statistics differs markedly from teaching mathematics. A variety of approaches can be appropriate to a statistical problem and the teacher must learn to accommodate discussion - in a mathematics class! This is not easy for most mathematics teachers. We also learned some of the danger points in the material and points to emphasise to the next set of teachers.

Evaluations of the programme were generous in their enthusiasm for the material presented and the conduct of the programme in general. Almost all participants said they would strongly encourage their colleagues to attend future programmes.

A final note on the conduct of this programme is in order here. Funding provided teachers with all materials, food, lodging, and transportation. In addition, since the programme was conducted during the school year, allowances were made for substitute teachers when school districts requested these. Funds of course were provided for the professional staff. It is important, in programmes of this sort, to conduct them, if at all possible, away from the teacher's usual school and with a group of diverse teachers. Much of the effectiveness of the programme lies in the informal as well as formal interaction of the teachers.

3. Regional Conference

In 1987, as part of a National Science Foundation grant, the Joint Committee conducted three Regional Conferences on Quantitative Literacy. These programmes differed in content; only the Indiana Conference will be discussed here; the conference

was funded in addition by the Indiana State Department of Education.

Teachers were invited to attend in pairs. Announcement of the programme and application forms were sent to applicants and participants in the 1985-1986 programme. Previous participants who were interested in attending were required to nominate a fellow teacher, who had not participated in a QL programme, to attend with them. In addition, the experienced teacher agreed to train the inexperienced teacher with some of the QL materials during the school year; both were then required to prepare a presentation on their experiences with the materials. Some curriculum supervisors were also invited.

The programme differed for the various groups of participants. There were some common sessions, devoted to the spirit and accomplishments of the QL programme. The experienced teachers attended sessions which expanded the statistical material to which they had been exposed, while the newer teachers were given some of the elementary material. Supervisors were sometimes addressed separately, but were often placed with one of the groups of teachers.

Perhaps the most impressive part of the programme was the sessions where teachers shared their experiences with the QL materials. Projects representing a great range of interests were presented. One teacher in particular impressed the group with the effectiveness of projects by students and with the fact that these projects involve the students in a way that classroom material often does not.

Supervisors reacted favourably to the material and were encouraged to create programmes involving the material in their schools. This led to at least one programme being established in a large Indiana school system.

4. The Indiana Quantitative Literacy Programme, 1987-1988

For 1987-1988, 60 teachers participated in the programme. They were divided in two groups. The October-April format of the previous programme was used again.

The programme provided training with the QL materials and required teachers to return to their classrooms and use the material, updating on this use in April. One feature of these programmes was the involvement of teachers who had participated in previous programmes; several were invited to share their experiences with the new group in a discussion which was titled "What Works". Classroom teachers instructing other classroom teachers has proven to be an effective strategy.

A note here is in order regarding the instructional staff. All of the Indiana Quantitative Literacy programmes, as well as the Quantitative Literacy Workshops described below, have depended on staffs which always involve experienced classroom teachers, some of whom have helped develop the published materials, as well as some professional statisticians. This balance of interests, both in teaching and the material being taught, has been invaluable in developing material and in presenting it to others.

5. Quantitative Literacy Workshops

A second National Science Foundation grant to the Joint Committee resulted in a programme of Quantitative Literacy Workshops held in five different locations in the summer of 1989.

Each of these workshops was held over a period of five consecutive days. In addition to instruction in the QL materials, the programmes contained project assignments, the participants generally working in teams of two or three to carry out the project. Projects normally included data gathering by the team, its analysis, and subsequent presentation to the entire group. In most cases a team of professional statisticians from the area in which the workshop was held was invited in to consult with the participants before the actual completion of projects. This proved to be a learning experience for both the participants and the statisticians.

Workshops also contained presentations on the applications of statistics in industry from local statisticians. Participants also met in two or three follow-up sessions during the subsequent academic year to check on the inclusion of statistics in the curriculum and to answer questions by the participants.

6. Kent State University

A special programme, funded primarily again by the National Science Foundation, was held in the summers of 1989 and 1990 on the campus of Kent State University in Ohio. This programme had as one of its primary goals the modernisation of the high school mathematics and computer science programmes. A course in data analysis was given to participants in the mathematics strand.

Content of the course in each case was taken from the basic Quantitative Literacy materials, but the Kent State programme allowed much more flexibility than previous programmes due to its length of six weeks. Participants were divided into groups of two or three and assigned projects. The first project, normally completed during the first week, was a "warm-up" exercise whose purpose largely was to show the difficulty in carrying out a statistics project. Participants were expected to run into trouble. They presented their results and then were assigned another project. Not surprisingly, these turned out to be much better thought out and better executed. The range of investigations was wide; many left with the intention of assigning projects to students.

One main goal of the Kent State programme was to combine the Quantitative Literacy materials with topics found in traditional statistics courses. For that purpose, in addition to the QL books, texts by Mario Triola (*Elementary Statistics*, Fourth Edition) (used in 1989) and David Moore (*Introduction to the Practice of Statistics*) (used in 1990) were also adopted. Beginning with the QL material, participants also were introduced to statistical analysis based on the mean rather than the median. Topics included: the normal curve, probability laws, binomial distribution, least squares regression, experimental design, conditional probability, and a chi-squared test.

Considerable emphasis was given to the use of MINITAB, a statistical package. Some instruction was given in the use of the hand-held computer; videotapes from the series *Against All Odds* were shown. Statisticians presented a panel discussion on the applications of statistics in industry and careers in statistics. A practicing statistician spoke on experimental design.

Plans are underway to duplicate the Kent State programme in other states; it is an innovative approach to changing the high school curriculum in areas of mathematics other than data analysis and in computer science as well as the intersection of mathematics and computer science.

7. Technology Preparation

A programme in Technology Preparation was instituted in Indiana in 1988 and has been tested in a preliminary way in five Indiana high schools. The programme is neither vocational nor college preparatory. Its goals include the increased awareness of technology in our society and ways to deal with that technology on the part of high school graduates.

Since statistics and data analysis are certainly part of the working tools of the modern graduate, the Indiana State Department of Education requested that a week-long programme in data analysis be conducted in the summer of 1990 for five members of the staff of each of the five test schools. Participants included, in addition to teachers of mathematics, teachers of social studies, science, and language arts. The clientele provided challenges and opportunities for this innovative programme.

Instruction was given in the Quantitative Literacy materials, but some emphasis was put on data that occurs in courses in social studies and in science. Statistics provides a unifying thread for integrating these courses. Special attention was given to the writing of reports and their oral presentation as well.

The Technology Preparation programme is scheduled to be instituted within the next few years in all Indiana high schools. As a result of this teacher education programme it is hoped that data analysis will play an important role.

8. Future directions in teacher education

- (i) The programmes discussed in this paper are diverse, but unified by the mathematical content provided. All the programmes have been effective in the sense that teachers see new material and become enthusiastic about including the material in the curriculum. Some new directions are beginning to emerge, however. These are:
 - (a) In addition to educating mathematics teachers, we should begin programmes for teachers of social studies and science. It is an open question whether to create separate programmes for these groups or to include teachers of these subjects along with mathematics teachers.
 - (b) Programmes should be developed for the education of elementary teachers in using and incorporating the QL materials into their classrooms. Special programmes must be created for this.
 - (c) Specific suggestions must be made for incorporating the QL material into the mathematics curriculum (and other curricula in the future). Suggestions must be made about replacing or enriching the mathematics in various courses with the QL material.
- (ii) New materials must be developed to expand the existing QL material. Topics should include: experimental design, conditional probability, least squares regression, tests of hypotheses, chi-squared tests, and contingency tables.