INNOVATIVE SECONDARY SCHOOL CLASSROOM EXPERIMENTS WITH STATISTICS EDUCATION USING THE COMPUTER

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Statistics and Probability teaching in schools has increased during the last thirty years as a result of innovative initiatives such as those of the School Mathematics Project in the UK and the Victorian Certificate of Education in Australia. These have been part of an overall change in attitude to mathematics itself which now sees the subject as more society-centred and interactive with students. One of the major innovations has been in the introduction and widespread use of computers to record, analyse and display statistical data and to simulate real-life processes. Spreadsheet programs such as Excel have been particularly useful in the classroom in giving students the hands-on ability to manipulate, visualise and analyse statistical data and simulate probability situations.

INTRODUCTION

During the past thirty years in the UK mathematics education in general, and the teaching of probability and statistics in particular, has developed from a subject-centred to child-centred to society-centred approach, first in primary and then in secondary schools (Rogerson, 1989). This progression is summarised in the chart below:

MATHEMATICS IN SECONDARY SCHOOLS IN THE UK

1960-70	*1970-1990*	*1990-*
Subject Centred	Child Centred	Society Centred
Taught as at University	Content revised & Selected	Selection to suit use in Society
Illustrative Examples	Multi-paced to suit Different abilities	Creation of situations from Society
Re-structured content particular to general	Revision of content based on student feedback	Re-creation of what from mathematics means in society

Prior to 1960, if probability and statistics were taught in schools at all they were considered a branch of pure mathematics. In the 1960's, there was an attempt to construct more "realistic" examples for school use. This led in turn to the teaching of probability in schools in a more child-centred way using practical apparatus such as dice and coins, while "real-life" data were increasingly used in statistics. Beginning in the primary school, statistics teaching has become society-centred through the use of relevant themes

based, for example, on social, historical and economic data. This in turn has modified our view of how much, and which, content should be taught in probability and statistics within the mathematics curriculum, leading to more emphasis being placed on those topics which are useful in society (Rogerson, 1987). This development has been very much in line with the seminal work of Kuhn (1972) and Lakatos (1976), and has changed the conception that scientists and mathematicians have of their respective disciplines. Although many texts still present statistics and probability as a lifeless authoritarian body of knowledge that has somehow accreted in a simplistic evolutionary fashion, there is also a growing number of books that recognise statistics and probability as a dynamic, interpretative and essentially *human* activity. The old conception of science and mathematics was such that there was little scope for students to express their own views or ever question the underlying framework. This is being replaced by a modern humanistic approach, which often involves the teacher as a participating guide for students working individually or in groups on society-centred thematic materials (Rogerson, 1986).

CLASSROOM IMPLICATIONS FOR THE TEACHING OF PROBABILITY AND STATISTICS

The above has obvious relevance for the classroom teaching of probability and statistics, both of which essentially depend on their interaction with the real world and the consequent necessity to *interpret* our answers. The main feature of this approach is the gradual integration of probability models and statistical techniques into the *real life contexts* of problems. This implies emphasising not only the purpose of a particular problem, and the reasons for choosing one technique rather than another, but also the application of statistical results through real-life decisions such as the siting of traffic lights, the building of new supermarkets, the use of new drugs, the choice of certain seed types to cultivate. The key to this approach is to emphasis the relevance of the *total social context* which determines the initial selection and collection of data, the choice of models and techniques to analyse that data, and the vital final stage of decision making on the basis of the statistical results. This approach *demystifies* the apparent scientific authority of statistical results and replaces a blind acceptance of significance levels, correlation coefficients and so on, with the human power of decision making. In this way we help to avoid the distortion of statistical results which stems primarily from treating statistical

results as if they had the status of mathematical theorems or of physical laws (Rogerson, 1990). At school level in the UK this approach to statistics teaching originated during the early developmental period of the School Mathematics Project (1960-1975), and has since influenced many projects, especially the Mathematics in Society Project (1980-) whose materials are now widely used (Rogerson, 1986).

Another local initiative which has pioneered the introduction of more probability and statistics into the mathematics curriculum has been the Victorian Certificate of Education (VCE) in Australia. All schools in the State of Victoria adopted the VCE from 1991 onwards in the final school Years 11 and 12. The mathematics curriculum was divided into three: (1) Change and Approximation, mainly what used to be called calculus; (2) Space and Number; and (3) Reasoning and Data, covering probability and statistics. The new subject divisions brought a large amount of statistics and probability into the mainstream mathematics curriculum and also provided a fresh look at the more traditional topics. It is a sad footnote that, since this innovative change, conservative forces within the mathematics community have replaced it, but fortunately much of the probability and statistics content has been retained in the present Year 12 Further Mathematics course.

The school-assessed Common Assessment Task (CAT) 1 for the original Reasoning and Data, and now Further Mathematics, courses is a good example of the innovative changes that have taken place. CAT1 involves the student in a month of intensive research on a written Project based on a real-life and stimulating topic which they must fully investigate and analyse. Recent examples of such topics include data sets from road traffic accidents, weather patterns and water supply, tidal movements and lunar phases, seasonal variation in retail business, and so on. The thorough analysis of the data sets provided usually requires the use of appropriate data representation, time series, simulation, correlation and regression analysis, interpolation and extrapolation and finally future prediction. Throughout the Project the student is required to answer specific questions relating the analysis back to the real life situation from which the data are drawn. The use of the computer has become almost obligatory: graphing and spreadsheet programs are used to help order, sort, display and analyse the given data, while word processing software is used to write up the Report. This aspect was commented on favourably in Money and Sentry (1990) when referring to the new VCE structure:

Reasoning and Data, where teachers have been able to find a wide range of topics suitable for investigation and students have been able to build their understandings on a firm basis of real and simulated data. Teachers have been innovative in adapting computer use - particularly spreadsheets - to this purpose: spreadsheets are more accessible than specialised statistics packages, they can often illustrate processes more clearly and can be used in interactive "What if--?" mode.

COMPUTER USE

It is now difficult to imagine any work in statistics and probability from Year 9 onwards not being enhanced and enriched by computer use. Excel is useful in statistics teaching because it allows students to enter and sort their own data, find and use formulae to analyse the data and represent it, and finally choose from the extensive Excel Chart Wizard graphs, the best way of illustrating the data. Even when the data are too numerous or tedious for students to enter themselves, presentation of already prepared data sheets in Excel still gives students the full capacity to investigate and analyse data sets without having to make further arithmetical calculations by hand. Students can visually compare the data and then choose from the many graphs available through Chart Wizard. One major breakthrough in the use of computers has been the rapid way in which data can be visually displayed. This can take on a dynamic aspect when various parameters in Excel cells are changed and the resulting effect on the graphs can be immediately seen and compared.

In the teaching of probability, Excel also has much to offer mainly through the simulation potential of the RAND function which can, in effect, produce random numbers appropriate to any situation - tossing a coin, throwing a dice, the roulette wheel or the many real-life simulations that are used as examples in the Further Mathematics CAT1. Finding an appropriate formula to simulate a given situation and then using the FILL DOWN facility of Excel allows unlimited (up to 16,000 and beyond!) simulations of any probabilistic situation. I have used this method often, not only in probability simulations of coins and dice, but for problems where the deductive theory is much more difficult or even inaccessible! For example, the problem of how many coin tosses *on average* it takes to produce three heads in a row. An extremely large number of simulations quickly gives a value very close to the theoretical probability once the correct model for simulation has been set up and the appropriate Excel formulas devised.

Excel is also ideal for deterministic iterations involving limits of series, algorithms to find square roots, Markov processes, and even the now famous fractal generating problems in chaos theory. For some years now I have used a two-week Year 9 Project to analyse the changes in the kangaroo population on Kangaroo Island, based on a simple form of the population growth formula: $x_{n+1} = kx_n(1 - x_n)$. Not only is this example extremely stimulating for the students, but in the process of investigating changes in the parameter *k* (representing how supportive the environment is for kangaroos) students actually discover for themselves long-term stability, period doubling and chaos. By varying the initial population and holding *k* constant they discover the famous butterfly effect! These and many other mathematical problems have been adapted for use with Excel and have provided stimulating alternative methods to visualise and solve problems in mathematics, some of which are not accessible to traditional deductive methods.

CONCLUSION

Teaching Probability/Statistics for Years 9-12 for the past 10 years has led to the development of many new materials and the use of new tools in the classroom. Since February 1996 all students in Year 9 in my school have used their own laptop computers in all classes, and by 1999 all students in Years 9-12 will be doing the same. These computer facilities have also been exploited for many other areas of the mathematics curriculum, for example Geometer's Sketchpad for Geometry, Graphmatica and other graphing programs for graph and function work, and Excel for a large variety of arithmetical work. The response of the students has been generally positive and their understanding of mathematics, and of statistics and probability, has been considerably enhanced. I envisage that as computers become more and more widely used in society and in schools, the computer will become an integral part not only of statistics/probability teaching, but of mathematics teaching itself.

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