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DEVELOPMENTS IN STATISTICAL EDUCATION

Abstract. This paper describes recent work carried out by the Schools Council Project on Statistical Education. The Project advocates a problem-solving approach towards the teaching of statistics in secondary schools (11–16 years age range). It sees statistics as an interdisciplinary subject primarily concerned with data. The article illustrates these important aspects with teaching materials which have been developed and tested extensively in a variety of schools. Finally an evaluation and assessment of the project's work is presented.

1. INTRODUCTION

Probability and statistics have crept into the school curriculum more by chance than design with the advent of modern mathematics. Perhaps this stochastic invasion into the traditionally hallowed compartmentalization of arithmetic, algebra and geometry (which fitted well into six periods a week!) needs to be charted.

Statistics has flourished in England as a subject in its own right, independent of mathematics. It is natural that this should be reflected at the school level. Thus the Schools Council has sponsored the Project on Statistical Education (POSE) to investigate and make recommendations in the 11–16 age range. As the developmental phase is nearing completion this is an appropriate time to report on the project's findings.

2. THE CURRENT SITUATION

This section mainly deals with the situation of statistical education in England, but similar patterns do exist in other countries. Throughout the paper we are referring to pupils in the age range 11–16: in England pupils generally go to secondary school at the age of 11 years and are allowed to leave after their 16th birthday. (Readers who want further details of the research described in this section should refer to Note 1.)

2.1. *Survey Results*

The project conducted a survey of 10% of all designated secondary schools in England and Wales to assess the present situation in statistical education as

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regards content, level, motivation and teachers' attitudes and to relate these to the position of statistics outside schools.

A draft questionnaire was tested in a few schools before the final version was written. The questionnaire was designed to include schools teaching no statistics and also to involve any subject department (like geography) teaching statistical ideas. A total of 530 schools were selected and replies were received from 397 schools (75%), a creditably high response rate for a questionnaire which was administratively difficult to complete.

The survey showed that statistics is taught in 5 out of every 6 schools who replied (over 60% if one includes non-responses). Of those schools where statistics is taught, less than 10% enter pupils for formal examination in statistics and even in those schools only a small minority of pupils would take such examinations. However, 4 out of every 5 pupils are entered for examinations in mathematics which include some statistics.

The topics most frequently taught are: pictorial representation, elementary descriptive measures, data collection and elementary probability. The usual resources of dice, cards, coins, ets. are used though a few schools (24) did mention commercially produced kits. The most popular text was the School Mathematics Project (S.M.P.), used by 55% of the schools.

Most teachers (81%) felt that the statistical needs of pupils are met adequately by the age of 16; they did not feel a shortage of teachers who could teach statistics in school. However, they would welcome a reference source book and work cards describing experiments for pupils. Theoretical material and pamphlets on topics were also popular. About two-thirds of the teachers had learnt some statistics as part of their college/university course, the other third had taught themselves.

In other subject areas, statistics is taught less frequently; the numbers of schools replying for various subjects where it is taught are: geography (83), biology (48), economics (32), sciences (10). The course content is similar to that in mathematics except that, interestingly, in both geography and economics more use is made of case-studies and published figures.

2.2. *The Problem of Mathematics*

Much statistics is taught within mathematics lessons so one needs to investigate in more detail what goes on there; particularly if, as the survey shows, over 80% of teachers feel that the statistical education given to pupils is adequate. There are two main sources: the commonly used textbooks and the examination syllabuses and questions.

The philosophy of the School Mathematics Project – to enable pupils to cope with the bombardment of so-called statistics from newspapers, advertisment hoardings and television screens and generally to emphasize data collection – is to be applauded. There are indeed suggestions within their texts which could be pursued by an imaginative teacher to fulfil these aims. However, the main text soon gets down to churning out dry statistical techniques (data representation, averages, etc.) ignoring the context of data and not really attempting to use real figures. Little or no mention is made of questionnaires, sampling, accuracy, time-series, trend prediction or simple inference.

Probability is also dealt with in a fairly standard mathematical way with emphasis on fractions based on equally likely outcomes. The usual experiments with dice or coins are described, with hardly a reference to chance in realistic situations. So the aim of showing probability as a measure of uncertainty and hence, as a foundation for statistics, is not realized.

Other books written to teach statistics within mathematics lessons also suffer from the same defect of trying to teach statistics without regard for the relevant context. The books simply give recipes for techniques, making statistics seem a rather dull, dry subject, devoid of interest: in fact, it is the applications which justify the techniques so both aspects need to be taught together if the subject is to be meaningful to pupils.

Turning to examinations, it is interesting to note that almost all mathematics courses contain some statistics, if only averages or representation of data. The same criticism applies to the examinations as to books – the questions concentrate on asking pupils to perform relatively meaningless techniques.

Examination syllabuses do usually mention data collection yet rarely include the closely related topics like questionnaires or sampling needed for it. There is a marked emphasis on the numerical quantitative side (which is easier to examine), there is not a proper balance with the qualitative side.

This emphasis is shown by Table I which shows the inclusion of certain statistical topics in a number of examination syllabuses. We have included a traditional syllabus (W1), a modern syllabus (Y3), a statistical syllabus (SS) and an examination syllabus devised by a school for its own pupils (Z1). It is interesting to note the greater emphasis on collection and tabulation of data in the last syllabus; it also includes practical work in the final assessment and makes no reference to probability. However, the standard school syllabuses are still fairly unimaginative, as illustrated by Figure 1 which shows the incidence of topics on the current C.S.E. mathematics syllabuses publicly available to schools in England. (This Certificate of Secondary Education is an examination aimed at less academic pupils at the age of sixteen.)

TABLE I
Topics in four C.S.E. examination syllabuses, England

	Syllabuses			
Topic	W1	Y3	SS	Z1
Data collection, tabulation		√	√	√
Questionnaires			√	√
Published statistics				√
Sampling			√	√
Reliability of data		√	√	√
Degrees of accuracy	√			√
Abuses of statistics			√	√
Picto, pie and bar charts	√	√	√	√
Histograms, freq. polygons		√	√	√
Cumulative frequency		√	√	√
Quartiles		√	√	√
Averages	√	√	√	√
Inter-quartile range		√	√	√
Standard deviation			√	√
Grouped data		√	√	√
Scattergrams, line fitting			√	√
Rank correlation			√	
Normal curve			√	
Trend prediction				√
Indices			√	√
Time-series			√	√
Probability		√	√	
Probability laws		√	√	
Conditional probability		√	√	
Independence			√	
Pascal (binomial)			√	

W1: Traditional mathematics.
Y3: Modern mathematics.
SS: Statistics.
Z1: School, validated examination.

2.3. *Other Subjects*

The approach to statistics in subjects other than mathematics is usually refreshingly different. Sometimes a 'cook-book' approach is adopted (where a particular statistical recipe must be followed) but often the teachers are more interested in looking at data to see what yields. Statistical techniques are used but they are taught with reference to specific applications. This is particularly true of modern approaches to subjects in the school curriculum. Books which were commonly quoted by teachers were investigated but one cannot say to

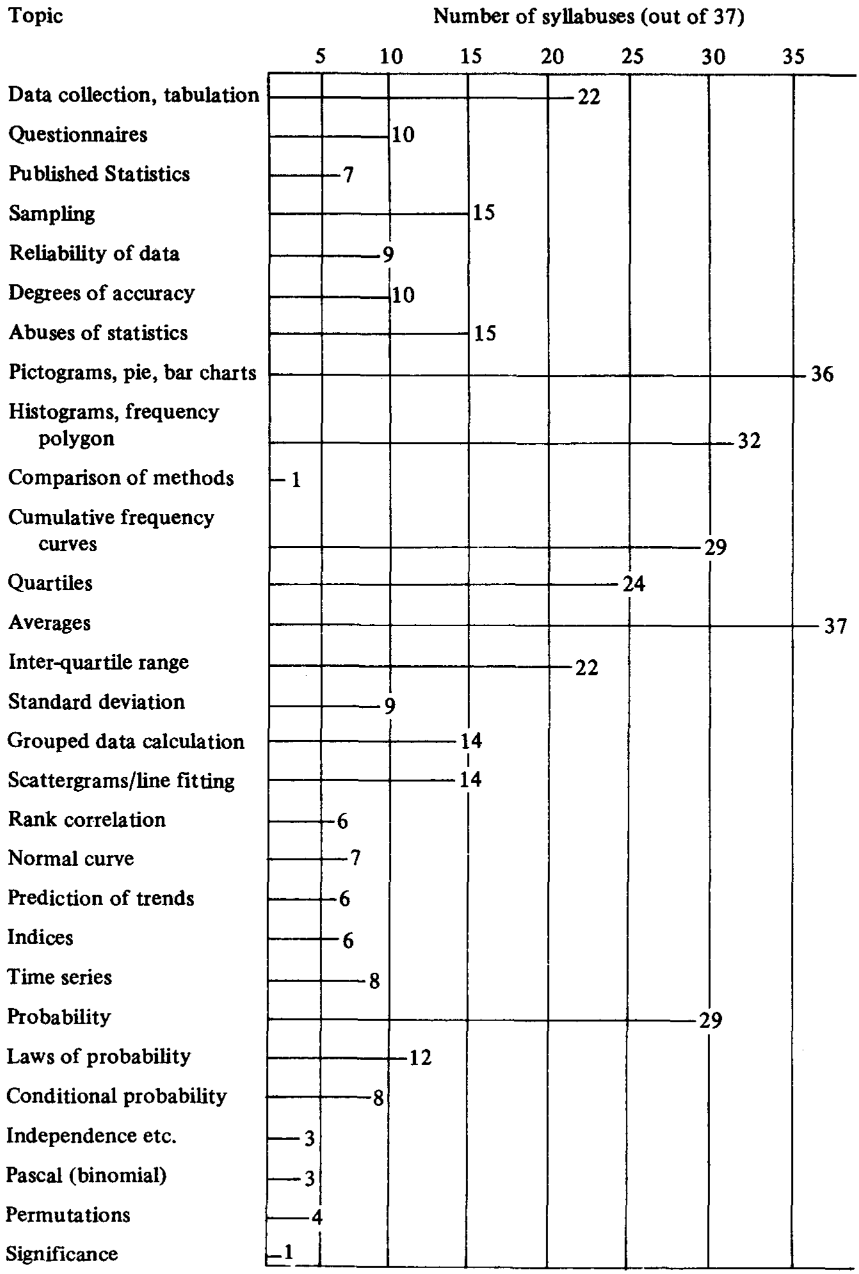

Fig. 1: Frequency of topics in C.S.E. examination syllabuses, England

what extent they are actually used as the curriculum is left to schools to determine individually.

In geography a recent innovatory project, Geography for the Young School Leaver, and its related examination were considered. The project, aimed at average and below average pupils, has been widely implemented. Economics is a less common subject at school, so only a few text books were investigated. In science several influential projects were analysed. The findings described below show the breadth and scope of statistics taught to pupils in the 11–16 age range, rather than how widely statistical ideas are taught.

Data collection, representation and interpretation is important in teaching geography. Published figures are used, perhaps from the national Census; various forms of representation are employed to display the data in an interesting way. Mathematicians wishing to avoid using artificial data have a possible answer here.

Pictograms show the frequency of ferry services and car ownership. Pie charts displays the popularity of different types of accommodation for holidays and the pattern of urban/land use. Bar charts and histograms are used frequently, sometimes with colours for emphasis: e.g., for population densities, unemployment patterns, numbers of tourists.

Questionnaires are used in geographical investigations for pupils to collect their own data. More care on design should perhaps be taught to pupils but conducting a survey is at least more realisitic and teaches more about possible problems that actually arise than an (incomplete) set of guidelines which is presented in a statistics textbook. Time-series can illustrate the changing pattern of hours worked or the use of roads at different times. Scattergrams demonstrate land use around a city.

Usually pupils are asked to make simple inferences from the data. This is more to do with statistics at school level than formal significance tests. For example, an examination question in geography gives a scattergram showing wealth against percentage of working population employed in manufacture for 11 countries. In mathematics the question would probably asked for a regression line or correlation coefficient (ignoring its likely irrelevance); the question actually asks pupils to choose from a number of statements which describe a possible relationship and the meaning of the data.

In economics published figures are widely used: the collection of such data was an important influence in statistics, yet it is rarely mentioned in textbooks. Various indicators of wages, prices, trade etc. are used, though more discussion of their validity would not go amiss. Time-series analysis is-applied to population trends, employment and the trade cycle. Sometimes even multivariate analysis (Phillips curve) is used but it is more usual to make only intuitive inferences by studying the data.

In science many simple statistical techniques crop up. The emphasis tends to be upon practical investigations by pupils which yield much data. Block-graphs illustrate, for example, seed germination, drying times of different materials and weed frequency. Variability is often implicit in many examples. Sampling is necessary to investigate land areas, daisies on a lawn or conkers on a tree. Averages are used to increase the accuracy of observations.

It is clear that the approach to statistics is quite different in mathematics classes from other subjects. For pupils in the 11–16 age range, it is such applications rather than formal techniques which are important.

3. PROJECT PHILOSOPHY

3.1. *Applications: Why Teach Statistics?*

The main case for teaching statistics in schools must lie in the increasing range of applications of the subject. Statistical ideas permeate almost all fields of human interest which involve quantification or measurement. As such it is vital that all pupils should develop a rudimentary understanding of statistics, if only because of the increasing use made of figures in everyday life.

There are many reasons one can advance to support the teaching of statistics in school. Here we present a summary. (For a more detailed case see Note 3.)

(i) Statistics is an integral part of culture and essential for all citizens.
(ii) Statistics is an essential part of numeracy.
(iii) Statistics is an important application of mathematics.
(iv) Statistics is an essential part of many subjects in the school curiculum.

The first reason is perhaps the most important in ensuring an adequate statistical education for all pupils. The retail price index affects everyone. Most countries have a national Census regularly and sample surveys more frequently to aid planning. Opinion polls are a standard feature of everyday life. Advertising uses and abuses statistics: people need to be prepared for this. Decisions in many spheres affecting individual citizens are often made on the basis of statistical data. The population explosion, food supply and other ecological problems affect the whole world. Clearly pupils need to develop an awareness to be able to cope with this statistical atmosphere which pervades so much of our life: they need to realize the power and limitations of statistical thought.

With respect to the applications of statistics, it is difficult to decide which ones should be in a core list taught to all pupils. An indication of major areas is presented here but further detailed work is needed in making the final choice, which may well differ from country to country.

In biology, probability models are important in genetics. Medical advances rely heavily on large-scale statistical comparisons. There has recently been controversy over the use of mass vaccination to prevent whooping cough: the arguments are quite subtle yet need to be appreciated by ordinary citizens who need to make the final decision. Smoking is acknowledged to be one of the major causes of statistics, though a casual link still needs to be established!

With respect to the political world, pupils need to be aware of the values and limitations of opinion polls. They should understand the necessity of a Census in facilitating planning. Index numbers are an important measure of inflation which affects everyone: pupils should be familiar with their meaning.

The social sciences and the humanaties are adopting a more quantitative approach. A Central Statistical Office is a permanent feature in many countries, producing facts and figures. Vital decisions are made on the basis of such figures, so pupils should be taught to understand them. Gambling is an important application where simple ideas of probability can help pupils understand the risks they are taking; similarly with insurance.

In the physical world, weather prediction is becoming more sophisticated. Pupils need to understand what levels of accuracy are appropriate in science. Clearly there are other applications in each of these areas which should be taught in school. We are only trying to indicate the variety of areas which could be included as part of the school curriculum. In fact some of these areas are already taught: however, more care needs to be taken in tackling the statistical aspects. POSE has developed units to illustrate the feasibility and desirability of an approach to statistics through its applications.

3.2. *Project Aims*

POSE is concerned with pupils of all abilities, unlike many projects which seem to consider only more able pupils. Material produced is designed to serve the statistical needs of the general citizen as well as laying a suitable foundation for those pupils who specialize later.

Statistics is defined as the study of data: collecting, sorting, representing, analysing and interpreting the different types of data that arise, making predictions, drawing inferences and making decisions. The context of the data must be kept in mind throughout an investigation. Probabilistic models are developed as a necessary foundation of statistical theory.

Statistics should be taught through its applications so a problem-solving approach is adopted in project materials. Each unit of work starts with a problem and aims to develop the necessary statistical techniques to solve it. This approach has two major difficulties: finding a range of problems suitable for schoolchildren and the fact that several new techniques may have to be introduced simultaneously in solving one problem. This is in marked contrast with the standard mathematical method of teaching a technique and giving pupils several (artificial) examples.

There are two general overall aims: that children should become aware of and appreciate

(i) the role of statistics in society – the many and various fields in which statistical ideas are used, including the place of statistical thinking in other academic subjects,

(ii) the scope of statistics – the power of statistical thought.

These two aims lead to a two way classification within which material is developed – Figure 2. The 'other' category includes important applications of statistics such as statistical methods in medicine, management, insurance and everyday life, which do not come under standard school subjects.

	Applications				
Ideas	Mathematics	Humanities	Science	Social Science	Other
Data Collection					
Data Tabulation					
Data Reduction					
Probability					
Inference					

Fig. 2: Statistical ideas and applications.

3.3. *Interdisciplinarity*

POSE believes that statistics is best taught when interdisciplinary links are taken seriously. The curriculum is already too crowded to be able to introduce a new subject. Besides, if one is aiming to teach statistics through its applications one obvious place is in the related subject lessons. For example, questionnaires could be taught through a practical application in geography, while index numbers come up naturally in economics.

However, there are problems with this approach which need to be overcome. Any interdisciplinary proposal will run into organizational difficulties. Who does what? How to avoid unnecessary repetition? Who teaches the basic ideas and when will they be needed? How to ensure a comprehensive coverage? Clearly these are problems which need to be sorted out in schools individually.

Given co-operation and a staff sympathetic to this approach to teaching statistics, the problems can be resolved. Initially, one needs a senior teacher to co-ordinate the teaching of statistics in school. Teaching syllabuses for each department need to be circulated and discussed in meetings. Joint timetabling might help. POSE is actively helping some schools to teach statistics in this way, so that these case-study schools may offer some guidance to others interested in this approach. Contact has been initiated in six varying types of school.

As far as the problem of a sequence of concepts of techniques to be taught, the teachers' handbook from POSE spells out hierarchies in statistical concepts and techniques. The approach suggested is a spiral one so that techniques will not necessarily be completely developed when first introduced. A full theoretical justification may often not be necessary or desirable.

These concepts and techniques are subdivided into 14 subsections reflecting major strands of five broad areas: data collection, data tabulation and representation, data reduction, probability and inference. The emphasis throughout is on data, the important raw material of statistics. The 14 subsections are broken down into individual topics. These are linked by a flow chart of ideas, showing which ideas should precede others at various levels, and the interaction between ideas. Finally, there is a desired syllabus to be covered for each year 11–16, incorporating a spiral approach. (Fuller details of these hierarchies can be found in the Handbook, see Note 3.)

4. TEACHING MATERIALS

4.1. *Trial Areas*

Whilst evolving its philosophy, POSE set up a network of schools willing to test out ideas. It is all very well devising proposals in an office but one also needs to try them out in reality.

Though a statistical project may have aimed to select a random sample, it would have been rather arrogant to pick schools and expect them to comply. Not only is it easier to let the sample choose you but the schools who take part are committed by their own initiative: at the developmental stage this is more important than worrying about vagaries such as the Hawthorne effect. A few schools joined in as a result of the survey: a non-random subset of a stratified sample.

All known leads were followed in building up a reasonable sample of schools willing to help in testing: late fruition of some of these leads resulted in a rather large sample size. But this proved a blessing in disguise as most schools could not test all the materials. Within this framework the team made great efforts to ensure a reasonable representation. The final sample included all types of schools in England and Wales teaching within the 11–16 are range: boys, girls and mixed; selective and non-selective; various age ranges between 8–12 and 14–18.

Overall the project had 55 trial and 80 associate schools. Trial schools agreed to test the project's material: two units a term for each of the four years 11–15 (grades 6–9) for four or five terms. Regular contact was maintained with trial schools to monitor progress. Associate schools agreed to test materials when it proved convenient and were generally interested in the project's development.

4.2. *Project Units*

Five of the project units are described to illustrate the type of teaching materials developed by POSE. Each unit was typed and duplicated onto A4 sheets, intended as worksheets for pupils. The unit was accompanied by teachers' notes which put the work in a wider context. The project's budget was limited so no graphic designers or illustrators were included in the team. Thus the ideas and language of the units had to be tested with allowance made for the relatively poor quality of layout and presentation. The five units described come from the different areas delineated in Figure 2.

(A) *science*. This unit, for 4th year (grade 9) pupils, looks at the connection between smoking and health. It begins with the smoking habits in England, showing how the habit has grown. Some major diseases associated with smoking are examined, and figures from doctors are cited. A scattergram of smoking and birth weight is considered as more evidence. Finally a critical appraisal is made and a distinction drawn between causality and correlation, together with a brief analysis of correlation.

(B) *social science*. This unit is described in more detail to give a better idea of the project's philosophy and method of working. Questionnaires are used to elicit opinion: this is becoming increasingly important with the centralization of decision-making. Most textbooks simply list 'dos' and 'don'ts' with a few remarks about sample selection.

The project's unit, entiled 'Making Opinion Matter', aims to present these ideas to 2nd year (grade 7) pupils more directly. It begins by giving the results of a survey of schoolchildren on school rules and punishment, inviting the class to comment and make up possible questions for their own survey. Pupils are encouraged to discuss their questions, looking for possible flaws.

Then a deliberately 'bad' questionnaire is given for pupils to answer themselves. In analysing and discussing the answers to each question they discover the flaws. For example 'height?' leads to different units and degrees of accuracy in the responses. After finding faults pupils attempt to write better questions, together with summary tables for collecting responses.

Pupils go on to study bias. A questionnaire with questions biased in opposite ways was devised. Half the class answer one set of questions, the other half the other set of questions. With most of the questions the two halves of the class seem to have different opinions – these differences are related to the wording of questions (Kapadia, 1979). Finally a list of important points about questionnaire design is given (at the end) and pupils are asked to write their own questionnaire on a self-chosen topic.

The unit was tested by mathematics teachers in schools in various parts of the country. Mostly the reaction was favourable though there were odd exceptions. One teacher felt that the topic was unsuitable in mathematics lessons. However, most schools reported that pupils became very involved in the work and benefitted greatly from discussion of various points. Teachers found the unit quite time-consuming. Some felt the need for more reinforcement material: this has been included at the revision stage. In general teachers felt that the objectives of the unit had been achieved. The language and comprehension was acceptable: the pupils' notes and accompanying teachers' notes were adequate. Overall, pupils had benefitted statistically. There were also many individual comments which are impossible to summarize here.

In the light of the evaluation received, this unit was one of eight selected to be re-tested: constraints of time and money meant that the other units, though fully revised were not re-tested. With this unit, an extra section was added to emphasize that questions used should be clear, precise and unambiguous. The wording in other sections was improved and simplified. Better illustrations were incorporated and the whole unit was printed more clearly (and expensively!)

A short test was devised for the unit, in response to a general request from teachers. For earlier testing, a general evaluation form for all units was circulated. In re-testing, a special evaluation form, asking specific questions accompanied the unit. In general this unit was more favourably received and is likely to be popular, as it is relevant to many subject areas.

(C) *humanities.* The unit on questionnaires is followed up by asking 3rd year (grade 8) pupils to carry out their own survey of the popularity of record albums in their school. Here the problem is of choosing a good sample: simple random and stratified samples are discussed. After planning the survey properly, it is carried out and a report written. Other surveys which often occur in geography, are suggested for pupils to investigate.

(D) *mathematics.* If a free card is given with each packet of tea how many packets does one need to buy to collect a set of four cards? Over-booking is frequently done by travel operators but can lead to difficulties. Such situations are explored by first year (grade 6) pupils using simulations. This is a fundamental tool in exploring the effect of chance in various situations.

(E) *other.* What does minimum weight and average weight mean? Third year (grade 8) pupils find out by actually weighing 50 bags of crisps. They learn about the problems of quality control through a simple game. They also try their hand at deciding at what point quality is sufficiently low to warrant an investigation. This illustrates some of the problems faced by a firm in conforming to legal standards.

These brief descriptions illustrate the general approach. Statistical techniques are introduced in each unit only within the context of the problem being studied. To help understand data better, pupils might draw a bar chart and comment on the results. An appropriate measure of central position or of spread is used when needed but pupils are encouraged to comment on its meaning. In each unit statistical ideas are employed so that their use and applicability is clear. Reinforcement of a particular technique is left to the teacher. There is a place for practice examples but, in the first instance, it is important that pupils should learn the rationale and applicability of ideas so that they can see the need for proficiency.

One novel feature worth mentioning is the inclusion of open-ended questions. Mathematics teachers are traditionally wary, they are used to questions with a unique correct answer. However, in statistics there can be alternative right answers which involve making different interpretations. Sometimes a subjective opinion is needed. Thus open-ended questions are used in the project's units and, after some initial doubts, have been successful: certainly pupils have been happy answering them.

Figure 3 below shows how various units covered different areas in the matrix shown in Figure 1. Quite a wide spread has been achieved by the 27 units of work produced by the project. It is clear that there are many worthwhile applications which can be developed in line with a problem-solving strategy. The coding refers to the target year group (add 5 to get the grade) and the subject area most closely related to the application developed (the final number is a linear ordering).

	Applications				
Ideas	Mathematics	Humanities	Science	Social Science	Others
Data Collection	1M1,1M2, 4M1	2H1,3H2	1Sc1,2Sc1 2Sc2	1S01,1S02, 2S01,3S02	101,301 102
Data Tabulation	1M1,1M2 4M1	2H1	1Sc1,2Sc1, 4Sc1	1S01,1S02, 2S01,3S02, 4S01,4S03, 3S03	101,102
Data Reduction	1M1	2H1,3H1, 3H2	2Sc1,2Sc2	3S03,4S03	301,302 102
Probability	1M1,1M2,1M3, 2M1,4M1,4M2		2Sc2,3Sc1		101
Inference	(1M1),(2M1) (1M3),4M1 4M2	2H1,3H1, 3H2	(1Sc1), (2Sc1),3Sc1, 4Sc1	(1S01)(1S02) 3S02,3S03, 4S01,4S03	301,302 (102)

Fig. Statistical Ideas and Applications.

4.3. *Sampling Reality*

Collating information about trials from schools is a difficult task, particularly with limited resorces. The project team had to collect feedback at the same time as writing new material for testing. The tight schedules for sending material to schools limited the time available for assessing the results of testing. A number of ways were devised to collect feedback from trial schools.

An evaluation form was designed to accompany each unit. This form asked a number of general questions: class taught, overall pupil reaction, attainment of objectives, reasonableness of prerequisites, pupils for whom unit is most suited, adequacy of pupil and teacher notes, overall statistical benefit. To get a more personal reaction a team member visited each 'active' trial school once a term. Usually classes were being taught project units so there was a chance to guage the reactions of pupils, as well as talking to the individual teachers involved in testing.

Trial schools were clustered in groups of four or more in seven pilot regions: each region also included associate schools. Teachers from each school were asked to attend a meeting in their region once a term to discuss the work of the project. Teachers from trial schools were also invited to a termly national meeting held at the project's base in Sheffield, when more general issues were discussed.

Towards the end of the main trial period it became clear that teachers wanted test questions based on the units. It was also felt that a detailed evaluation form should accompany each unit asking more specific points. So, with the last set of units tested, a special evaluation form and test questions were distributed. As this procedure proved successful, some units were revised and tested again: the units chosen were those which had been least tried or those which had led to more problems than others.

5. EVALUATION

Having set up an elaborate mechanism, how well did it work? Obviously some aspects were more successful than others. As a team member, one can evaluate to some extent but a full assessment needs to be made independently.

5.1. *The Schools*

It must be stressed that all schools became associated with the project only on a voluntary basis. In fact schools in England are rather autonomous, they choose the curriculum which is offered to pupils, there is no central control. Thus teachers volunteered to become involved.

Overall teachers were most helpful and co-operative. There were occasional administrative problems and sometimes suitable classes were not available. Some teachers did not test materials with older pupils because of examination pressures. But, for the most part, units were tested quite thoroughly.

The reaction of teachers at local meeting and national conferences was mixed. At first teachers were critical of some of the teaching materials but generally supported the approach. They were concerned at the time needed for testing but accepted that a data-oriented approach to statistics was likely to take longer than a conventional approach. The team responded by adapting teaching materials and introducing blank tables to shorten the time taken. Certainly the reactions of teachers to units produced later was much better: some schools were happy using revised versions of materials which they had initially rejected.

5.2. *Reports*

It is almost impossible to summarise adequately the evaluation reports on each of the tested units. There was much variation of responses on the same unit, quite apart from reactions to different units. Thus we shall limit ourselves to some general comments and include a few selected comments on the units described in Section 4.2.

Overall pupils found the work in most units acceptable or interesting and pitched at about the right level. The stated objectives were clear and mostly attained; the prerequisites were found to be reasonable. Teachers generally tested the materials with the suggested age range, they usually agreed that the target age was appropriate though sometimes it was unsuitable for less able pupils. The units usually took longer to teach than the indicated design time. The teachers' notes were thought adequate but there were problems with the pupil notes. (Constraints of time and money limited the quality of presentation). In commenting on each section teachers found the statistical content adequate but there were criticisms in layout and comprehension. Generally, however, teachers felt that pupils had benefitted statistically from the units.

Turning to the units briefly described in Section 4.2., here are a few mixed comments.

A Worthwhile graphical work to plot, interpret and correlate. Led to open class discussion, many pupils interested in price of cigarettes over the years.
Unit led to visit from Health Education officer, giving county statistics and promoting interest in preventive medicine.
Idea of comparing doctor's health and smoking habits with general population good but unfortunately real-life statistics complex.

B Material tedious not sufficiently allied to mathematics. Approach considered 'too clinical'.
In answering a questionnaire it was seen that (i) the voice of the administrator can affect answers (ii) it is not always easy to persuade people to answer honestly – allowance must be made in analysing results.

C Pupils enjoyed this unit because there was much which required discussion and opinions. I really felt this class had a good grasp of the fundamentals required to organize a fair poll at the end.
We (pupils and I) found much of it interesting and worthwhile – importance of obtaining a good sample well appreciated.
Ideas good but I wish I could think of some way of getting to the point of the exercise in less time.

D The concept of simulation was difficult to understand. Even at the end many children did not fully understand the topic
All pupils except remedial would manage most of it, though the calculation of means might create problems.
Children operated the unit as a race and hence got on quite well.

E I enjoyed this topic, particularly because of the practical crisp weighing experiment which gives a reality to apply notions like standard deviation, mean and range.
We were able to discuss the trade-off of speed and accuracy in production line situations and the relative cost of retaining one over-generous operator against one who got so near the border that she risked prosecution for skimping.
At this age the practical problems give rise to intelligent and meaningful discussion.

5.3. *Revision*

The evaluation was very useful when the team began to revise the material in preparation for publication. There were many points relating to specific units but some general changes were also made.

The final versions (c.f. Note 2) have been standardized to aim at average and above average pupils. Detailed attention has been paid to readability, particularly grammar and sentence structure. Questions requiring written answers are clearly distinguished from discussion questions; rhetorical or leading questions are avoided. General instructions have been put into teachers' notes to shorten pupil notes. Ideas for reinforcement material are included in the teachers' notes. Test questions accompany each unit. Suitable illustrations are included.

In fact as revision of the materials turned out to be a big job, the help of a number of practising teachers was enlisted. A small conference was held to discuss the general strategy and the working definitions so that there would be homogeneity in the final drafts. The teachers set about the task of revision, keeping in touch with the project by post. Even though the work was shared out, it was still an onerous task: in compensation the units were all the better because teachers had helped in this way.

6. CONCLUDING REMARKS

It is perhaps too early to make an assessment of POSE philosophy and materials. However a few comments may be appropriate to include. We describe the reactions of those involved with the project at various stages. We compare the impact of the project against the stated aims. Finally we outline some of the problems which still need to be solved.

6.1. *Reactions*

Those who become involved in the project are generally interested in statistical education anyway. Their assessment may be slightly biased but it is also likely to be more informed.

During the first year POSE organised an open national conference for teachers and educators. The aim was to provide a forum to discuss the project's ideas and statistical education. The general concensus was that statistics should be taught through its applications: many topics were suggested for consideration. It was also agreed that statistics should be taught by the subject teacher as it arose; there were a few dissenters who were worried that a 'cook-book' approach may be adopted.

The project team has accepted many invitations to run workshops and in-service courses for teachers and students. Generally the reaction has been most favourable, resulting in more names being added to the newsletter list. In some areas several courses have been run to meet the demand.

6.2. *Impact*

It is always hard to assess whether the aims have been realized in a project's work. Subjective judgement can be rather unreliable. Nevertheless we would assert that the project has shown the feasibility of its approach. The units of work produced do show a variety of applications, pupils are encouraged to think about a problem rather than mechanically apply a technique. Though not all the material is suited to pupils of all abilities, much of it has been successfully taught to both able and less able pupils. The problem-solving approach has been welcomed by teachers, many of whom would not have the time to collect the relevant background data in order to produce similar material.

The project has been less successful in persuading teachers of different disciplines to use its materials. Interdisciplinarity is a problem that needs careful thought. However a start has been made with a few case-study schools. And, overall, the project has shown the desirability of teaching statistics across the curriculum. Perhaps the last words should come from teachers.

Recent units have been found simpler, children are taking to them better and can work more on their own. A significant innovation has been occuring with the improved readability and presentation of the more recent units. Use *has been made of worksheets of POSE material to permit boys to work at different speeds such that three distinct units were in use by different students in the same classroom. POSE approach helps pupils remember ideas and become aware of real problems as they arise, useful as part of general education.*

NOTES

* The author worked with the project for three and a half years and has made extensive use of working documents produced by the project team in preparing this paper. He would particularly like to thank the director, Mr. Peter Holmes, for permitting the use of these documents. The author was formerly at the School Council Project on Statistical Education, University of Sheffield, Sheffield, England and is now at the Mathematics Department, Polytechnic of the South Bank, London SE1 0AA, England.

[1] Schools Council Project on Statistical Education: *Project Papers 1–10* (to be published).

[2] Schools Council Project on Statistical Education: *Project Units* (to be published by W. S. Foulsham in 1980).

[3] Schools Council Project on Statistical Education: *Teachers Handbook* (to be published by W. S. Foulsham in 1980).

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