Students' Project Work and the UK Applied Statistics Competition

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1. Background

With the introduction of the UK National Curriculum, coursework will now be formally assessed *from primary level upwards*. Furthermore, GCSE examinations, at age 16, have recently increased the weighting for coursework assessment (e.g. 20% minimum, 50% maximum for mathematics). As a result, more cross-curricular projects can now be expected, often under the broad heading of data-handling. Experience with entries to the Annual UK Applied Statistics Competition suggests that many teachers and their students will find it difficult to cope with these changes.

To enter the yearly Statistics Prize, teams of students (in age-groups 9+ to 13, 13+ to 16, and 16+ to 19 years of age) must submit a report on an applied statistics project which they have conducted themselves. Money and commendations are awarded in each age-group with one additional prize given for the entry making the best use of a computer. Statistics Prize entries must be *team* projects. While not precluding such groupwork, GCSE assessment does not encourage it because an individual's particular contribution must be identifiable and separately assessed.

Supervising students' coursework is difficult for teachers. Usually the syllabus suggests that some kind of (questionnaire) survey is an appropriate project, thereby tending to convey the erroneous impression that statistics is only social surveys. Nevertheless, this is an important move towards making at least one view of applied statistics accessible to a large number of students, and their teachers.

A teacher with a class of thirty students, all of whom are to be individually assessed, may well resort to a general "chalk-and-talk" approach to questionnaires, to the use of pre-structured responses, and to basic ideas of sampling. Such things are seen as preliminaries to the real purpose of producing something tangible to be assessed. It is the data presentation and analysis stages which are perceived to be most important, and since these stages of the thirty individual projects seem easier to manage if they are all essentially the same, the teacher gives a further general session on presentation, and analysis and the students then apply this individually.

The result tends to be projects undertaken "for the sake of doing projects". A class of thirty students produces thirty project reports based on thirty essentially identical studies, with identical styles of questionnaire, the same sampling design (almost invariably accessibility, but sometimes thirty class censuses), finished off with the same (obligatory) pictures, tables, graphs, and computations of the same derived statistics. Only the specific topic differs from project to project, e.g. preferences for "pop" records rather than for videos, etc. Discriminating between them is almost a case of deciding which student draws the prettier pie chart.

An alternative approach which may convey more sense of purpose to the students is to have all the students carry out research under one general "umbrella" heading. For example, "fashion" allows students to investigate many different aspects; sales, marketing, clothes design, standardisation, production, attitudes, and preferences, etc. Different approaches to data gathering will be encountered, and interesting comparisons between individual students' methods and data may be undertaken. The teaching approach shifts from "chalk-and-talk" overviews and teacher-centred instruction-giving, to a student-centred one relying on the group collaborating to identify useful and interesting aspects to investigate, and to plan how to obtain information which can sensibly and fairly be compared and contrasted. Not only is the statistical teaching/learning process more efficient, but it may also give important vocational insights into the "umbrella" subject itself. Furthermore, in describing and evaluating their investigations within the group, students exercise important skills of statistical communication, providing more meaningful possibilities for *oral* assessment, which is now a feature of UK examinations.

The first approach tends merely to test the student's ability to describe the broad parameters of the project in rather theoretical terms, i.e. to give a résumé of the teacher's notes. Students' critical appreciation skills are not invited because the teacher's directives pre-empt them. The "umbrella" approach, however, encourages important interactions between students, as they describe what they are doing and why, talk about its relationship to other students' investigations, debate which approaches are better, which evidence stronger, and what has been discovered.

In adjudicating the Statistics Prize, such interactions are not always available for evaluation. However, entrants have gradually been encouraged to include more discussion of background issues in their project reports, sometimes with amusing results. Unlike more mature researchers, students do not always keep opinions to themselves, nor show the same delicacy over matters of confidentiality.

"Fashion" was actually set for 'A'-level coursework last year. Given the broader range of statistical methods which should be available at this level, a wide coverage of these can be introduced through practicals with different focusses, e.g. comparisons of distributions of clothes sizes in different locations, clothes prices at different outlets, customer characteristics at different times, their classification by eye, and implications for quota sampling, etc. The examples are never-ending, but many teachers lack the confidence to conduct this kind of project work themselves, let alone to orchestrate it.

Statistics Prize entries using the "umbrella" approach have been preferable to those where small teams within a class do equivalent projects like the individuals in the first approach, especially when each serves to reinforce the impression that the students are doing what they are told, but that the teacher is wrong in what he or she is telling them.

A third common approach is that of the *single* project undertaken by a team of students who carve up the relevant research and statistical work between them, each taking responsibility for different aspects of the same project, be it data collection, analysis, art-work, typing, coordination, etc. Although not necessarily better than the "umbrella" approach, it does reflect the style of much of the real-life statistical work. In the Statistics Prize it has generally produced more evidence of real team-work and synthesis of input. Some "umbrella" projects have not reached the standard of integration which I have described, and instead end up as collections of rather disparate studies with a superficial theme. At their worst, they are merely like the first approach; equivalent surveys on different aspects of, say, media preferences; films; magazines, records, TV programmes, videos, etc.

If this last style is adopted, the teacher must rely heavily on the opportunity to assess on-going oral contributions to see that no student's acquisition of statistical knowledge and skills is impoverished as a result, since not all students will have equivalent or direct experience of all the research processes. This third approach is generally unacceptable for school level examinations, but should this necessarily be so? Is it the *doing*, or the *understanding*, of the research processes which it is more important to assess? If we assess only the doing, especially when the student is essentially following the teacher's instructions, we learn little about the student's understanding. Is it possible that students may gain, in ways which are just as important statistically, by taking part in, and contributing to, group project work, even though not directly executing each single statistical process themselves?

The question really relates to what are the *necessary*, and what are the *sufficient*, conditions for developing *statistical understanding*. Statistics Prize entries certainly indicate large gaps in students' understanding which the present approaches to project work do not solve. The ability to apply statistics does not merely "rub off" onto students because they have been exposed to practical work. Being told about how to do projects does not seem to work either. Relevant *perceptual and cognitive skills* must first be *identified*, *specifically trained*, and *exercised*.

Current teaching encourages the idea that the data are all-important. Once obtained, data take on a life of their own. They can be arranged, plotted, drawn, processed arithmetically, etc., in so many time-consuming, pretty ways. Busy-ness and activity seem to be major virtues for the students to display. A student, especially one younger than 16 years old, who sat contemplating the data, deciding which of the various statistical techniques would be appropriate, is unlikely to find this behaviour rewarded.

On the face of it, it seems reasonable to encourage an active approach to data. Some activity, however, is *constructive and productive*, other sorts are merely *mass-productive*. The reasoning behind data processing should be all important, but it is this which gets lost when all the focus is on the processing itself. For example, geographers taught to take three measures of a river's depth "in order to eliminate error", blindly follow this rule, apparently unaware that the arithmetic mean of measures such as 24cm, 28cm and 77cm is *never* going to eliminate the obvious error of a ruler held upside down.

Likewise, students who can answer a theoretical examination question of the kind, "Write short notes describing three of the following sampling methods, saying when each would be appropriate, and why: (i) simple random sampling, (ii) systematic sampling, (iii) quota sampling, (iv) stratified sampling, (v) accessibility sampling", nevertheless completely fail to use this knowledge when conducting a piece of practical coursework. Representative sampling in particular is ignored, and a whim or megalomania, seems to determine whether students use a census or a sample survey approach. Research efficiency does not seem to be considered.

The purpose of pilot studies is another area which seems to be overlooked in practical work. Questionnaires and other observation instruments are not field-tested, nor do students show any awareness of the *statistical* purposes of pilot studies. Sixth form courses include all the confidence interval work necessary for determining appropriate sample sizes for required precision levels, or meaningful detection rates, but students do not use it in their practical studies.

2. Cross-curricular considerations

Teachers are now under pressure to collaborate across the curriculum, partly for academic reasons, and partly to rationalise the otherwise burdensome coursework requirements in each separate subject area. Statistics, and more particularly data handling, can provide a bridge, enabling one project to serve several subject areas. The following example of an attempt to initiate a cross-curriculum project has much to tell us. A mathematics teacher, interested in statistical education, and with a responsibility allowance for promoting cross-curricular work in her school, established a team of colleagues; three other mathematicians, four scientists and four English teachers, and they proceeded to choose a project for the students which could be a useful teaching/ learning medium for each of the contributing disciplines.

Broadly speaking, the science teachers wanted the students to collect data relating to an ecological issue; the mathematics teachers were to use it to teach data handling; and the English teachers were to teach communication skills relating to technical report-writing. The scientists indicated that the other discipline teachers were saving them some of the teaching that they would otherwise do, so the coordinator assumed that they were familiar with the statistics which the mathematicians would now teach. She did, however, prepare a project outline for all the teachers, identifying the concepts and skills that were to be covered, more to ensure parity for the students than to tell the teachers what or how to teach.

The project proceeded to the general satisfaction of most of the teachers and students. Data were collected, analysed, talked and written about. Only the coordinator seemed disappointed. It clearly had not been sufficient for her to name the relevant statistical concepts, she should also have taught her colleagues what she meant by them. The major problems seemed to lie at the project-planning and data collection stages, the responsibility of the scientists. Their priority seemed to have been to obtain data, surprisingly with no real consideration of sampling or controlled experimental design. The resultant data were therefore inappropriate for teaching the required statistical inference processes, even to the extent that one group had not even managed to collect data from both of the comparison areas. To that particular science teacher, it was more important that her students learnt to collect data "in a scientific way" (which in fact meant using a particular measuring instrument), and for them to be taught to graph the data (by the mathematicians) than for them to see an investigational purpose to the exercise, one which could yield possible explanations and answers to relevant "why?" questions. This fragmentary approach to methodology teaching is sadly fairly typical.

A far better approach, of course, would have been to have the students planning the study, generating their own "why?" questions and working out how to find answers, and how to ensure that the answers which they obtained would be reliable and helpful. This would also have given the English teachers the chance to develop the students' discussion skills.

Team-teaching would have been a better approach here because:

(i) *All areas* have important perspectives/contributions to make to the teaching/ learning process at *all stages*. It is not particularly useful to say that the project is to be cross-curricular if it is still partitioned by discipline boundaries.

(ii) Such an approach provides an important in-service training function and yields real cross-curricular work, not merely one-off liaisons.

(iii) It allows students to see statistics in action, as it often is in vocational settings, as a collaboration and interaction between specialists with different skills and perspectives working on a common task.

However, from the statistical education point of view, each discipline teacher needs to find that discipline's relationship to statistics before statistics can provide a meeting ground, a common "language", with other disciplines. A basic idea of its principles and a certain baseline awareness and appreciation of its possibilities (with respect to "my" discipline) are needed first of all. Statistics Prize entries show that this kind of cross-curriculum project is usually better handled in primary schools. There, the teachers are general in their orientation, so they already have an eclectic view of research activities. At secondary level, however, this perspective has often disappeared and has to be encouraged in the teachers first before their students will get a taste of *real* cross-curricular work.

3. Proposal

Practical statistics teaching should start from the principle of finding out how to do *efficient* research. This is such a simple and yet flexible concept. Efficiency can be interpreted in so many different ways that the elements of choice and decision-making are immediately introduced. This is usually an important new experience for students, and their teachers, who are not used to being given such power. As a theme for research, efficiency has an obvious appeal. It is hard to see how practical research can be efficient if the resulting message is wrong, so it fixes the most crucial research objective, that of finding the truth, right at the outset.

Students are obliged to consider alternative strategies, however, and to find criteria, probably the more common sense and intuitively-based the better, for critically evaluating between different ways of *investigating* and *describing* that *truth.* Such a guiding theme has utility for all ages and all levels of statistical sophistication. After this principle is grasped, all the other statistical techniques are just "sums done for a purpose", which is exactly what they should be.