EMBEDDING STATISTICAL ASSESSMENT WITHIN CROSS-CURRICULAR MATERIALS.

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Many subjects in the school curriculum engage with contexts where multiple factors interact. Historically however, data have rarely been used at school level in such contexts because of the difficulties inherent in understanding multiple variable relationships. Stronger links across traditional subjects has proved an elusive aspiration for curriculum developers. We are currently engaged in a pilot project with the Northern Ireland Curriculum Authority (CCEA) to use some innovative interfaces with multivariate summary data as a focus for multiple perspectives on various contexts. Innovations in curriculum design offer opportunities for innovation in assessment. Often statistics assessment focuses primarily on accurate performance of routine calculations or graphical construction. Here the use of data is primarily to enhance understanding. This paper will explore mechanisms for embedding assessment of key statistical concepts within cross-curricular activities.

INTRODUCTION

Curriculum tasks and assessment tasks serve to define what is to be learned; more radically, they define what is worth knowing. The use of multivariate data will refine educational goals, and will pose a set of interesting challenges by posing questions about statistics that are not obvious when handling just one or two variables. For example, there are a number of key ideas in handling realistic multivariate data, such as:

- variables are subject to 'limiting effects'
- interactions are common
- confounding (the 'third variable problem') should always be considered
- effect size is critically important when modeling

We have no direct knowledge of how these concepts develop, the misconceptions that students hold, nor about appropriate diagnostic actions at school level.

Innovations in curriculum design offer opportunities for innovation in assessment. Often statistics assessment focuses primarily on accurate performance of routine calculations or graphical construction. Teachers testify that the interpretation of data is the part which they find most difficult to teach, and to assess. It is also the part that pupils have traditionally found most difficult, especially weaker pupils who have struggled through calculations and graph drawing to get to the point where they look for the interpretation of their data. There is a scarcity of resources which offer advice on strategies for interpreting data, or on suitable language to use in describing patterns in data. Pupils need exposure to a variety of contexts that allow them to become accustomed to talking about data in situations where they already have background contextual knowledge that they can bring to bear. Here, the use of data is primarily to enhance understanding: the pupils do not engage in detailed calculations; and the drawing of graphs is automated while giving the user control over the way the data is presented

Ridgway *et al.* (2007a) set out a framework of core concepts involved in handling multivariate data. Here we report evidence on the accessibility of some of these concepts for pupils, illustrated with student work.

THE NORTHERN IRELAND CURRICULUM AT KEY STAGE 3 (AGES 11 - 14)

CCEA are currently introducing a new curriculum for Key Stage 3 (pupils aged 11 - 14), encouraging teachers to move towards more collaborative work across traditional subject boundaries. It aims to make the curriculum more relevant, and to address wider issues relating to current working practices. The current assessment regimes, which focus almost exclusively on competitive and individual activities, do little to provide information for employers on some important workplace skills.

CCEA state (2002):

> *In addition, patterns of employment are changing and, consequently, the needs of employers. Feedback from employers' organisations indicates concern about levels of literacy and numeracy in the workforce, but there is also a feeling that those leaving schools and colleges should be better equipped for the world of work. This means better able to work with other people, better self-management and better problem solving.*
>
> *These are skills that schools help to develop in young people, not just as preparation for working, but preparation for the whole of life.*
>
> *The other important change in society is the development of new technologies. These are having an ever increasing effect in the classroom and need to be reflected in the curriculum. Information is easy to find now and knowledge for its own sake is less important than it once was. It is more important that we know how to make use of information, how to evaluate its usefulness, to sort out patterns and to solve problems with it.*

Central to these ambitions is introducing a more realistic view of the complexity of problems in the real world. The ability to manage information and handle data across the curriculum from real world contexts is one of the important skills that the revised curriculum seeks to develop. It is against this background that CCEA have commissioned our group at Durham to produce some data-rich resources to act as a focus for different curriculum perspectives (see Ridgway *et al.*, 2007a).

PUPIL PROFILING

To report progress to parents CCEA are developing pupil profiles in a number of sections. The first is *Skills Developed Across the Curriculum* and it reports on Communication, Using Mathematics, Information and Communication Technology: the requirement is that these will be assessed at levels, with supplementary comments from teachers.

The second section is *Achievement in Learning for Life and Work* and it will provide qualitative comments under the headings of *Employability, Home Economics, Local and Global Citizenship, and Personal Development*. The third section is *Attainment within the Learning Areas* where teachers will report on progress within recognisable traditional subject areas such as English, Modern Languages etc. Mathematics makes a separate appearance here.

CCEA have identified five broad skills areas on which teachers are expected to comment in the first two sections of the profile. These are:

a. Thinking, Problem Solving and Decision Making
b. Self Management
c. Working with Others
d. Managing Information
e. Being Creative

Within the UK, this marks an important shift in emphasis in what teachers are expected to assess and report on. See http://www.nicurriculum.org.uk/ for further information about the curriculum and its assessment. CCEA acknowledge that they draw heavily on the principles of 'Assessment for Learning' articulated by Black and Wiliam (1998).

Birenbaum *et al.* (2006) argue that if assessment for learning is to become a reality in classrooms then a paradigm shift in assessment practice is required and integrated assessment systems need to be developed.

ASSESSMENT IN THE DURHAM – CCEA CURRICULUM DEVELOPMENT PROJECT

There are no formal requirements in the project in respect of assessment. Pupil profiling requires teachers to make judgements on their students across a range of skills which have not previously been explicitly assessed or reported on, but there is no prescription from CCEA as to

how they should do so, and there will be no compulsion on teachers to use the materials we develop in the project.

We are trying to embed opportunities for the assessment of some of these broader skills into the materials we develop, in the belief that those skills are an integral part of the activities we ask the students to engage in.

The recommended structure is for pupils to work in small groups of 3 or 4 with one computer, and to discuss the patterns and trends that they see in the data. Instead of being presented with the 'facts' in the form of headline statistics, they are asked to discover stories the data have to tell. Initial studies indicate that pupils are very engaged with the activities and that uncovering the data stories for themselves has more impact than being provided with them explicitly – which in many seems to engender a feeling of being 'preached at' where the data context relates to use of alcohol, tobacco, drugs etc.

Typically an activity will ask one or two specific questions, which involve reading the graphs correctly, to help focus attention on the way the data is structured. Then descriptions of the behaviour of groups, and comparisons between groups, or behaviour over time and asked for. The most common approach is for the pupils to make some observations from the initial picture of the data, explore the data through the use of the sliders to see how the extra variables affected the initial picture, and then manipulate the position of the variables in order to see particular relationships more clearly. Teachers observing the pupils at work have described the level of discussion as much more focussed than they had previously seen from those pupils.

The data interfaces are accompanied by a booklet setting out the task, with spaces for pupils to write responses, so there is a record of the outcomes i.e. the conclusions the group have drawn. As might be expected, the quality of the pupils' written responses did not always fully reflect the depth of understanding they had displayed during the discussion. However, teachers felt it was still considerably better than they had seen from these pupils when interpreting data presented in more traditional formats.

Group work presents challenges for assessment, where any attempt at evaluating individual contributions is, in many senses, contrary to the spirit of groups. In the profiling which CCEA are introducing, working with others is to be described by a comment rather than measured and reported in levels. The discussion in groups seems to lend itself well to providing a substantive basis on which teachers can form a view on individuals in this skill area. Some of the activities have got a number of facets, and the teacher can set different facets to different groups, providing the opportunity for each group to report its findings to the rest of the class, with each report contributing something new to the understanding.

EXAMPLES OF ACTIVITIES AND STUDENT RESPONSES

Ridgway *et al.* (2007a) provides more detail on the project and the activities, and accompanying data interfaces can be accessed through our website (http://www.dur.ac.uk/smart.centre/). Here we offer brief explanations of sample activities with student responses to illustrate some of the intellectual exchanges going on.

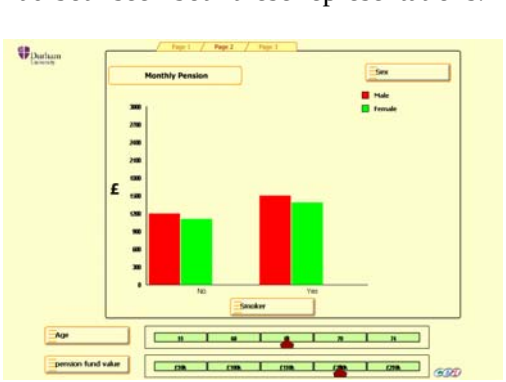
Pensions activity

Figure 1 shows the basic monthly pensions that male and female non-smokers could buy with a pension pot of £200,000 at a number of ages.

Figure 1: Screenshot of pensions data interface.

During the exploration of the data on pensions, there was lively discussion on possible explanations of the lower pension payouts for females, where a number of other factors likely to exacerbate the pension situation for females were raised. More women are in lower paid, or part-time jobs than men; more women take career breaks for family reasons and will not contribute to pensions for as long; more women would like to retire early to help look after, and enjoy, grandchildren. Opportunities for teachers to discuss confounding variables arose naturally, and while the treatment at this age will not be exhaustive, exposure to key statistical ideas when they arise naturally may well prove to be more effective in the long run.

At the end of the investigation into pensions pupils were asked to summarise in their own words the effects on monthly pensions of the age at retirement, the value of the pension fund, sex and whether the person was classed as a smoker by the insurance company [smoking over 20 cigarettes a day for an extended period], which were the explanatory variables they had had access to. Responses accurately identified these effects, with an appreciation of the relative scale e.g. that the difference in pension was greater between smokers and non-smokers than between men and women, and pupils manipulated the position of the variables in the graphs in order to convince themselves of their claims (see figures 2a, 2b). While it could rightly be observed that this effect size comparison can be done from either one of these graphs, pupils, aged around 14 years old, of modest academic ability, were much more confident in making this claim once they had both seen both these representations.



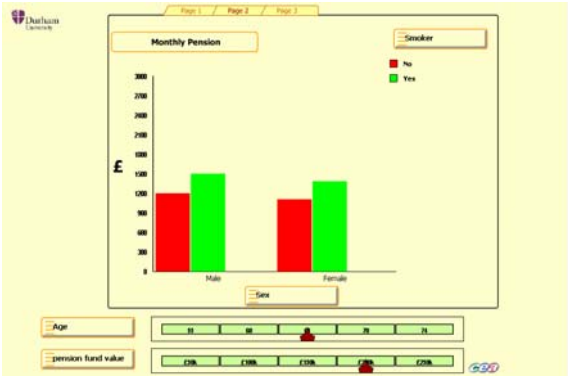


Figure 2a, 2b: Transposing the position of variables can be used to compare effect sizes.

Alcohol activity:

Figure 3 shows data on the proportions of 11 to 15 year old children, interviewed in 2004, who had had an alcoholic drink during the seven days prior to the interview. Data is shown for each age, separately for boys and girls. The slider at the bottom, allows comparable data from 1990 to 2004 to be viewed at two yearly intervals, allowing trends over time to be explored. Other pages in the activity have data on the frequency of drinking, the amounts drunk on average and what young people drink.

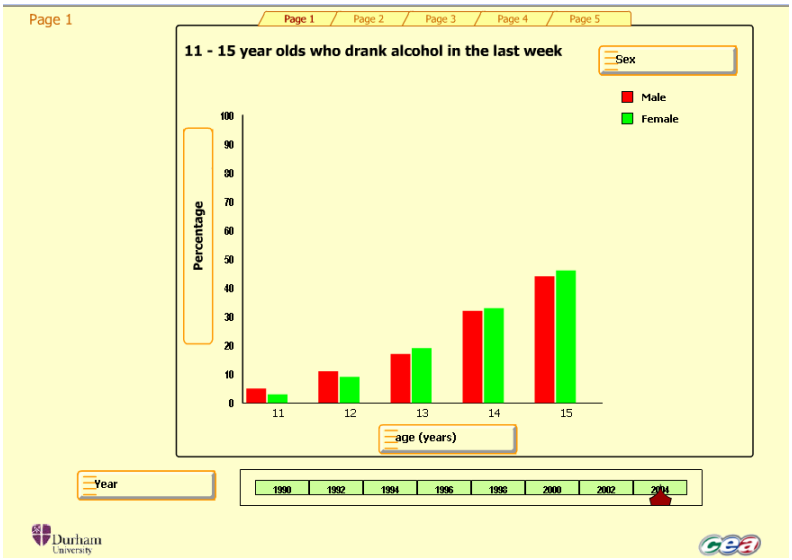


Figure 3: Screenshot of alcohol data interface.

Pupils described the differences between age groups, and identified differences in the way boys and girls behave over time. While this is a simple example of interactions between variables, it appears very natural to pupils at this age that this is an entirely reasonable description of what happens in the real world. Two comments from different groups about this data illustrate that they have understood the key stories in these data, even if the articulation is far from perfect, and there is always the temptation to offer causal commentaries alongside statements derived from the data.

- *Yes, between 11 & 15 the level of drinking goes up and there is a big difference. At the ages of 12-13 the girls start to catch up with the guys.*
- *Boys drank more than the girls when they were younger but as they got older the girls drank much more than boys. There is a big difference between 11 & 15 year olds. Because girls are trying to act more grown up.*

DISCUSSION

While the treatment of statistical information in these materials is very informal, we conjecture that familiarity with more realistic data at an early age is likely to mean that formal treatments have some conceptual foundation on which to build when they are introduced at a later stage in pupils' mathematical and statistical education. Moreover, for those who do not proceed in those directions in their education, and they will be in a large majority, they will have some experience of complex data which should equip them better to act as informed citizens. We have argued elsewhere (Nicholson *et al.*, 2006; Ridgway *et al.*, 2007b) that the statistics in the current curriculum does not do enough to equip our young people for the world they will live and work in: we hope materials such as these may help to improve this situation. Ridgway *et al.* (In press) report that computer-based multivariate reasoning tasks, supported by user-friendly interfaces, are no more difficult for pupils than cognitively simpler paper-based reasoning tasks, and we hope to extend that study further using some of these curriculum materials.

In the initial trialing reported here, teachers have used the materials with groups of pupils who they felt were reasonably typical of their school. Having used the materials in that way, some of the teachers are keen to extend their trialing to include pupils who struggle with their maths, especially those with disabilities such as dyslexia. Much remains to be explored as to whether any long term benefits accrue from the engagement that pupils show with these materials, either in mathematics or by developing a greater sense of coherence of their body of knowledge.

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