RECONCEPTUALISING 'STATISTICS' AND 'EDUCATION'

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Although most interesting problems are multivariate (MV) and students and citizens need to be able to reason using MV data, appropriate challenges are rarely encountered in class. In this paper we argue that the curriculum (and ideas about statistical literacy) should encompass reasoning with MV data. Statistics education can occur in a range of disciplines and in informal setting –notably on the web. Strategically, there is a need for dialogue with educators in other disciplines. We also argue for greater collaboration with data providers, who are engaging increasingly in 'People Net' (PN) activities–in short, a reconceptualisation of the education community. The SMART Centre has developed generic software shells that facilitate the import of MV data into interactive displays. We also describe their successful use in Citizenship classrooms where students interpret large-scale survey data on topics such as sexually transmitted infections and drug use.

INTRODUCTION

School statistics has undergone few fundamental changes in a long period of time. In the United Kingdom (UK) at least, there is a focus on the mastery of technique and rather little on interpretation of results (Ridgway McCusker & Nicholson, 2007a). The techniques themselves focus on the analysis of univariate and bivariate data (usually artificial) and make heroic assumptions about the nature of populations, in order that parameterised distributions can be used to model their behaviour. As a consequence, school statistics is largely useless in dealing with any data sets students might encounter in their lives outside school. This situation is (at best) unlikely to inculcate statistical literacy (SL) and at worst is damaging and potentially dangerous. If students know nothing about interaction or Simpson's paradox, where not conditioning on all the relevant variables may result in reversing the direction of an association, they are likely to draw conclusions about multivariate (MV) data that are completely wrong and may make important decisions using false conclusions (see en.wikipedia.org/wiki/Simpson's_paradox).

Curriculum areas such as geography, citizenship, personal, social and health education (PSHE), all deal with complex contexts where multiple factors impact situations, and where relevant, real data are available. These subjects make little use of relevant quantitative information because of the perceived difficulties in making sense of MV data. Teachers often come from non-quantitative backgrounds and so do not feel confident using quantitative methods in general.

The Istanbul Declaration (OECD, 2007) was endorsed by the Organisation for Economic co-operation and Development (OECD), the United Nations (UN), and the World Bank (among others) and promotes an evidence-based approach to social progress. It recommends involving citizens in the definition of 'progress' and appropriate indicators and advocates 'appropriate investment in building statistical capacity'. Data providers increasingly are concerned to have their data understood and used to influence policy.

In this paper we sketch ways in which data producers are attempting to improve the communication of statistical evidence. We present examples of curriculum activities based on interpreting MV data that show how the statistics curriculum might be reformed and promoted across the curriculum by some unlikely allies. The public presentation of evidence and opportunities to use MV data in school opens a whole new arena for statistics educators, that not only challenges current conceptions of statistics education but also suggests alliances with influential groups who share a strong commitment to fostering SL.

BACKGROUND

There is a large literature on the problems that students and adults have with simple concepts, such as interpreting static two-dimensional graphs, and tabular information (e.g.,

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Batanero et al., 1994). One might predict that working with MV data would be impossible for people with no statistical training. However, empirical explorations (e.g., Ridgway, McCusker & Nicholson, 2006) show that computer-based three variable tasks are no more difficult for 12-14 year olds than are two-dimensional paper based tasks. Du Feu (2005) has shown that much younger children can work meaningfully with multivariate data displays they have created in the form of tactile graphs built from LEGO®.

The creation of dynamic interfaces that facilitate interaction with MV data offers exciting opportunities for statistics education but also poses a number of challenges to our understandings as educators. There are opportunities to engage students with realistic data and to draw conclusions about factors influencing their own lives; opportunities to engage teachers across the curriculum in improving SL; opportunities to expand the notion of SL to take account of MV data; and opportunities to engage a much wider community in the development of SL. However, we do not yet know how to make use of these opportunities. Educational practitioners need to engage with this wider community.

Key agencies in the development of SL include government statistics offices, non-governmental agencies, and sites that are supporting 'People Net (PN)' activities (often called Web 2.0 activities), as well as providers of print and video media. Some national statistics offices are developing ways to make their data more useful and better understood. Some examples are given below.

Statistics Canada (www.statcan.ca/start.html) works directly with educators to develop resources. Schools have free access to E-STAT and its entire database of social and economic statistics, as well as to census information–so pupils have access to a huge amount of detailed data, with an intuitive interrogation interface allowing them to produce their own tables of summary data. They can produce thematic maps and a range of standard graphs. StatCan has plans for an audio podcast to give students help in choosing data for project work, which will be available for download in MP3 format (Townsend, 2007). The Australian Bureau of Statistics (www.abs.gov.au/) uses SuperTable from Space Time Research to make all their data easily accessible to all users. Like E-STAT, SuperTable provides a powerful analytical tool for interrogating data.

Mittag and his collaborators (Mittag & Marty, 2005) have developed interfaces that allow user interaction with Eurostat data; an important feature of this work is a facility to connect to on-line tutorials about statistical concepts. Gapminder (www.gapminder.org) is an excellent tool for the exploration of multivariate relationships, and has been adopted by the United Nations Statistics Division for the display of the Millenium Development Goals.

Sites promoting PN activities such as Swivel (www.swivel.com) and Many Eyes (services.alphaworks.ibm.com/manyeyes/home) offer a variety of interfaces, and some encourage users to upload and discuss data. Some government statistics offices (and OECD) are working to make their data available in such forums. PN technology affords opportunities for communicating with young people in ways familiar to them. Dynamic visualisation of data has some important champions. Enrico Giovannini, the chief statistician at OECD, argues that providers of statistics have to exploit all available technologies to help users make sense of data (Giovannini, 2007). Walter Radermacher, President of the German Federal Statistical Office, argues for 'intelligent graphics' that are data-driven, allow user interaction, and make use of animation (Radermacher, 2007).

In spite of all these developments, our ability to display MV data effectively is at an early stage of development. None of the agencies described earlier present MV data very effectively; there is an urgent need to develop interfaces, and to understand the development of reasoning with MV data in pupils and adults. There is now a window of opportunity for the statistics education community to collaborate actively with data providers to help provide good effective MV displays, which can significantly improve the quality of their websites and interactive publications, the quality of PN offerings and debate, and the relevance of the curriculum that can be implemented in schools (Ridgway, McCusker & Nicholson, 2007b).

Trying to fill these needs, the SMART Centre has designed a number of software 'shells' in Macromedia Flash® that run on web browsers and that facilitate the display of MV data. These are available as 'freeware'; data can be uploaded to our website (www.dur.ac.uk/smart.centre/). A variety of displays, which allow up to six variables to be displayed under user control, is available. Designs are based on a number of key principles:

- They allow the easy exploration of multivariate data that are almost impossible to explore in other ways;
- It is easy to upload data sets;
- Interfaces are intuitive for new users;
- Interfaces encourage users to engage actively with data to construct their knowledge, for example, by allowing them to choose the ways that variables are displayed and by the use of sliders;
- Applications are easy to distribute and occupy very little disk space.

METHODOLOGY

This study reports part of the development cycle for data rich activities in citizenship contexts in Northern Ireland based on the use of the resources described above. Seven schools were involved; two of them with academically selective intakes (grammar schools) and five other secondary schools with no academic selection entry criteria. Five of the schools provided a total of eight small groups of pupils who worked on tasks in the presence of the class teacher and a researcher, allowing detailed observation of the intellectual exchanges taking place. Following these observations, the interfaces and the curriculum materials were further refined, and six of the schools provided 13 classes to trial the resources in more realistic classroom conditions. Schools were asked to provide pupils covering the range of abilities typical in their school from the lower secondary age range (ages 11 to 14 years). Discussions with teachers before trialling these data rich activities had identified data interpretation as the biggest problem area within the statistics curriculum; teachers felt that pupils struggle with interpreting data, and teachers reported they find it more difficult to help pupils in this area than in other areas.

MV ON TRIAL–IN THE CLASSROOM

MV classroom resources were created about a range of topics that include alcohol use, drug use, sexually transmitted infections (STI), poverty, and obesity, and using data from large scale surveys loaded into a variety of SMART Centre MV displays. Activities were designed to provoke students to explore and interpret data. Essentially, early questions were designed to encourage student familiarity with the interfaces and to reward simple graph reading skills. The core activities required pupils to interpret MV data in meaningful ways (for example, by making a presentation to the whole class about trends over time in the incidence of a particular sexually transmitted disease). Here, we use a single data set (STI) to illustrate some general findings.

Figure 1a. Chlamydia Infection Rates in 2000

Figure 1b. Chlamydia Infection Rates in 2004

Students quickly get used to swapping the positions of the variable labels for sex, age range and time, and use these explorations to build up a stronger picture of the relationships in the data; see Figures 2a, and 2b for examples.

Figure 2a. All the Data for ages 16 – 19

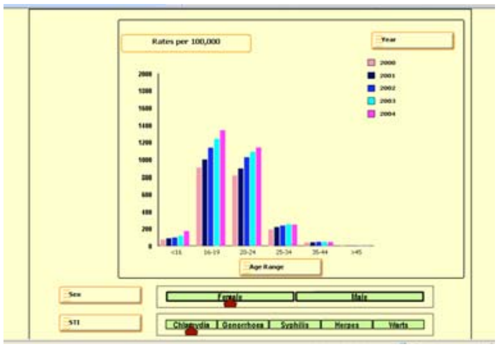

Figure 2b. All the Data for Females

The relationships within these data are more complex than anything pupils have previously encountered, so building confidence in their ability to describe relationships is important if they feel they can draw a sensible conclusion about something in the data. One test is whether the same conclusion holds when the display is reordered. In Figure 2b, it looks as though there has been a steady increase in rates for all age groups of girls between 2000 and 2004. Figure 2c has reversed the position of age and year on the graph, and the profiles in each year look very similar. Now, the steady increase in rates from 2000 to 2004 can be seen by scanning across looking at each colour.

Figure 2c. All the Data for Females with Age and Year Swapped Over

There are two striking features of the data on syphilis (not shown here). One is that this infection is extremely rare in comparison with the others. Second is that there are no obvious increases in the incidence over time. Pupils discussed these features sensibly. We conclude that 12-14 year olds can understand MV interactions in realistic contexts. The visual nature of the data representation makes it very easy to identify anomalous data points. This can encourage a critical evaluation of data, even when interpreting data that is presented by authoritative sources.

Statistics and graphs will show relationships between variables but do not provide explanations as to why the relationships exist. Some causal statements are obviously wrong, where the data are inconsistent with what would happen if the reasoning were true, but being consistent with the data is not sufficient for the reasoning to be true. These materials provide many opportunities for teachers to explore alternative plausible explanations for relationships that are evident in the data and to identify scenarios that are inconsistent with the story told by the data. This is an area where teachers have reported feeling very insecure, and we conjecture that they feel more comfortable with it when using our materials precisely because the data are complex and the context rich enough to support multiple, plausible, causal explanations.

An important feature of the materials is that the contexts are of interest to the pupils, and they have sufficient familiarity with the context to be able to think about what the data picture means in the real world.

LESSONS FROM CLASSROOMS

Classroom observations have provided evidence that young pupils across the attainment range can engage with and understand complex messages in MV data. This is an important result and opens up a large field for research into the nature of reasoning with MV data and appropriate pedagogy across the curriculum. It also gives grounds for optimism about the possibility of developing SL in schools and in the adult population.

Another important observation is that teachers with weak backgrounds in mathematics (and no knowledge of formal statistics) were able to use these materials effectively in class. Unsurprisingly, they did not use the language of 'variables' and 'interactions', but they were able to facilitate engagement and good insights by the pupils into the data. In interviews, teachers reported that pupils were able to make sense of the relationships in the data.

In mathematics lessons, the level of communication of statistical ideas was reported to be much higher than normal. Students were prepared to talk about these real, important, contexts whereas before they had been much less forthcoming in talking about the data they met in traditional mathematics courses.

We believe that a major component of the statistics curriculum at school level could be taught as a semi-qualitative discipline with semi-quantitative overtones. The mathematisation of trivial problems (e.g., learning to do *t*-tests on artificial data) is a major disincentive for pupils and teachers outside (and perhaps inside) mathematics. There are major conceptual problems in making plausible generalisations from small-scale studies (vividly exemplified in some studies reported in education research journals and in the popular conception that 'you can prove anything with statistics') that do not apply to studies on population data. The semi-qualitative approach advocated here requires us to identify some of the core statistical (and SL) issues when dealing with MV data. We need to understand the development of these ideas and ways in which development can be facilitated.

We have begun to assemble a list of core heuristics when exploring MV data. These include:

- critique the quality and source of the data;
- describe and explore phenomena before you try to explain things;
- focus on effect size not significance level;
- check that the effect size is a lot bigger than the likely error of measurement;
- identify variables that have the strongest effects;
- look at absolute levels–are they big enough to be worth worrying about?;
- look for non-linear relationships;
- explore the effects over different values of each variable–look for different functional relationships over different values of a variable (if it is cold, nothing happens…then as it gets warmer…);
- look for changes over time;
- look for interactions, and think about 'data surfaces';
- think about possible confounding variables outside the variables being analysed;
- disaggregate the data and see if the patterns of relationships stay the same as in the aggregated data;
- look for the 'dog that didn't bark'–were there things you expected to see but didn't?;
- be cautious of claims about causality–especially in observational data.

Work needs to be done to expand and exemplify items on this list and to develop appropriate pedagogic interventions to develop appropriate SL skills. This agenda is directly relevant to the school statistics curriculum. At least as important is its relevance to adult SL and the need to make these ideas part of 'common sense' in the media (including PN debates).

CONCLUSIONS

Reasoning with MV data is a key aspect of SL that has received little attention. It deserves prominence within statistics education, and could become a bridge to a range of curriculum subjects that can benefit from the exploration of realistic data. Key agencies such as statistics offices and NGOs are keen to promote SL but are aware of the problems they face. PN offers opportunities to develop SL in pupils and in the adult population. Small-scale classroom trials give us clear evidence that pupils, across a broad range of academic ability, can reason successfully with MV data. None of the teachers who took part in the classroom trialling had prior experience of modelling relationships in multivariate data, giving encouragement that training teachers to work with MV data using these interfaces is a realistic and achievable aim. There is a great deal of work to do in understanding reasoning from MV data and in making it more effective. However, there are tools to hand to help us reconceptualise our notions of ‘statistics’, ‘statistical literacy’, and ‘education’.

At the Joint ICME/IASE Study conference, we plan to describe the outcomes of work we have just initiated with data providers (including OECD and Statistics New Zealand) and to provide detailed results from a pilot study we have completed using MV data in schools as well as the results from more formal trials using MV data in Citizenship on a funded project due to finish in May 2008. We believe this work to be central to many of the goals of the ICMI/IASE Study and a springboard for any publications planned to develop materials for professional development and curriculum.

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