'Open Data' and the Semantic Web Require a Rethink on Statistics Teaching

1. ON STATISTICAL LITERACY

A number of authors offer generic descriptions of statistical literacy (SL) that are likely to be robust over time. Wallman (1993) in her Presidential Address to the American Statistical Association offers …. *the ability to understand and critically evaluate statistical results that permeate our daily lives... to appreciate the contribution that statistical thinking can make in public and private, professional and personal decisions*. Gal (2002) states that SL refers to ...*the need for people (including learners in both formal, non-formal, and workplace contexts) to develop the ability to comprehend, interpret, and critically evaluate messages with statistical elements or arguments conveyed by the media and other sources.* Important elements in these conceptualisations of SL are understanding (and critiquing) the statistics encountered in everyday life, and using statistics when making decisions. Media are presenting increasingly complex data in a wide variety of displays; 'evidence-based policy' is a mantra amongst politicians. Notions of SL (and their exemplifications in the curriculum) need to keep up with these changes.

Other authors, including Schield (2012), map out important components of SL that include:

- knowledge about data sources and the ability to evaluate the quality of evidence
- understanding concepts used to describe society (e.g. inflation, unemployment, GDP, poverty, GINI, 'happiness')
- ability to understand and draw conclusions from a variety of representations – tables, graphs and other visualisations
- knowledge about research methods (such as the relative merits of surveys, experiments, and meta-analyses).

However, of necessity, all of these authors offer just partial insights, as the statistics used in the media change. The lacunae in this list are associated with recent developments towards a data-driven society. Here, we review developments that require changes in our conceptions of SL, and map out what we believe the new conceptions should include. We then describe some curriculum materials and their use that can help develop important SL skills.

2. RESPONDING TO AN INCREASINGLY DATA DRIVEN SOCIETY

Important developments include: the Open Data movement; the graphical explosion; the rise of data driven journalism. We consider these briefly, then focus attention on the implications of the Open Data movement for curriculum and pedagogy.

2.1 The Open Data movement

There is a philosophical tradition dating back as least as far as Condorcet (1792) which asserts that an important part of education is to inform citizens about governance, and evidence about the state of society, so that they will be aware of injustices and structural social inequalities. Condorcet believed in *savoir liberateur* – liberating knowledge that would enable people to free themselves from social oppression. More recently, initiatives such as data.gov in the USA and data.gov.uk explicitly state political objectives associated with empowering democratic processes. For example, http://www.whitehouse.gov/open quotes President Obama: *Openness will strengthen our democracy and promote efficiency and effectiveness in Government.*

2.2 The graphical explosion

A great many ways have been developed to present data graphically since Playfair's (1786) invention of statistical graphics, often to inform people about political situations (e.g. graphical displays of income distribution produced by the Neuraths in the 1940s to demonstrate huge inequalities (see Neurath, 2010)). Major data providers are embedding their data in powerful visualisations in the hope of making data more accessible (e.g. OECD's data is accessible via Gapminder and eXplorer). Key development targets for countries, such as the UN Millenium Development Goals, are presented in the form of an interactive dashboard, to encourage public engagement. Strong claims have been made about the power of graphics to engage users with data (e.g. Yau, 2011). 'Infographics' are often visually seductive, but are not always a good representation of the data (see e.g. Tufte, 2001).

2.3 Data driven journalism

A highly significant cultural trend is the emergence of 'data driven journalism' (e.g. Bradshaw, 2010; Brooke, 2010; Rogers, 2011; Gray, Bounegru, and Chambers, 2012). Print and TV media, increasingly, are providing interactive graphics on their websites to support their news reports. Media such as the BBC, Guardian, Washington Post, Stern, Economist and New York Times have excellent repositories of data embedded in interesting displays, and promote the use of high quality data in their reports. Good examples and resources include: Matthew Ericson's descriptions of the design processes at the New York Times http://www.ericson.net/content/; The Guardian's datablog http://www.guardian.co.uk/news/datablog; and Matt Stiles (NPR) dailyviz, that presents interesting data visualisations, and invites ideas for future visualisations http://thedailyviz.com/

3. OPEN DATA AND THE SEMANTIC WEB: PROMISES AND PITFALLS

The 'semantic web' (sometimes referred to as Web 3.0) is one of the most exciting and important developments in ICT in recent times. A major problem for anyone who wants to access data on social issues is that relevant data can be found in (literally) thousands of data bases, spread over (literally) hundreds of websites. The core ambition underpinning the semantic web is the provision of a portal which allows users to work actively on huge, disparate sources of information relevant to a common theme. Users can locate data that is available on distinct databases, via simple keyword searches. Portals often provide suggestions for related themes and links to other sources of data. Users can then conduct analyses, and can re-present data in new ways. They can create mash-ups (assemblies of data, graphics and text) on their own websites, where (for example) data displays are revised automatically, whenever the source data is updated. ProgrammableWeb *http://www.programmableweb.com/* provides links to over 6000 mashups.

An excellent example of the development of the semantic web is provided by data.gov - a resource created at the behest of the US government, that is designed both to provide easy access to government data (from about 350,000 raw and geospatial data sets), and to make it easy to use and intelligible. Other examples include: data.gov.uk; UNdata; and OECD's Statsportal.

Many websites, however, present difficulties even for sophisticated users. For example, Simon Rogers, editor of the Guardian newspaper's datablog and datastore, offered these comments (Rogers, 2011) about the website of the UK's Office for National Statistics (ONS) *It should be pointed out that the ONS has incredible info on this site – but it is also the world's worst website*. It is impossible on many websites to extract multivariate data that extends beyond three variables (e.g. ONS, Eurostat). So the Open Data movement has still got a great deal of work to do, simply to make data from single websites accessible to sophisticated (let alone unsophisticated) users.

An exciting feature of the semantic web is the provision of Standard Application Programming Interfaces (APIs). ProgrammableWeb gives access to over 3,500 APIs that users can use to display data – examples include 'heat maps' to display spatial data. Users can also perform calculations on data, and can present it in novel ways. APIs have been created that allow data to be displayed and distributed on a number of platforms – including mobile phones. It is easy to embed mashups in Facebook, YouTube, and other social networking sites.

The semantic web (in principle) allows users to explore radical new conceptions about associations and causality between variables that were very hard to explore before. Data relevant to both practice and theory can appear on different websites, and can now be synthesized and explored. Social scientists from different disciplines and traditions can now explore phenomena in new ways, and can create multilevel theories at different grain sizes, and can incorporate variables in novel combinations.

Very strong claims have been made about what the semantic web delivers, and will be able to deliver. Many of these claims are unjustified. The video used to introduce data.gov contains this assertion*: it is now as easy to analyse data as it is to buy a pair of shoes or a TV on-line* (http://www.socrata.com/datagov/new-data-gov-platform-video-overview/ downloaded August 2011). It is certainly easy to create new variables, and to see how different values are distributed spatially. Datamasher is a site linked directly from data.gov, and provides several examples of 'heat maps' relevant to childhood obesity in the USA, state by state. A number of new variables have been created, using data from different government websites. These include plots of:

- fast food restaurants PLUS adult obesity rate PLUS % overweight children
- % obese children DIVIDED by % obese adults
- number of suicide deaths PLUS % obese children.

A fourth display purports to show "kids who are fat *because* their parents are fat" [italics added]. The variable displayed in the heat map is (State by State) the percentage of obese children multiplied by the adult obesity rate.

Such displays are evidence of the need for better SL in the community associated with the semantic web.

The rise of data driven journalism will enhance the use of data in the media, and will exacerbate the problems of interpretation and misinterpretation. The provision of powerful tools does not necessarily lead to empowered citizens. The extensive and increasing use of the internet to inform personal decisions will put similar demands on SL. We identify two sorts of challenge; first is to put more emphasis on components of SL related to data quality (conceived broadly); the second is to develop ways to help people with little formal training in statistics to understand multivariate data. Both of these need to be introduced in school and university curriculums.

4. IMPLICATIONS OF THE SEMANTIC WEB FOR SL

If educators ignore the emerging semantic web, we run two distinct sorts of risk. First is that evidence-informed democracy will simply fail as an idea. Second, we subject students to a curriculum that is largely irrelevant to their daily lives. Here, we set out some of the components of SL that are essential to working effectively with the semantic web.

4.1 A rose by any other name…

For the semantic web to work, there needs to be a way to describe variables that is common to all the databases that are accessed. As well as compatibility in terms of the ways that data are accessed, the deeper problem is the compatibility of metadata. Different agencies are likely to use identical terms ('poverty'; 'crime', 'educational attainment' and the like) for key concepts, but to measure them in different ways. Ongoing work on the Resource Description Framework (RDF) addresses this problem directly – the RDF sets out to allow structured and semi-structured data from different sources to be combined (see WC3 Recommendations (2004)). From the viewpoint of SL, an awareness of the potential problems associated with the compatibility of metadata is probably sufficient. However, there is a pressing need for greater awareness of key issues around measurement – notably on reliability and validity; examples are given in a later section.

4.2 Data accuracy

A critical approach to the source and reliability of data is an important component of SL. The internet is not simply a repository of reliable (or unreliable) information. There are systematic attempts by some information providers to deceive and defraud others. Authors often pretend to be not what they are; examples include fraudsters claiming to be lotteries or philanthropists, and companies who set out to create the impression of extensive web-based 'grass-roots' support for their products (so-called 'astroturfing'). Even data from supposedly reliable sources should be questioned. Brennan, Watson, and Charles (2012) examined official UK Hospital Episode Statistics, and found, *inter alia*, in a one year period that there were (supposedly) over 17 000 male inpatient admissions to obstetric services, and nearly 8 000 male admissions to gynaecology.

4.3 The politics of measurement

Decisions about what to measure can be of great social and political importance (for example, the Istanbul Declaration (OECD, 2007), and the OECD Global Project are based on the idea that Gross Domestic Product (GDP), and other measures of economic performance, should not be the sole measure of progress within a country - see Stiglitz, Sen and Fitoussi (2009); the quality of life, sustainable development and the environment should also be considered. The International Monetary Fund appears to disagree: the Principal Global Indicators which they list at http://www.principalglobalindicators.org/default.aspx are exclusively economic and financial indicators.

Decisions about how to measure anything raise important scientific issues. Concepts and associated measures of variables such as speed, velocity, acceleration and temperature now seem self evident, and in no need of exploration or challenge. However, a great deal of theoretical and practical work was required to develop these 'self-evident' measures. In the social arena, there are a great many concepts with 'self evident' meanings, such as literacy, health, poverty, inequality, and crime. However, the definition of these concepts is problematic, and an awareness of the difficulties, and the importance of understanding something about the nature of measurement, and the importance of the choice of measures (at both a practical and political level) will be an increasingly important component of SL. A starting point can be found in the work of Swan and Ridgway (see Ridgway, Swan, and Burkhardt, 2001) who created resources for undergraduates entitled Creating Measures, where users invent, then critique, different measures of the same physical attribute (such as ‘squareness’ or ‘smoothness’). The purpose of the critiques is to encourage the development of an aesthetic of measurement (what are good and poor properties of measures?).

4.4 Understanding representations

The large number of different sorts of visualisations that are being created means that an essential component of statistical literacy will be the ability to decode and work with novel representations. Gapminder is available as a free download, and a large number of data sets can be uploaded. Open Statistics eXplorer is a generic platform that can be used (free of charge) by educational and research establishments. The SMART Centre provides a facility for users to use their own data sets to create interactive multidimensional displays (see http://tomcat.dur.ac.uk:8080/smart.centre/). The Data Visualisation Centre within the UK Office for National Statistics makes its data displays available for use by non-profit organisations (see their dynamic population pyramid, for example http://www.neighbourhood.statistics.gov.uk/HTMLDocs/dvc1/UKPyramid.html). Google is increasing the number and quality of visual analytic tools it provides. The plethora of visualisations is likely to present considerable challenges for citizens (and educators), given the problems that users encounter when working with tables (e.g. Watson and Nathan, 2010), graphs (e.g. Swan and Philips, 1998) and box plots (e.g delMas, Garfield, Ooms and Chance, 2007). It is to be hoped that increasing the variety of representations in the media will lead to greater fluency in readers.

4.5 Understanding Multivariate Data

Perhaps the biggest barrier to widespread use of the semantic web is that people without a good deal of formal training in statistics may not be able to interpret multivariate data correctly.

5. THE NEED FOR CURRICULUM REFORM

In the UK, statistics teaching provides very little to support SL. At school level (in the UK at least), the statistics curriculum can be seen to have its roots in the early 1900s. The pace of scientific discoveries has increased dramatically over the last 100 years – in the early 1900s, there was very little scientific knowledge compared to now. Then, key questions in agriculture posing binary oppositions (‘Is this fertilizer better than that one?’) provided vital information. The power of statistics was to make it possible to do small scale studies that could be generalized across a variety of settings. Consequently, the curriculum became dominated by important ideas such as sampling and hypothesis testing. The absence of computational power meant that heroic assumptions, such as Normality and linearity (the idea that all the relationships between variables can be represented by a straight-line graph) had to be made to make problems tractable. The UK statistics curriculum focuses on the mastery of statistical techniques suited to small sample, one and two variable problems, with very few illuminating examples where these techniques are or have been applied, and can be seen to be useful (See Ridgway, Nicholson and McCusker, 2007b). So the original impetus for the discipline of statistics (applied mathematics designed to help decision making in a particular set of contexts) has been lost, and what remains are the pieces of applied mathematics. The result is that many of our most able and motivated statistics students are ill-prepared to understand data that are discussed increasingly in the media, and that can now be accessed via the semantic net. The need to build capacity here is urgent. We begin with a bald (but we believe self evident) assertion.

Every interesting problem in health, crime, poverty, environment, education, and personal well being is multivariate, has non-linear relationships, and has confounding variables.

Large scale complex data sets present different challenges in learning situations than do small data sets with few variables. First, the data are primarily observational, and so inferences about causality should be tentative. Linear relationships are rare; and interactions are common. For example: UK data show that white students have higher educational attainment overall than black students; students receiving free school meals have lower attainment overall than students who are not on free school meals; but white students on free school meals have lower attainment than black students on free school meals – so the effects of the two variables interact, and are not simply additive.

The balance of knowledge and skills in the curriculum needs to be reweighted, away from an emphasis on linear models and significance testing, towards interpreting large scale multivariate data. Given the difficulties that students experience working with just one or two variables, these challenges might seem insurmountable. However, we have a variety of evidence to suggest that this is not the case. First, our studies (Ridgway, Nicholson, and McCusker, 2011) show that statistically naïve students (aged 14-16 years) working with large scale authentic data often have good insights into concepts such as effect size and interaction. In other studies (Ridgway, Nicholson, and McCusker, 2007a), we show that visualisations which pose questions based on multivariate data can actually be easier (in psychometric terms) than paper-based questions focused on one and two variables.

If we are to respond positively to the challenges and opportunities offered by the semantic web by engaging in curriculum reform, we need to be confident that the reforms can be made to work in representative classrooms. Our current work in classrooms (e.g. Nicholson, Ridgway and McCusker, 2011) with social science students engaged with authentic multivariate data on health and social inequalities offers scope for optimism. This is described briefly, below, and some lessons for pedagogy are set out.

6. AN EXAMPLE: EXPLORING COMPLEX DATA IN SOCIAL SCIENCE CLASSROOMS

The Nuffield Foundation funded a project, Reasoning from Evidence (RFE), which created visualisation tools to present multivariate survey data to support the teaching of Sociology in courses for 16 – 18 year olds. In the UK, admission to university is determined by success on content-based examinations (GCE) in a narrow range of subjects. Students who want to take university courses in social sciences usually take preparatory courses in subjects such as sociology or psychology.

The starting point for any theory should be a clear understanding of phenomena. This poses a problem for teaching social sciences, particularly at the school level, for a number of reasons:

- every social phenomenon is influenced by a number of factors;
- until the recent open data movement, access to authentic data was problematic;
- data in textbooks are (usually) out of date before they are used in class;
- formal statistical analyses of multivariate situations are difficult to conduct and to understand. Even if the teacher understands the analysis (unlikely, given the background of most teachers), the students will not.

In class, the use of data has largely been restricted to headline statistics based on aggregated data, and explorations of the associations between single factors and some phenomenon of interest.

A key theme in GCE sociology is ‘inequalities in educational attainment’. We describe the materials we developed, focused on this topic, here. At the end of compulsory schooling (age 16 years) pupils take a number of subject-specific examinations (English, mathematics, geography, etc), that are set nationally. Performance is graded on a letter scale, and A* to C grades are viewed as ‘a good pass’. Schools are obliged to publish the examination results of their pupils, and tables are created where schools are ranked in order of pupils’ examination results (some parents use these tables when deciding where to send their children). A commonly used measure of school success is the number of students who pass 5 or more subjects at grades A* to C, including English and mathematics. National data are available on student performance, disaggregated by ethnicity, sex, and eligibility for free school meals (FSM or NFSM) – a surrogate for relative poverty (see http://www.education.gov.uk/rsgateway/DB/SFR/s000900/index.shtml).

Textbooks report well-known phenomena:

- girls perform at least as well, and usually better, than boys in every subject that is tested at the end of compulsory education;
- pupils in lower socio-economic groups perform less well than students in higher-economic groups;
- there are big differences in the performance of different ethnic groups.

The attainment data actually reveal far more interesting patterns, and students can discover these patterns for themselves when presented with the data in an interactive display. Figure 1 shows the performance of girls and boys (and All pupils) for each of the main ethnic groups. Students can choose to compare all pupils in each ethnic group, or just those on FSM, or just NFSM pupils. Tabs at the top of the display provide more detailed data allowing the exploration of differences between ethnic subgroups within each of the main ethnic groups. Variable names (FSM?; ethnic group; sex) can be dragged to different locations, to facilitate active data exploration – for example, to see which factors are associated with the biggest effects. The interactive display and guidance on how to use it, with classroom materials, can be found at www.dur.ac.uk/smart.centre/nuffield.

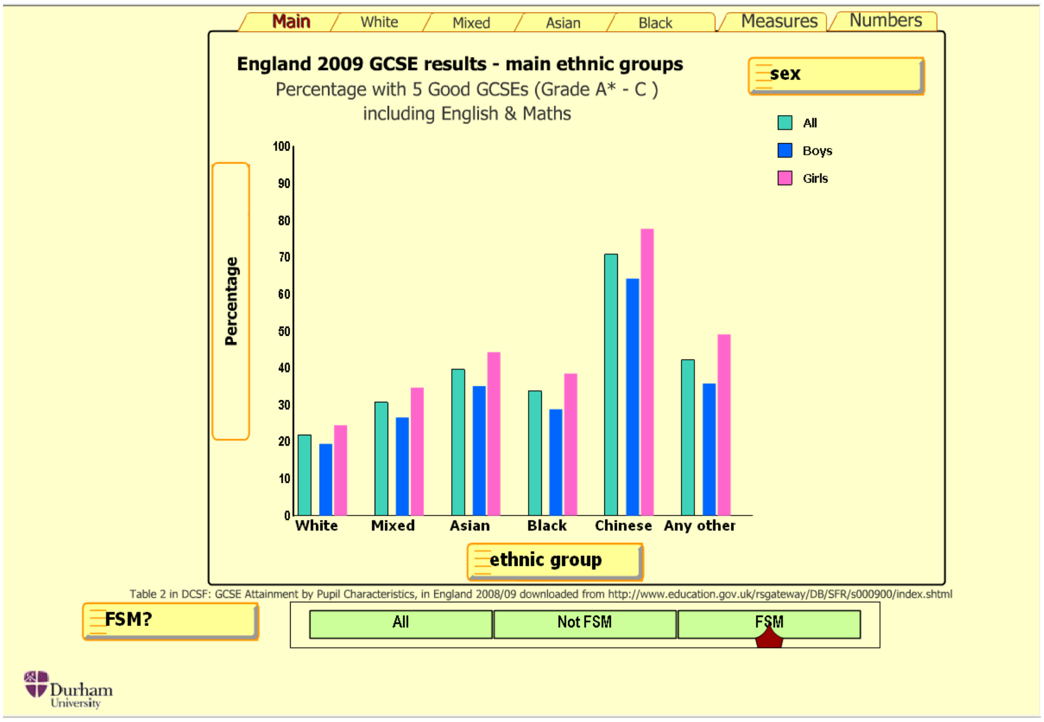

Table 2 in DCSF: GCSE Attainment by Pupil Characteristics, in England 2008/09 downloaded from http://www.education.gov.uk/rsgateway/DB/SFR/s000900/index.shtml

Figure 1: Ethnic differences for pupils eligible for free school meals

6.1 Key Statistical ideas

To describe these data effectively, one needs to be sensitive to some big statistical ideas:

- There are huge differences in attainment between groups – pupils from itinerant groups achieve about 5% passes; Chinese pupils achieve about 70% passes (range, effect size);
- Within every group (ethnicity, school meals), girls outperform boys by about 5-10% (simple main effects; effect size);
- Eligibility for free school meals is associated with attainment in a dramatic way for the white population (FSM pupils achieve less than half as many passes as NFSM pupils; white pupils eligible for FSM have worse examination results than black children eligible for FSM), but hardly at all for the Chinese population (interactions).

6.2 Encouraging a critical view of data

The sociology curriculum explicitly requires students to study research methods - including strengths and limitations of quantitative approaches and of the data they generate or use. Our visualization tools describe the provenance of the data, and provide ways to access the metadata.

The tab labeled *Measures* in figure 1 shows the performance data when English and mathematics must be included in the 5 examinations to be passed. Unsurprisingly, it shows changes in attainment patterns in some ethnic groups more than others. The tab labeled *Numbers* shows the number of pupils in each of the classification groups, so that students can see that the 'White' sample comprises 480,000 students, and the Chinese sample comprises just 2,275 students.

From the viewpoint of theory, we might want to use FSM as a surrogate for poverty, or social class, or both – students can be invited to discuss the plausibility and pitfalls of such assumptions.

The corruptibility of indicator systems provides an interesting topic for discussion. Goodhart's law (1975) refers to the idea that once a social or economic indicator is made a target for some aspect of policy, it then ceases to measure what it used to measure. This happens because stakeholders find ways to raise or lower scores on the indicator via superficial, rather than deep, changes in system activities. Data on educational attainment provides an example. When first introduced as a measure of school performance, the proportion of pupils gaining 5 good grades at GCSE was generally accepted as a reasonable measure of the raw academic performance of a school. However, very quickly schools explored ways of increasing their rating on this measure by a variety of means such as entering pupils for qualifications which counted for as many as 4 GCSEs (e.g. in Art) with associated curriculum distortions (e.g. some students spending as many as half of their lessons studying Art) and by assigning a disproportionate amount of the school's resources to the borderline group of pupils who were identified as being capable of achieving 5 good GCSEs but were at risk of not doing so (by teaching them in very small classes or by offering one-to-one tutor support in one or two subjects).

Displays that present multivariate data have been used in more than 20 sociology classrooms. Teacher responses have been uniformly positive. Studies using similarly structured materials with a wide range of student ages and attainment have also elicited very positive teacher responses.

7. PROMOTING NEW STATISTICAL LITERACIES

The classroom materials we have developed begin to address some of the key elements of SL that were identified earlier. We believe (and have evidence to suggest) that they foster appropriate dispositions and habits of mind about data and evidence that should be components of SL. These habits are set out below, with pointers to the ways that they can be fostered in class.

The ability to evaluate the quality of evidence

Providing information about data sources, and embedding information about metadata into displays, and discussion points for teachers, draws attention to data provenance and quality.

Handling new representations

The explosion in techniques for data representation means that the ability to critique and interpret new displays has become important. Exploring our interfaces provides some experience of this.

A sophisticated approach to measurement

Teacher notes on topics such as Goodhart's law, and the appropriateness of using FSM as a surrogate for poverty and/or social class, provoke relevant discussions.

Conceiving statistics as modeling

Because of the power of statistical models to describe a wide range of phenomena, it is easy to design a curriculum where students are taught statistical techniques and models for their own sake, devoid of context. Here, the focus is primarily on describing phenomena. Students are unlikely to believe that all phenomena can be modeled via linear algebra (although we have not tested this conjecture directly).

Action-oriented statistics

Statistics is seen in the context of an investigative cycle, where the end point is a theoretical account and some action designed to change the current situation. A central idea is to use population data to draw conclusions and plans for action that will be applied to all subpopulations (so interaction, effect size and Simpson’s paradox are important). It also encompasses ideas such as risk, and utility.

8. STRATEGIC AND PEDAGOGIC PRINCIPLES FOR CURRICULUM REFORM

Any educational innovation depends on teachers changing some aspect of classroom activities. People are more likely to change practices if the new practices: make life more fun; make life easier; solve a problem the person knows they have got; has a good deal of social approval. We set out some important pedagogical principles.

Address a major educational goal

The semantic web presents challenges to pedagogy. An important educational goal is to help students become sophisticated users of evidence. This, clearly, involves shaping dispositions – in particular, to increase engagement, and a willingness to explore new data, new representations, and new ideas.

Begin by showing students the potential payoff from learning about statistics

> Vygotsky (1978) argues that people need to see the value of a tool before they invest effort in its acquisition. The use of contexts that are of direct interest to students (e.g. crime, alcohol use by young people, incidence of sexually transmitted infections) motivated students to engage with statistics.

Solve problems teachers know they have got

> We The SMART centre offers access to current, authentic, data, and exploratory tools that are easy to use in a class setting (so we act as a bridge between the classroom and the semantic net). We have also chosen to present content that is central to the curriculum – see https://www.dur.ac.uk/smart.centre/nuffield/

Use constructivist approaches to teaching

> We encourage active exploration of data, hypothesis generation and testing, rather than memorisation of other people's summaries.

Make life easier for teachers

> We give teachers resources that reflect well on them in class, and that lead to valuable classroom activities. We provide guidance in sufficient detail to allow them to succeed, but in a way that will be compatible with a range of teaching styles.

Make life easier for students

> We present very extensive data sources relevant to the theme in question in a single location that is easy to navigate.

Make life more fun for teachers

> Resources lead to enjoyable classroom activities.

Encourage responsible modeling

> The nature of the data presented contains implicit messages that encourage users not to make the statistical assumptions that are commonly made, such as linearity, and a belief that complex phenomena can be understood via an assembly of one and two variable analyses. Data are presented in a responsible way: the source of the data is stated clearly (with links), and the metadata are displayed in a comprehensible way (with links to 'real' metadata descriptions for the bravest students).

The Trojan mouse

> Teachers and students seem hardly aware that they are engaging in statistical thinking. Important ideas are discussed but are not labeled as being 'statistical'.

It is reasonable to ask about the components of the school statistics curriculum that should receive less attention, if multivariate data is to be explored. We offer some starting points; Schield (2012) offers more. Statistical inference is conceptually difficult. More use should be made of exact probability tests, and heuristic devices of the sort advocated by Wild, Pfannkuch, Regan and Horton, (2011). Sampling distributions should be introduced via computer simulations.

9. CONCLUSIONS

Developments with open data, such as the semantic web, offer unprecedented access to large scale, authentic data sets on a huge variety of topics, relevant to public policy and personal happiness. Successful use of such data requires a rather different skill set to skills encapsulated in many current views of 'statistical literacy'. Key skills involve a critical appreciation of data provenance and quality, and understanding of statistical ideas associated with multivariate analysis of large data sets.

The (UK) school curriculum is grounded in 1920s statistics – it is focused largely on one variable and two variable problems, and the emphasis is on testing hypotheses based on small samples. The semantic web offers multivariate population data, and can form the basis for theory, and for political decision making. Key 'new' SL skills are to describe the qualitative and quantitative features of complex phenomena. Ideas such as effect size and interaction are central to these descriptions. There are two distinct challenges to face; one is to address SL in the public domain; the other is to shape the school curriculum so that school leavers are equipped to benefit from the semantic web. We are optimistic that data rich resources can be developed and embedded in a number of curriculum areas which can be the basis for appropriate curriculum change.

9.1 Post Script

Other free teaching materials such as interactive displays on sexually transmitted diseases, alcohol use by young people, poverty, heart disease and TB can be viewed at http://www.dur.ac.uk/smart.centre/freeware/.

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