ROYAL STATISTICAL SOCIETY
DATA | EVIDENCE | DECISIONS

Institute and Faculty of Actuaries

A world full of data

Statistics opportunities across A-level subjects

Roger Porkess

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Assistant Researcher: Stella Dudzic

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Royal Statistical Society
12 Errol Street
London EC1Y 8LX
Telephone 020 7638 8998
www.rss.org.uk

The Institute and Faculty of Actuaries
Staple Inn Hall
High Holborn
London WC1V 7QJ
Telephone 020 7632 1458
www.actuaries.org.uk

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About the Royal Statistical Society

The Royal Statistical Society (RSS) is one of the world's most distinguished statistical societies. It is a learned society for statistics, a professional body for statisticians and a charity which promotes statistics for the public good. It was founded in 1834 as the Statistical Society of London (LSS) and became the RSS (Royal Statistical Society) by Royal Charter in 1887. In 1993 the RSS merged with the Institute of Statisticians. Today the society has around 6,500 members around the world, of whom some 1,500 are professionally qualified with the status of Chartered Statistician.

The Society is active in a wide range of activities, reflecting the diversity within the discipline of statistics. The RSS focuses strongly on statistical education in its broadest sense, as stated in its Royal Charter, and offers a range of educational qualifications and continuing professional development opportunities for statisticians.

In 2010 the Society launched the *getstats* campaign. With support from the Nuffield Foundation, the campaign aims to increase statistical literacy and wants to raise the profile of statistics and its increasing relevance in today's data-rich society.

About the Institute and Faculty of Actuaries

The Institute and Faculty of Actuaries (IFoA) is the UK's only chartered professional body dedicated to educating, developing and regulating actuaries based both in the UK and internationally. We represent and regulate our members for the benefit of the outside world and oversee their education at all stages of qualification and development throughout their careers.

Actuaries work in a variety of roles in the public and private sectors across a wide range of industries. Actuaries provide commercial, financial and prudential advice on the management of a business's assets and liabilities, especially where long term management and planning are critical to the success of any business venture. They also advise individuals, and advise on social and public interest issues

Members of the IFoA have a statutory role in the supervision of pension funds and life insurance companies. They also have a statutory role to provide actuarial opinions for managing agents at Lloyd's. Members are governed by the Institute and Faculty of Actuaries. A rigorous examination system is supported by a programme of continuing professional development and a professional code of conduct supports high standards reflecting the significant role of actuaries in society.

Foreword – David Hare
President of the Institute and Faculty of Actuaries

Whether reading the results of a trial in our workplace or choosing a credit card with the best annual percentage rate (apr), we all use statistics in our daily and working lives and yet the general understanding of statistics in the UK is known to be poor. To make informed decisions we need to understand the information that is presented to us and if that information is statistical then any gap in knowledge can make people vulnerable. The teaching of statistics is something that the IFoA considers important and valuable for everyone.

It used to be the case that statistics was the study of mathematicians, but as Roger Porkess notes in his report, in many academic disciplines where statistics was once peripheral it is now becoming central. Roger examines ten, non-mathematics, A level subjects in his report where data is important and where statistics now play an important role. His conclusions provide food for thought for us all, but should be of particular interest to those who work in education either as teachers or in roles that set the curriculum.

It is necessary for actuaries to have a strong grasp of mathematics and statistics, and reasoning, to be able to perform our roles in the public interest. We see that a better understanding of statistics by future professionals in other disciplines within the working environment will be to the benefit of industry, government and the public.

Foreword – John Pullinger
President of the Royal Statistical Society

In a world awash with data, statistical understanding is increasingly important in all areas of society. Statistics is the language of the future data economy. The ability to understand numbers, interpret data and communicate evidence is an essential feature of the modern workplace, and crucial to competitiveness in the global market. In the academic world, almost all subjects are increasingly quantitative. And facility with data and statistics is a vital life skill: every citizen needs to be able to make sense of concepts such as risk and probability on an almost daily basis.

Just as literacy in English was the key to success in the 20th century, literacy in statistics will be the key to success for individuals, businesses, governments and countries in the 21st century.

It is crucial that this imperative is reflected throughout the curriculum. Across subjects at A level, there are opportunities for statistics to play a greater role, enriching both those subjects and students' understanding of statistics.

This report makes recommendations to policy makers, curriculum developers, school and college managers, examination regulators and awarding bodies, those responsible for school mathematics, providers of teacher training and professional development, teachers, providers of teaching materials, and the statistics community. That they are aimed at such a broad spectrum of organisations and actors reflects not only the great and increasing importance of statistical education, but also the extent to which we all have a stake in getting this right.

This report makes an important contribution to the debate, but it is also a call to action. The world of tomorrow will be full of opportunities for individuals – in education, in employment, and as citizens – who have the skills and confidence to deal with and interpret ever-increasing amounts of data. The recommendations in this report are intended to help us equip all of our young people to seize those opportunities. The Society will continue vigorously to pursue this goal. We hope you will join us.

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Preface

In January 2012, the Royal Statistical Society and the Institute and Faculty of Actuaries published *The Future of Statistics in our Schools and Colleges*[1]. This gave an overview of the state of pre-university statistics education at the time it was written.

That report covered the statistics provision in GCSE and A level courses in relevant subjects. However, there was clearly a need for a deeper and more aspirational study focused on A levels, taking account not just of current syllabuses but also of the directions in which the various subjects are moving.

My sincere thanks are due to the Royal Statistical Society, particularly Roeland Beerten, for embracing this suggestion and to the Institute and Faculty of Actuaries for funding it. Throughout, it has felt a privilege to be working on it.

This report is based on roundtable discussions, and follow-up correspondence, with ten different subject communities, together with input from various other sources. It may be seen as the advice from between 80 and 100 eminent people. It has been immensely rewarding listening to their expertise and tapping into their enthusiasm. The many quotes they have provided for the report are intended to capture their collective wisdom.

A major surprise was the extent to which all the subject communities were saying the same things. There are issues and opportunities that are common to them all, transcending the demarcation lines between them. Section A of this report draws together the requirements, opportunities and constraints in the ten different subjects as a set of generic findings.

Section B gives a summary of the evidence obtained for each subject, and so has ten sub-sections. These are presented in a uniform format, allowing the different subjects to be compared and contrasted.

The various meetings were convened by the Royal Statistical Society and thanks are due to Debra Hurcomb and Moussa Haddad for contacting such a large number of people.

Finally, I would also like to thank Stella Dudzic, who came with far greater knowledge about the issues than her position of Assistant Researcher would lead one to expect. Stella proved a great help, not least in capturing just what people were saying at meetings.

Roger Porkess

Executive summary

Rationale

As a result of digital technology, data are now being collected on a scale that was unimaginable even a few years ago, and the information extracted now affects every aspect of our lives. This is true not only in our personal lives but also in the workplace and in higher education; in academic disciplines where statistics was once peripheral it is now becoming central.

It is critically important that we equip our young people with the skills they will need to live and work in this data-rich world. This is true not just for their own well-being but for that of the country within the global economy.

This report describes the outcomes of research into how this changing environment can be reflected in A level classrooms across different subjects and the teaching opportunities that are becoming available.

Methodology

The research looked at ten different A level subjects: biology, business studies, chemistry, computing, economics, geography, history, physics, psychology and sociology. In all of them data are important, and so there is a role for statistics.

Roundtable meetings were held at the Royal Statistical Society with participants invited from each subject community: employers, university lecturers, teachers and members of learned societies, subject associations and examination boards. Email discussion continued after each meeting as drafts of the summary were circulated and their final form agreed.

Scope

This report is specifically about statistics, defined very broadly, and not about the rest of mathematics. However, it recognises that statistics inevitably requires a level of competence and engagement with mathematics.

The focus of the report is what can, and should, be done in the future; although this is likely to build on current A level practice, it is not restricted by it. It is aspirational.

Outcomes

The expectation at the start of the research was that in most of the subjects some topics would be found where greater use of statistics would be beneficial, and perhaps some new areas of study that might be introduced. The main part of the report would describe these outcomes, with the reports from the various subject meetings forming separate sections.

However, as the research progressed it became clear that essentially the same issues were arising in all the subjects, despite their obvious differences. Even the subject specific opportunities usually fitted into an overall general pattern. Looking across so many subjects provided a perspective that would not have been available from them individually, and this was enhanced by the diversity of the subjects considered.

So, as well as including the reports for the individual subjects, this report describes a set of generic outcomes which are relevant across the whole education system. These are described in terms of end-user requirements, opportunities and constraints. Most of the recommendations are made on the basis of these generic outcomes.

The generic outcomes raise a fundamental question. Is the current curriculum structure, fragmented into different subjects, capable on its own of providing our students with an adequate preparation for their adult lives? At the time of writing this report the government's position is that almost all students should continue with some form of mathematics post-16 in addition to their other subjects, and this should be an opportunity for students to become much better prepared in working with data.

End-users

Two types of end-users were considered: those in higher education accepting new undergraduates and employers taking on new graduates. The requirements of both groups can be summarised as being that people should be statistically literate although the meaning of this term is more sophisticated for the latter group. At both levels, people need the confidence to engage with data, and the competence to be able to interpret them. In the workplace communication is particularly important.

Opportunities

Two major types of opportunity are identified: an increase in the use of investigative work and making more use of the power of computing. Many of the opportunities in the different subjects can be described within these two categories. However, in addition there are particular topics that could find their way into A level teaching of their subjects for the first time.

At A level investigative work was formerly often assessed by coursework and it was there that students experienced a full problem solving cycle, including the use of appropriate statistics to interpret their results. However in 2008 some subjects lost their coursework component and an effect of this has been to disconnect the statistics from the rest of the syllabus.

Increasing the amount of work requiring the full Statistics Cycle (see page 22) should be seen as an important opportunity for students to become more statistically literate.

Computing has revolutionised workplace practice and many areas of research, with much more emphasis on using data to provide evidence. Many degree courses have been changed as a result, and this is an ongoing process as the consequences of big data are absorbed.

However, so far the impact on A level courses has been minimal, with the risk that they will become increasingly detached from the world beyond.

This report explores ways in which the power of computing could be used to improve students' learning at this level, and particularly their use of data. This will probably require the introduction of new concepts and techniques into school level statistics.

There is a strong case for developing new courses and qualifications in data analysis, bringing together computing and statistics.

Constraints

Three major constraints are identified: the effects of GCSE Mathematics; the very large number of teachers needing CPD; the unintended consequences of the current accountability system.

Almost all students take GCSE Mathematics and this includes some statistics. Since most then give up mathematics, this provides the basis for the quantitative work they will do in their chosen subjects. However, it does not provide them with the transferable skills they will need; even students with good mathematics grades, who can answer questions in mathematics examinations, seem unable to use the same techniques elsewhere.

It would fall to teachers of the various subjects to deliver the opportunities identified. However, while experts in their own subjects, many have only a limited knowledge of statistics and this is often confined to the particular techniques demanded by the syllabus. A very considerable programme of CPD would be needed to enable all these teachers to engage with any new ideas.

Almost all the teachers consulted in this research regretfully expressed caution. What they said can be summarised as ‘*It is more than my job’s worth to try anything new if it is not going to come up in an examination question*.’ This emphasis on teaching for the test is a direct result of the current accountability system, with its heavy emphasis on examination results.

All three of these constraints may be seen as opportunities. There are ways of addressing them that would not be prohibitively costly, and the benefits of doing so would be widespread.

Recommendations

It's a revolution. We're really just getting under way. But the march of quantification, made possible by enormous new sources of data, will sweep through academia, business and government. There is no area that is going to be untouched.

Gary King[2]

Policy makers

1 A statistically literate population is critically important for the future of the country. This need pervades almost all aspects of our national life and should be recognised in policy decisions relating to the education of all our young people.

2 The theory of statistics is deeply rooted in mathematics, particularly probability. However, statistics teaching should also draw on the understanding to be gained from its practical use across a wide range of disciplines. Statistics provides critically important techniques for obtaining evidence and insight, and for problem solving.

3 The proposals in this report should be tested and calibrated through pilot projects. A variety of organisations, such as charitable foundations, subject associations and curriculum development bodies, could undertake this work; it need not all fall to government.

Curriculum developers

4 The present subject-by-subject approach inevitably leads to a somewhat fragmented curriculum which cannot ensure that all students are given the skills, such as working with data, that they will need as adults. This is recognised in the government's ambition that the vast majority of young people should continue some form of mathematics up to the age of 18, and this will inevitably involve new courses that run alongside A levels. The recommendation of this report is that these courses should include substantial work with data.

5 Those responsible for curriculum development should recognise that many subjects would be strengthened at A level if greater emphasis was placed upon obtaining and using evidence from data. This would provide students with a better basis of subject knowledge and general statistical literacy for continuing study.

6 Whatever the subject, problem solving usually involves a cyclical process. Part of this cycle involves collecting relevant information and in many cases this takes the form of statistical data. This needs to be recognised in curriculum development in almost all subjects.

7 The ubiquitous use of computing, and particularly the advent of big data, presents major challenges for curriculum development if subjects are to be up to date and to take advantage of the opportunities that are now becoming available. This will require a higher level of statistical understanding across a wide range of subjects.

School and college managers

8 Much greater use should be made of the power of computing to allow data to be analysed, interrogated and visualised in all relevant subjects for the 16 to 18 age range. Suitable data analytic tools should be standard equipment in all schools and colleges.

9 Every secondary and tertiary school or college should have a designated Statistics Coordinator who is responsible for fostering the use of statistics across all relevant subjects and for ensuring that good practice is followed. This person should have a detailed knowledge of how statistics is used in all subjects taught in the institution and of differences in terminology in common use. Training, leading to a suitable qualification, should be made available for teachers about to take on this role.

Examination regulators and awarding bodies

10 The assessment regime should promote those statistical skills and attributes that will be important to students in future life. Traditional examinations, like those associated with mathematics, should not be the only assessment instruments in common use for statistics.

11 All students should be given greater experience of extracting information from real data, including small sets that they have collected for themselves in undertaking investigative work and large secondary data sets. This should be fostered by assessment requirements.

Those responsible for school mathematics

12 Given the important role of GCSE Mathematics in preparing students for the mathematics and statistics that they meet in other subjects, much greater emphasis should be placed on the provision of transferable skills. Training should be given to mathematics teachers to ensure they understand how this will alter their classroom practice.

13 Attention should be given to the mathematics curriculum in New Zealand, and the prominent position of statistics-based problem solving within it. The high uptake of mathematics among older students for whom it is no longer compulsory should be noted.

Providers of teacher training and professional development

14 Initial teacher training courses in all relevant subjects should have substantial input relating to the use of data.

15 Suitable CPD should be provided to all those teaching the statistics that is embedded in their own subjects. Serious consideration should be given to this being conducted online, making use of suitable software.

16 Training courses leading to a suitable qualification should be established for teachers about to become Statistics Coordinators.

Teachers

17 Together with the generic section, the relevant subject specific part of this report should form part of the background to teachers' classroom practice and their involvement in professional development.

18 Mathematics teachers should recognise it as part of their professional role to understand and be in a position to support whatever mathematics and statistics is being covered in the subjects offered in their schools or colleges. Consequently, the whole of this report is relevant to them.

Providers of teaching materials

19 Authors of textbooks and other teaching materials should look beyond immediate examination questions. They should enable teachers to provide students with deep conceptual understanding. Their publishers should encourage them to read this report.

20 A number of organisations and individuals are currently involved in providing computer-based materials that provide students with access to the rich sources of data across all the subjects covered. They should see themselves as helping to create the environment described in this report.

The statistics community

21 A major piece of research is required into the relationship between digital technology, the driver of the boom in data, and how and what statistics should be taught in mathematics and the rest of the curriculum.

22 A pilot *Data Analytics* course should be developed for use alongside A level subjects. This might contribute to the government's ambition for the large majority of young people to study some form of mathematics up to the age of 18.

Notes and references

1 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

2 King G. (Director of the Institute for Quantitative Social Science, Harvard University) quoted in *The Age of Big Data*, The New York Times, 11 February 2012

1 Introduction

1.1 Statistics and the national wellbeing

Digital technology has made it possible to collect, store and analyse data on a scale that was previously unimaginable. The impact on our lives is inescapable. Decisions that affect us profoundly are now made on the basis of evidence derived from data, and this is true at national policy level, in the workplace and in our private lives. In higher education around the world, subjects that were previously seen as largely descriptive have become increasingly quantitative.

It is increasingly clear that evidence-based research and policy are fundamental to understanding and responding effectively to the challenge of assuring the health and social and economic wellbeing of people. Administrative data, routinely collected and carefully used, has the potential to drive research that improves lives. We wish to grasp this opportunity. Using data to build strong evidence will also support deficit reduction as policy makers and commissioners will be able to base their payment regimes on a clear understanding of what works – driving better service outcomes and lower costs.

Open Data White Paper: Unleashing the Potential[1.1]

Working with data makes the world an exciting place for those adults who are able to engage with the opportunities that it creates. They are not only equipped to understand and participate in everyday life, but also to take a leading role in the development of society and of the national economy.

We are now inevitably locked into the global economy. To survive in this, let alone flourish, at every level we need people who can work with data, whether it is applying standard quality control techniques on the shop floor, seeking out the evidence for good management decisions or making new discoveries based on relationships and connections that were previously hidden in large data sets.

This is not a situation which is going to go away like some passing fashion; it will be with us for the foreseeable future. The knowledge and skills needed today are quite different from those a generation ago; tomorrow's even more so. Manifestly, we must provide people with the confidence and competence to work with data or we will watch our economy wither.

There are major implications for our education system. It must equip students for the world they will live and work in and currently this is not happening. Large numbers of young people are leaving school or college too frightened of numbers to engage with data, be it at work or in higher education. Even those who are comfortable with figures have usually not learnt much about data.

All students need to appreciate just how important working with data is likely to be throughout their lives. That knowledge will motivate them to become statistically literate, but in addition they will need to be given an interesting and inspiring experience, making working with data something to be welcomed and enjoyed. The opportunities highlighted in this report will help to turn this vision into reality.

1.2 Research questions

The initial research question can be stated in the following terms.

- Statistics is now used extensively in most subjects in higher education and in employment. What teaching opportunities does this present for A levels in relevant subjects?

This question was discussed with members of ten subject communities. Their responses are described in the subject specific sections in Section B of this report.

However, as the research progressed it became clear that many of the same issues were arising in most or all subjects. This observation gave rise to three additional questions. These are covered both in the earlier generic part of the report and in the subject specific sections.

- What are the end-user requirements?
- What are the generic opportunities?
- What are the constraints?

1.3 Scope

The original research proposal was framed in terms of teaching opportunities in A level subjects. However, as the research proceeded, it became clear that the overall findings were relevant to other curricula, such as Scottish Highers and the International Baccalaureate, and could be informed by them; consequently references are also made to these systems. The scope covers the phase between the current end of compulsory education at age 16 and entry into higher education.

1.4 Terminology

In this report, the term *statistics* is used inclusively, covering the wide variety of procedures and techniques for turning data into information that are used across the school curriculum, in higher education or in employment.

It thus includes processes that occur prior to data being available: problem analysis, experimental design and data collection (including sampling).These might be found in a *research methods* course. It also covers work that takes place once data are available; at an elementary level this is often called *data handling* and at a more sophisticated level, *data analysis*, and the interpretation of data. Other titles of courses where such work might be found include *quantitative methods* and *data analytics*. It also includes the mathematical statistics taught in university statistics courses, and the quality control measures used in many workplaces.

The term *hypothesis test* can be used rather differently in science and statistics. In science it is not always associated with the use of statistics. To avoid possible confusion, scientists sometimes use the term *null hypothesis significance test*. In this report, this longer form is used in places where there might otherwise be some possibility of misunderstanding.

1.5 Methodology

This report covers the following ten subjects.

Biology	Geography
Business studies	History
Chemistry	Physics
Computing	Psychology
Economics	Sociology

The main research took place in three-hour roundtable meetings, one per subject, with a balance of suitable people attending. Those invited came from the following groups.

Higher education	Teaching
Learned societies	Curriculum development bodies
Subject associations	Awarding bodies
Employment outside education	Mathematics

The views people expressed at the meetings were attributed to them as individuals rather than to any organisations to which they belonged.

Before the meetings, attendees were sent the template for the subject reports and invited to prepare a short statement. The meetings themselves followed a standard pattern, starting with people's statements, followed by a period of open discussion. The second half of the meeting was devoted to a discussion of what should be written into the template for that particular subject. The only exception to this pattern was the very first meeting, biology, which was used to define the template. For all subjects the discussion was enthusiastic and would have gone on longer had time allowed.

Following each of these meetings a draft summary was prepared, using the template. This was circulated to participants and progressively refined. In some cases there were also follow-up meetings with particular individuals. The final versions have been used in the descriptions of the various subjects in Section B of this report.

As the research progressed, subject by subject, it became clear that there were important generic issues. These are covered in Section A of the report. They are classified under three headings: End-user requirements, Opportunities and Constraints. It will be seen that these are not entirely independent; for example, overcoming an identified constraint can be regarded as an opportunity.

1.6 Other recent and current research, reports and developments

1.6.1 Landscape

This report is written at a time of considerable public discussion about the role of mathematics and statistics in the school curriculum. A number of reports have recently been published or are currently being prepared. However, the ground covered in this report is significantly different from that in any of the others, so there is no sense in which it is a duplication of work that has already been carried out.

Apart from *The Future of Statistics in our Schools and Colleges*, this report is unique among those mentioned here in being specifically about statistics. The others are about mathematics, with statistics included but in most cases almost by default. By contrast the focus of this report is the needs of statistics; the rest of mathematics is mentioned only where it impinges on them.

1.6.2 Wider participation in post-16 mathematics

In 2010, the Nuffield Foundation published *Is the UK an outlier?*[1.2] This report looked at the uptake of mathematics post-16 in 24 comparable countries and found that England, together with Wales and Northern Ireland, had the lowest participation rate.

This finding was taken up in 2011 in *A world-class mathematics education for all our young people* (the Vorderman Report)[1.3], which recommended that mathematics in some form should become compulsory up to the age of 18.

At about the same time the Advisory Committee for Mathematics Education (ACME) published *Mathematical Needs: Mathematics in the Workplace and in Higher Education*[1.4]; this went further by identifying content that a wide range of employers regarded as important and much of this was statistical. Both of these reports emphasised the importance of meeting the needs of a much wider range of people than the limited number taking AS or A level Mathematics.

More detailed work relating to widening participation in post-16 mathematics has followed. In 2012 ACME published a report in two parts, entitled *Post-16 Mathematics: improving provision and participation* and *Post-16 Mathematics: planning for success*[1.5], and in 2013 the Nuffield Foundation published *Towards universal participation in post-16* mathematics[1.6]. Both of these studies recognise the importance of statistics in any future provision.

1.6.3 Mathematics in A level examinations

In 2012, two similar and complementary pieces of research were published, analysing the use of mathematics, including statistics, in current A level papers. *Mathematics within A-level science 2010 examinations*[1.7], published by the Science Community Representing Education (SCORE), covered Physics, Chemistry and Biology. *Mathematics in A level assessments*[1.8], published by the Nuffield Foundation covered Business studies, Computing, Economics, Geography, Psychology and Sociology; statistics featured more prominently in this report.

The overall conclusions of both reports were similar: that there is less mathematics in the examination papers than might be expected from reading the syllabuses, and what there is tends to be routine simple calculations. Both these reports were about assessment of mathematics in recent examination papers so they were focused on quite different issues from the future statistics teaching opportunities that are the subject of this report. However, it would be fair to say that these reports acted as a wake-up call to the various subject communities and so may have encouraged them to engage with this research, which they all did with enthusiasm.

1.6.4 Transition to higher education

During 2012 to 2013, the Higher Education Academy STEM team carried out a strategic project to provide a strong evidence base about the requirements for mathematical and statistical skills in degree courses and with a key emphasis on the transition from the secondary education sector. The project aimed to complement both existing and current work in the area.

The subject areas considered were: business, chemistry, computing, economics, geography, psychology and sociology. In biology and physics similar pieces of work had recently been carried out and so it was decided not to duplicate them; they are, respectively, *A survey of the mathematics landscape within bioscience undergraduate and postgraduate UK higher education*[1.9] and *Mind the Gap*[1.10].

The project consisted of a review of the literature in each subject area, surveys to higher education staff and students to gain their perceptions and understanding. The HEA also held a series of discipline specific discussion events bringing together secondary teachers, higher education lecturers, students, professional bodies, and examination boards to explore the issue in detail from different viewpoints. The resulting series of discipline specific reports focus on questions of interest regarding the mathematical and statistical skills in each degree subject area[1.11].

This project built on a number of recent pieces of work including the reports from ACME, SCORE and the Nuffield Foundation, and those for biology and physics, referred to above, in Sections 1.6.3 and 1.6.4.

1.6.5 Statistics education development work using ICT

In recent years many organisations have done work designed to use ICT to make statistics more accessible to school and college level students. This work is an important part of the background against which this report has been written. Space does not allow an exclusive list to be provided here, but the following UK based developments are particularly relevant to this report.

CensusAtSchool

The Royal Statistical Society Centre for Statistical Education (RSSCSE), now based at Plymouth University, started the *CensusAtSchool*[1.12] project in 2000 in conjunction with the Office for National Statistics. The project, originally a one-off, was linked to the UK population census of 2001. It has now become international, running in Australia, Canada, Ireland, Japan, Korea, New Zealand and South Africa as well as the UK.

In the UK, each year school students complete a different questionnaire with questions about their lives and aspirations. The worldwide database, which contains well over two million responses, can be sampled over the internet for use in creating teaching and learning materials, as well as CPD for teachers. The involvement of different countries vastly increases the potential for exchange of information between school-aged children and provides a unique way to assess global, social and other changes.

The SMART Centre

The SMART Centre[1.13] is based at Durham University. Among other activities, it creates displays which present data in ways that can be understood and so stimulate debate about important issues, grounded on good evidence.

The Centre's development and research focus on creating interactive displays, studying user interactions and researching user understandings. Their communication activities focus on working with data providers on the presentation of evidence, supporting journalists with interpreting evidence and creating a school curriculum that helps students to reason with evidence.

Geographical Information Systems

Geographic Information Systems (GIS) provide innovative ways to analyse and visualise data. As well already being explicitly part of the GCSE and A level Geography syllabuses, GIS tools are currently being used, or have the potential to be used, to enhance teaching within all the subjects discussed in this report. Development work is ongoing. Ordnance Survey have compiled a list of links to GIS packages available to UK schools. The images in this report were provided by Esri UK and the Environment Agency.

The Office for National Statistics

The Office for National Statistics[1.14] established a Data Visualisation Centre in 2007. This uses data visualisation tools to make official statistics more meaningful and accessible to people who are not statisticians. To do this the Centre develops new tools and standards for presentation; their visualisations cover a wide range of subjects and are available online. Visualisations based on data from Census 2011 are now available.

The National Archives

The National Archives[1.15] are digitising selected record series in conjunction with academic partners. Most recently, in partnership with the University of Sussex, they have worked with a large data set of household expenditure surveys undertaken by the Ministry of Labour; as part of an ESRC funded project a group of teachers worked with The National Archives and the university to create classroom resources for secondary school students investigating poverty and affluence in Britain during the 20th century.

1.6.6 Current government reforms

At the time of carrying out the research and writing this report (2013), the government is planning reforms to the whole education system. The changes include a new National Curriculum, affecting all children up to the age of 16, and new regulations for A level and vocational qualifications.

It is also intended that a large majority of students will take some form of mathematics post-16 in the years ahead, and new courses are proposed for a large target group of students who would previously have given up mathematics after GCSE. These courses are likely to include some statistics.

Notes and references

1.1 The Cabinet Office (2012) *Open Data White Paper: Unleashing the Potential*, Section 4.19

1.2 Hodgen J. *et al* (2010) *Is the UK an outlier?*, Nuffield Foundation

1.3 Vorderman C. et al (2011) *A world-class mathematics education for all our young people*

1.4 ACME (2011) *Mathematical Needs: Mathematics in the Workplace and in Higher Education*

1.5 ACME (2012) *Post-16 Mathematics: improving provision and participation and Post-16 Mathematics: planning for success*

1.6 Hodgen J., Marks R. and Pepper D (2013) *Towards universal participation in post-16 mathematics*, Nuffield Foundation

1.7 Science Community Representing Education (2012) *Mathematics within A-level science 2010 examinations*

1.8 Nuffield Foundation (2012) *Mathematics in A level assessments*

1.9 Koenig J. (2011) *A survey of the mathematics landscape within bioscience undergraduate and postgraduate UK higher education*, Higher Education Academy

1.10 Morgan B. (2011) *Mind the Gap: Mathematics and the transition from A-levels to physics and engineering degrees*, Institute of Physics

1.11 Higher Education Academy: www.heacademy.ac.uk

1.12 CensusAtSchool: www.censusatschool.org.uk

1.13 The SMART Centre: www.dur.ac.uk/smart.centre

1.14 Office for National Statistics: www.ons.gov.uk

1.15 The National Archives: www.nationalarchives.gov.uk

Section A

Generic findings

2 End-user requirements

The requirements of two end-user groups, higher education and employers, were discussed in terms of what statistical skills would be beneficial for students starting courses in higher education, and for new graduates entering employment. These are recorded for each subject in Section B and are summarised here.

Before doing so, however, it is appropriate to report on the concern, mentioned by many end-users, at the number of students who are so frightened of mathematics that they do not engage with it; most of these students see statistics as a part of mathematics and so also something to be shunned. Instances were given of university courses in statistics that have been renamed so as to obscure their content, or even discontinued with the statistics hidden in other courses. Current school courses seem to be engendering fear of mathematics in many students and this is having a serious impact on end-users.

2.1 Higher education

Across all the subjects, there was strong agreement from those in higher education that new undergraduates would benefit from being sufficiently familiar with data that they can engage competently with new data sets as and when they meet them. This would mean that before arriving at university students should have done work that gave them a set of basic skills.

Reporting data	Using suitable diagrams to illustrate data. Using suitable measures to summarise data. Interpreting the main features of a data set, including any patterns, in terms of the situation that gave rise to it. Translating information from one form to another: tabular, graphical and narrative. Describing the information contained in a data set orally and in writing, in terms of the situation being investigated.
Data types	Knowing the difference between a sample and a population. Being aware of the source of a data set and the method of collection. Understanding the different types of variable and related measurement techniques. Understanding about natural variability and experimental error and the differences between them.
Analysing data	Framing suitable questions to ask when using data to investigate a situation. Being aware of the need for error analysis. Being prepared to criticise data and their presentation.

A deficit in these fundamental skills among new undergraduates was highlighted by those from higher education in the roundtable meetings. Clearly it would be advantageous for pre-university students to spend more time working with data at quite an elementary level, and consideration needs to be given as to how this can be done most effectively.

An approach that is sometimes suggested is to abandon the more advanced statistics in current use and to spend the time instead on teaching these skills; the usual target is null hypothesis significance testing. The counter-argument is that these skills are better learnt from the experience of working with real data rather than through traditional teaching. Hypothesis testing arises from investigational work in which students collect and work with their own data. Such work is not only of great value in its own right, whatever the subject, but it also provides students with hands-on experience that can only improve their familiarity with data.

So this report does not recommend removing hypothesis testing. However, hypothesis testing should not be carried out in isolation but as part of the Statistics Cycle illustrated on page 22. The work in the rest of the cycle requires students to make decisions about the relevant data and how to collect, process and interpret them.

2.2 Employment

The requirement of employers can be summed up by saying that new graduates should be statistically literate.

They should have all those skills identified for students entering university, but at a higher level. While there is no evidence that the acquisition of these skills is age related, it is clearly advantageous for students to have a good foundation in them on which to build while at university. So what happens in A level classrooms is important for employers.

In addition, new graduates should have additional knowledge and skills commensurate with the sophistication of the qualifications on which their employment is based. Those identified during this research are listed below.

Statistical knowledge	Understanding those statistical techniques that are relevant to their subject and employment. Using statistical software packages appropriately. Interpreting models expressed in mathematical and statistical terms. Understanding and critically appraising the quantitative information in a research paper, a government report, a pilot study or the media.
Working in the organisation	Explaining statistical concepts (such as the significance of a test result) to colleagues without any background in statistics. Relating data to the needs of the organisation. Interpreting trends. Using data to make judgements about possible interventions. Understanding the risk-benefit analysis for a proposed course of action.

3 Opportunities

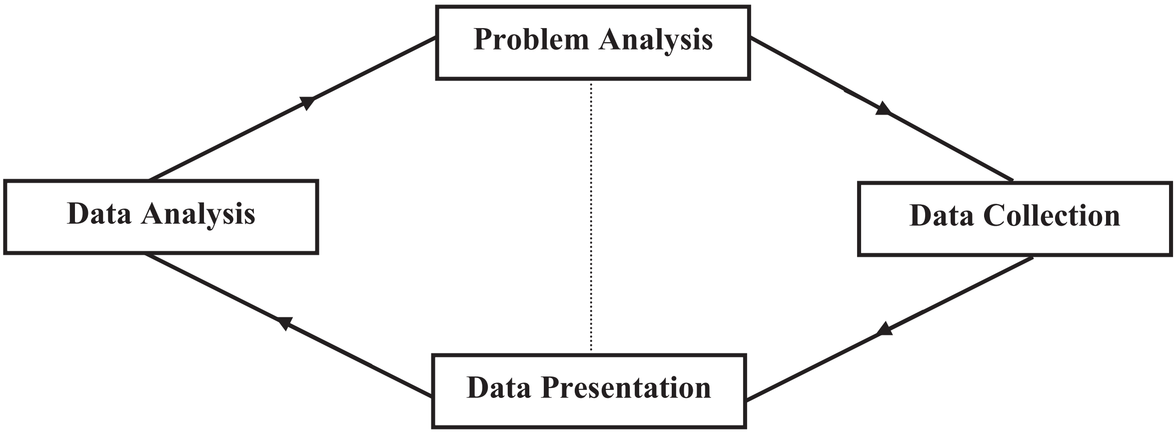
3.1 Investigative work

Outside the disciplines of mathematics, and statistics itself, statistics is used as a means to improve understanding of the subject in question and not for its own sake. It provides a set of tools that allow questions to be answered and problems to be solved.

Statistics is about solving real problems. An undue emphasis on its mathematical foundations is detrimental to the discipline ... Although mathematics lies at its core, statistics as a discipline involves several essential components beyond mathematics. Notable among these are an appreciation of the concepts and methods of the area to which statistical techniques are being applied and computational skills.

Professor David Hand[3.1]

A cycle of activity is often involved. This is illustrated below and in the rest of this report it is referred to as the *Statistics Cycle*[3.2]. Many subjects, for example science and business, employ essentially the same cycle, although using rather different language to describe the processes, for example hypothesis, evidence, evaluation and refinement in science. So the Statistics Cycle is representative of a general approach to investigation and problem solving.



The Statistics Cycle

The processes named in the four boxes are described in the table on the next page.

Sometimes a display provides a compelling answer to the original question and that route is represented by the dotted line in the diagram. Often, however, a formal mathematical analysis, for example a null hypothesis significance test, is required and this is covered in the Data Analysis box.

Process	Description	Topics
Problem Analysis	This process involves the work at both the start and the end of statistical problem solving. It begins with the analysis of a problem and the design of the proposed approach to tackling it, possibly including setting up hypotheses. Essential decisions are needed about experimental design, what data need to be collected and how they will be used. In the subsequent stages the data are collected, presented and analysed. Finally the outcomes are considered in relation to the original problem analysis and the modelling involved. The conclusion may be that a satisfactory solution to the problem has been found or it may be a recognition that the approach taken has not been satisfactory; the interpretation may not make sense, or it may not provide sufficient discrimination to be useful. In cases where the problem has not been solved satisfactorily, it will usually be necessary to repeat the whole cycle.	Experimental design Modelling Errors
Data collection	This process covers the work undertaken when students collect their own (primary) data. Decisions have already been made as to what data need to be collected. It includes deciding how the data will be collected, and then carrying it out. The outcome of this stage is a set of original data. This process also covers the work in sampling from extensive sets of secondary data, such as those on large databases.	Sampling techniques
Data presentation	This stage begins with data, which may be primary or secondary, and involves the application of a variety of descriptive techniques and their interpretation. Typical examples are grouping and tabulation, display diagrams and simple statistical measures (such as mean and standard deviation, and index numbers).	Tabulation Data display Statistical measures Index numbers
Data Analysis	The work in this stage involves mathematical analysis, leading to some inference that is relevant to the problem. Such work often requires a deep understanding of probability. This stage ends with results that can be applied to the original problem. In simple situations, the data presentation may be sufficient to allow the problem to be solved. In such cases it may be possible to bypass this stage. Much of the statistics in higher education courses comes under this heading.	Use of distributions Statistical inference Null hypothesis significance testing Probability Risk

Processes in the Statistics Cycle

The subjects selected for this report were those with the greatest scope for using statistics in their A level teaching. Investigational work is an important feature of all of them, be it through fieldwork, science experiments or self-directed problem solving.

Until 2008 such work was commonly assessed through coursework. This often involved working through the complete Statistics Cycle, and so provided students with experience of using statistics, often with their own data, in the context of the subject. Ideally the use of statistics allowed students to answer questions that were of real interest to them.

In many of the subjects the coursework requirement was discontinued in 2008. A consequence of this is that some syllabuses have become fragmented, with the statistics now no more than an isolated set of techniques that are required for the examination but are no longer integrated into students' work.

It can be claimed that what matters is the experience students receive rather than what is assessed. So, for example, computers provide teachers with powerful tools to help explain the subject and for students to interact with it, but such work need not be directly assessed. The purpose of the assessment is to test their understanding rather than how it has been achieved.

The counter-argument is that if something is not assessed it will usually not be taught.

Indeed the assessment instruments used have a profound effect on most students' learning experience.

Many of the current A level syllabuses were drawn up at a time when coursework was about to be removed but without any experience of the effect this would have on classroom practice. Most of those consulted felt that the assessment system could do more to ensure that all students really do get the opportunity to carry out hands-on data collection and analysis; there is considerable scepticism about the effectiveness of the assessment methods that have replaced A level coursework.

Two other possibilities have been proposed.

The first of these is the use of pre-release material, typically involving data that students need to analyse before the examination. This is not unlike a small scale set book, as used in subjects like English Literature. The text is given but students do not know what questions are going to be set on it.

Pre-release material is already used for some A level examinations, for example in business studies, economics and sociology. Its value in economics is described by a teacher in the following words.

The pre-release material in economics allows students to focus their learning intensively. With the use of both qualitative and quantitative data they are able to consider a huge variety of questions and, in order to succeed must spend a considerable amount of time practising and rehearsing the application of theory from a variety of angles. The use of data is particularly powerful here as it raises many issues and students are forced to consider how economic theory may, or may not, be at work in reality. For example, the material for June 2013 required that students consider the links between economic growth and inflation in Eastern Europe both pre and post the 2008 crisis. The causes and links are multiple and students have to work hard to see the links and talk about them eloquently and analytically, and they must be able to evaluate the data and theory. This is not something they are required to do with a more traditional exam. The use of pre-release data lends itself to more considered and complex analysis than can be expected with traditional exams.

Kirti Shah, Head of Economics, Haberdashers' Aske's Boys School

Another possibility is a comprehension question in which students are required to read an article and answer questions on it. This would provide an opportunity for students to engage in statistical work and, at the same time, would foster the skill of being able to read research papers that employers have identified as particularly valuable.

In their 2012 consultation on A level reform, Ofqual committed themselves to ensuring validity of assessment[3.3], meaning that the assessment should cover those things that are important. If this were to be the case generally, there would inevitably be much greater use of statistics.

As well as being a central element in all the subjects covered in this report, investigative work serves another important purpose. It provides students with experience that will help them to meet the end-user requirements of confidence and competence with data.

When designing their own experiments students have to think about different types of data and decide in advance how they will be collected and analysed; sometimes they may decide to start with an initial pilot run through the Statistics Cycle. Experimental design is a critical link between problem analysis and subsequent collection and data handling. However, currently many students do not have the chance to design their own experiments and investigations. Some only do standard experiments where all the design work has already been done for them; this must count as a lost opportunity.

3.2 Computing

Statistics and computing are parents to modern day data analysis.

Professor Xiaohui Liu, Computing advisor

Any explanation for the large increase in the use of statistics in higher education and employment must begin with the development of digital technology. It has made it possible to collect and process data on a scale that was unimaginable just a few decades ago. This affects every subject in this report.

So it is very surprising that using computers to access the information and evidence now available from data has so far had remarkably little impact on the way most A level subjects are designed, taught and assessed.

The earlier report, *The Future of Statistics in our Schools and Colleges*[3.4], included the following statement.

The remit did not extend to the subject of the relationship between digital technology, the driver of the boom in data, and how statistics should be taught. It is, however, inevitable that sooner or later a major piece of research and development work will be needed in this area.

This report is nothing like that piece of work but it does reinforce the need for it and establish some of the areas which should be considered.

3.2.1 Data analytic tools (statistics packages)

There is a marked difference between, on the one hand, higher education and the workplace and, on the other hand, schools and colleges in the tools used for data processing and analysis.

In higher education nearly all such work is carried out using a data analytical tool, also known as a statistics package, but some use is also made of spreadsheets. In the workplace dedicated software is common and spreadsheets are also widely used.

By contrast, in many schools and colleges, the choice is effectively driven by the current assessment and consequently data analytic tools are hardly ever seen. Most students work with a calculator and in addition some use is made of spreadsheets.

Many psychology teachers find Excel useful in their teaching of statistics, not least because all students have free access to it in their centres. My own view is that it does offer the opportunity to develop basic skills in using statistics software which are transferable to the more sophisticated packages, such as SPSS, used in universities.

Morag Williamson, Psychology advisor

Although data analytic tools, both proprietary and open source, are available, use of them is currently not taught in UK schools. However, this is not the case in the United States and elsewhere; high school classes in a variety of subject areas are taught to use such software.

The issue is not just one of ease of use, although it is argued that data analytic tools are intrinsically more suitable for statistical analysis than spreadsheets. The best tools for use in schools and colleges, for example that used in New Zealand[3.5], are also learning devices. The aim for this age group should be educational rather than to train students to use whatever software happens to be commonly used elsewhere at the time.

Data analytic software tools are simpler to use than spreadsheets because they have been designed to perform statistical analysis through graphical interfaces and hence lower some of the barriers that students experience. This type of software still requires students to understand the data and the type of statistical techniques that they are required to perform, but they do not need to understand the database design that is required for spreadsheets. Data analytic tools are able to produce the diagrams that are required to gain an understanding of the data they are analysing.

Dr Kathy Maitland, Computing advisor

The output from some data analytic tools makes more information available than is typically either needed or wanted. The quantity of material that is often automatically produced can confuse students. If data analytic tools are to be used effectively, students need to be very clear about the problem under investigation, the nature of their data and the outcomes they want. Some requisite skills are given below.

Skills needed alongside data analytic tools

- Questioning the provenance of the data and how they were collected
- Knowing about different types of variables and measures
- Interpreting a variety of statistical diagrams and understanding when a particular kind of diagram is (and is not) appropriate
- Understanding the importance of initial data analysis, for example using appropriate diagrams, before carrying out statistical calculations
- Developing an early appreciation of data analysis strategies
- Knowing when it is (and is not) appropriate to use a particular procedure
- Using the data to model a situation, interpreting the output from the software in terms of that situation and communicating the results to other people
- Being able to analyse and discuss results critically, and to spot when the outcome from the software is inappropriate or wrong
- Developing the ability to find out about unfamiliar statistical procedures
- Having a generic understanding of statistical inference

These are important skills in their own right but they are often underdeveloped in students, including many of those learning statistics within A level Mathematics. The greater emphasis placed upon them when a data analytic tool is well used should enhance them. Fostering these skills will bring much greater benefit to students than just learning to use the software.

3.2.2 Data

In many of the subjects considered in this report students undertake investigative work in which they collect small sets of their own data. This work is highly valued; it is seen as intrinsic to good learning of those subjects. It also provides students with hands-on experience of using their own raw data to answer questions that are of real interest to them. So, quite apart from its importance in any particular subject, it also helps students to become more statistically literate.

Such work often leads on to a hypothesis test which can be carried out using a calculator and a book of tables. There is some debate as to the extent to which the use of data analytic tools for such hypothesis testing is appropriate at A level. There are those who argue that, at this early stage, the benefits to students' understanding of a hands-on approach outweigh those of developing the software skills they will need once they leave school or college. However, this view is far from universally held.

Having the processing, a low level skill, done by the computer frees up the student to engage in higher level thinking: about the nature of the study or experiment, about the provenance and reliability of the data, about the assumptions made in the analysis, about the validity of the methods used, about the implications of the outcome.

Neil Sheldon, Advisor

Whether or not students are encouraged to use data analytic tools with small data sets, their value for large sets cannot be questioned. They make it possible to interrogate large sets in a way that simply cannot otherwise be done.

In doing so, they raise issues about what statistical techniques are really important. For example, with a set of hundreds of thousands of items of multivariate data it is possible to find a significant correlation between many pairs of the variables. In this and many other situations, it is important to ask about the *effect size*, but this concept does not feature in the current syllabus of any subject (even mathematics) at A level.

Hypothesis testing now needs to be seen in a wider context than using a small sample to make inferences about parameters for the population of interest. For example, in a report on birth weights, the Office of National Statistics includes all the data for live births in England and Wales in 2005. Such a data set invites questions to be asked and hypotheses to be formed, such as whether the relationship of birth weight to ethnic status is changing over time. Answering such questions requires null hypothesis significance testing, based on using the 2005 data as a sample of birth weights over a larger period of time or, possibly, of all the birth weights that there could have been.

So the need for null hypothesis significance testing, and the provision of estimates with associated measures of uncertainty, will not disappear. It will also be the case that the increasing accessibility of large data sets to the range of subjects covered in this report means that new sources of evidence are becoming available to teachers and students and in practice it will often happen in A level classrooms that conclusions are drawn from such data with sufficiently high precision to allow strong inferences to be made.

Work is currently going on around the world to develop techniques for handling very large data sets, *Big Data*, and this has the potential to change the way that much of the current school curriculum is approached.

Statistics has traditionally been recognised as the discipline to study data analysis. However, this notion is being increasingly challenged in the modern era of Big Data.

Data analysis is closely associated with modern electronic computers whose role is not just to allow statistics software to be run on them, but also provide a variety of other capabilities for dealing with big data. These include additional analysis options, large database/data warehouses, cloud or GPU computing, real-time data stream processing, powerful visualisation, parallel or distributed programming, unstructured data analysis (texts, video, etc.), to name a few. Even tedious data management tasks such as data format conversion, compression, movement across platforms, etc., would need much computational effort.

So statistics and computing are like parents to modern day data analysis, and they have to be properly married (integrated) to enable analysis to be done properly. Computing without statistical rigour would inevitably lead to many mistakes while statistics without computing won't get very far these days. So they are meant to be taught together if one needs to have the most effective way of training next generation data analysts or data scientists, in light of big data.

Current graduates from A levels and undergraduate programmes, often with a background in just one of the two subjects, are likely to be handicapped when it comes to dealing with modern large data sets. So rather than artificially separating the loving parents, perhaps we should have an interdisciplinary A level in Data Analytics (statistics + computing), which would be essential for many modern multidisciplinary areas in science, engineering and medicine.

Professor Xiaohui Liu, Computing advisor

Once suitable tools are in place for handling large data sets, it will be natural for teachers to collect them and to use them to help students learn. This is likely to change what goes on in a typical classroom, as shown in the following examples.

- In the sciences experimental data are routinely collected electronically but this does not currently extend to other subjects, and there is scope to use more and different devices, for example smart phones.
- It is now possible to share data. An example of this is CensusAtSchool where the Royal Statistical Society's Centre for Statistical Education maintains a large database of information provided by students from around the world.
- It is now possible for teachers to provide students with individual random samples drawn from large secondary data sets. Students can then work on them and compare their outcomes, gaining an understanding both of the subject content of the data set and the inherent variability of the data, and also of sampling error.
- Similarly, students working on the same project can share their data and so build up a much larger picture. This provides the opportunity for them to see a distribution emerge as progressively more data are included.

The computer has totally revolutionised the subject. It's arguable that statistics is now more of a computational discipline than a mathematical one. You cannot do modern statistics without a computer. The computer has enabled us not merely to work more quickly but also to do things we would never have thought of before. Bootstrap methods are an example. It scarcely needs saying that Bayesian methodology has undergone a revolution in recent years, again because of the computer.

Big data is of course another important development and very large data sets are involved in all sorts of areas from genomics to astrostatistics. Data mining and machine learning are subdisciplines of statistics, driven by the computer.

In terms of the future, the impact of the computer has not stopped. More powerful computers are developing all the time. People think we have come a long way in past 30 years but I think the next 30 years will be even more impressive.

Professor David Hand[3.6]

3.2.3 Data visualisation

*Students get very excited – and policy makers and the corporate sector – when they can **see** the data.*

Hans Rosling[3.7]

New computer-based display techniques present teaching opportunities by turning data into images.

There is, of course, nothing new in the principle of data visualisation. Forms of data display, such as pictograms, bar charts and pie charts have long been around. It is, however, now possible to present large data sets very quickly and to home in on part of the data set or to introduce more detail.

Displays can now be animated with respect to particular variables, such as time, and it is easy to change from looking at one variable to looking at another variable. This has profound implications for school and college statistics which are currently confined to the use of single variable or bivariate data. Such displays make multivariate statistics accessible. This has been an important feature of work done at the SMART centre at Durham University; they describe their tool in the following words.

It works with multivariate data, but it is accessible to naïve users in that it is based on comparative bar charts and so the structure of the information is familiar and recognisable to almost all users. The power is in the user's ability to manipulate the display, using sliders to look at different sections of the population, swapping the position of variables in order to make explicit different comparisons, and in the capacity to display related data sets in separate tabs within one file. This gives the user the capacity to actively explore the data and identify the stories in the data for themselves.

James Nicholson et al[3.8]

Animated displays, especially when they are interactive, can also help to extend students' understanding beyond the immediate data sets. They can convey important statistical concepts relevant to data analysis, for example sampling variation, and they can develop a deeper general awareness of uncertainty.

Geographical Information Systems are now part of the GCSE and A level Geography syllabuses, but other subjects have still to take the equivalent step to any significant extent. The example that follows could be highly relevant to sociology or criminology, as well as having obvious practical applications.

Crime in a town[3.9]

Data have been collected for the incidence of crime in a town, and they are shown in two different ways. Diagram 1 shows a traditional paper-based presentation, using one location and different times of day. This diagram provides a summary of the data for one year and so the fine detail is lost.

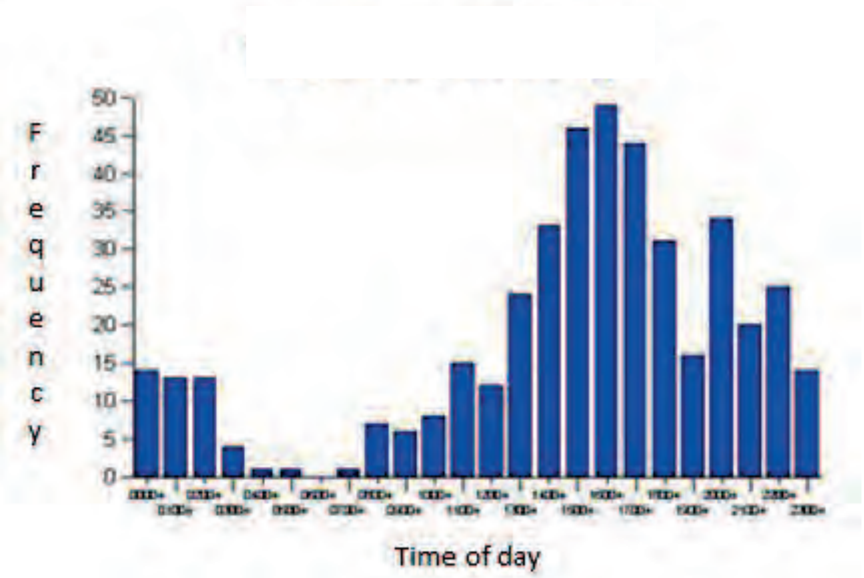


Diagram 1

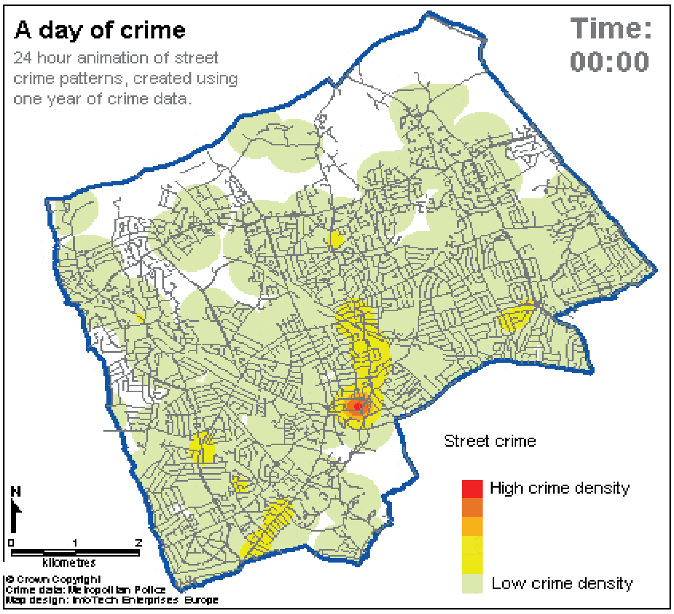


Diagram 2

Diagram 2 is a visualisation on a map of the same data (at 00:00 hours). When visualised in this way, the data reveal spatial hotspots of crime at that particular time. When viewed as a dynamic GIS application, it would show the hotspot moving around depending on the time of day. At 00:00 hours, the map shows it is at the town centre, presumably after pub closing time. If, by contrast, at 17:00 hours the hotspot is outside the football ground, the likely explanation would be supporters behaving badly after matches. By visualising such statistical data the police can deploy appropriate resources, helping to prevent and so reduce crime.

It is worth noting that the power of this dynamic example cannot be fully shown in a written report such as this. The format does not allow the effect of advancing the time to be shown, something that would be available to the teacher and students in a classroom.

Much more information is made available when the data are available through a computer information system, and in a format that invites questions to be asked and the data to be explored. As a teaching and learning device it is in a completely different league from traditional diagrams or charts, let alone a table.

Every subject covered in this report would benefit from such information systems. However, there are still relatively few examples of their becoming available and used in subjects other than geography, where their use is well established.

As well as being used with the best of intentions, data visualisation has long been exploited for commercial or political purposes. No doubt that will continue to happen with the more impressive computer generated displays that are now available. That makes it all the more important that students work with these systems and gain the confidence to evaluate them critically; it will be an important life skill.

3.2.4 Modelling and simulation

In the workplace, data are routinely used to derive models that are then subsequently used for prediction. Typically the underlying problems have no analytical solutions. This procedure is not currently widely used in any of the A level syllabuses covered in this report, and so it represents an opportunity for interesting teaching and improved learning.

The example in the previous section was linked to fixed data. However, modelling also allows interactive displays to be developed in which students can see the effects that changing the data would have. This increases the range of questions they can ask, including those relating to the sensitivity of a system to small changes and others related to risk.

Another broad area in which computer models could be used more is in simulation. This can be used in a variety of ways.

- It allows students to collect data from experiments which for a variety of reasons, such as cost, safety, health and ethics, could otherwise not be carried out.
- Simulation can make concepts available visually and in doing so make them accessible to some students to whom they would otherwise be denied.
- It can reinforce theory, for example by demonstrating the effects of repeated sampling.

A particular form of simulation involves the use of serious games. At the research level, games are now sometimes used in predictive modelling competitions[3.10]. An example that currently occurs at A level is the use of the Prisoner's Dilemma to illustrate competition in economics.

3.2.5 Access

While there are many opportunities for using computing to improve A level students' engagement with statistics, being able to make use of them obviously depends on their accessibility. There are several issues.

Software

Suitable software tools are already available. Some are open source but this is not always as advantageous as it seems. A better level of service often comes with proprietary brands, including keeping them up to date; by contrast, users often experience hidden costs with open source software.

Data format

There is considerable variation in the format used for secondary data sets and this can make them difficult for teachers to use in the classroom. This even applies to those from government sources.

Costs

Most major software providers are willing to make low cost versions available for school use; this is not always entirely altruistic; many hope that when, in a few years' time, students enter employment they will be predisposed to their brands.

Skills shortage

Many teachers currently lack the expertise in either or both of statistics and computing and so are unlikely to make available to their students opportunities that are dependent on both.

Accountability and assessment

Between them, the present accountability and assessment systems are seen by many as a straitjacket, effectively preventing teachers from doing anything that is unlikely to appear on an examination paper.

Good computing provision that is widely used in our schools and colleges should be seen as among the fundamental requirements of running a modern education system. It is critical to ensuring that what students learn is up to date and relevant to the next stages of their lives.

Notes and references

3.1 Hand D.J. (1998) *Breaking misconceptions – statistics and its relationship to mathematics*, The Statistician Vol 47.2, pages 245–250

3.2 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, page 9, The Royal Statistical Society

3.3 Ofqual (2012) *A Level Reform Consultation*, Crown Copyright

3.4 ibid. 3.2, page 9

3.5 The software is called iNZight. For more information see: www.stat.auckland.ac.nz/~wild/iNZight

3.6 From an interview with Professor David J. Hand: www.statisticsviews.com/details/feature/4892951/Statisticians-are-the-modern-explorers_-An-interview-with-Professor-David-J_-Han.html

3.7 Rosling H, cited from TED I Wiley Visualizing Data Instructor Materials, page 3

3.8 Nicholson J., Ridgway J., McCusker S. (2012) *Getting real statistics into all curriculum subject areas – Can technology make this a reality?*, Proceedings of the IASE Roundtable

3.9 Source: Esri UK

3.10 See, for example: www.kaggle.com/competitions

4 Generic constraints

4.1 School and college mathematics

4.1.1 The need for transferable skills

A complaint that was common to all the subjects considered in this report is the difficulty students experience when trying to apply the knowledge they have acquired in GCSE Mathematics to other subjects.

This is not merely a case of some students not being very good at mathematics, although that is certainly true of many taking A levels in some of the subjects being considered. There are students who are successful in mathematics who are nonetheless unable to put the techniques they have learnt to use in other subjects.

Even students with high grades (A/B) at GCSE Mathematics struggle with the statistics required in A level Psychology.

Dorothy Coombs, Psychology advisor

This has led to a perception that mathematics, and so statistics, is being taught in isolation from the rest of the curriculum. There are two particular aspects to this.

- In many subjects there is clear frustration that, although they can provide interesting and appropriate data and examples, these do not find their way into mathematics classrooms. Consequently the teaching there is unnecessarily abstract.
- The sequencing of mathematics teaching seems to be independent of when the various topics are used in other subjects.

The problem of the appropriate statistics not being taught in maths so that it can be applied in a timely manner in science has persisted for far too long

Annette Smith, Chemistry advisor

In some of the subjects covered, for example psychology, the lack of transferable mathematics skills and the associated attitude of disengagement were seen as limitations to the improved use of statistics in A levels. Although it would be desirable to do more work based on data, too many of the students are just not able to handle it.

There have been many reports in which the general level of students' mathematics has been criticised. Although successive governments have tried to rectify the problem, it has remained remarkably intractable.

However, while acknowledging the desirability of raising the overall standard of mathematics, this report makes a quite different point: that more attention needs to be given to teaching for transferable skills.

Among those consulted there was almost universal agreement that a change in culture among mathematics teachers would be very helpful, with the greater emphasis on the use of mathematics to solve problems in the sort of contexts that arise across the rest of the curriculum.

In order for students to better understand the mathematics that they are doing, they should be encouraged to construct the narrative around their work – to be able to tell the story that the mathematics is telling. An example would be the use of percentages in everyday life.

Annette Smith, Chemistry advisor

The vast majority of young people will not read mathematics at university but they will use it in other subjects, at work and in everyday living.

I set problem solving questions on statistical and mathematical concepts in practical contexts for my first year undergraduate students and have observed that those who find this cumbersome at the time subsequently appreciate how these helped them with the final exam and the rest of their degree work. One student told me 'One thing I like about the classes is that you expose us to more questions; even though at the time they can be annoying in the sense that they seem complicated, … they will act as triggers for memory in the long run'.

Meena Kotecha, Economics advisor

Understanding that part of the problem with the current mathematics GCSE arises from the fact that students do not acquire transferable skills provides an opportunity to improve the situation.

4.1.2 A post of Statistics Coordinator

The difficulty that students experience in transferring their knowledge of statistics from one subject to another is aggravated by differences in terminology between subjects, some of which are quite deeply embedded. This makes it easy for students to compartmentalise their knowledge, seeing no relationship between the statistics they learn in different subject areas.

A first step in mitigating this problem, and so helping students, is for teachers to know where such differences occur. So, in every institution, at least one teacher should have an overall knowledge of the statistics used in the various subjects being taught.

The role of such a person should, however, extend beyond giving advice on how best to work round differences of terminology into one of disseminating good practice generally. The title of Statistics Coordinator is recommended. While statistics remains part of mathematics, the Statistics Coordinator would usually be a member of the mathematics department. However, the knowledge and skills required for this role are quite different from those of a typical mathematics teacher and so specialist training would be required.

4.1.3 Mathematics in New Zealand

In recent years considerable thought has been given to the mathematics curriculum in New Zealand and changes have been implemented. In 2008, the curriculum was renamed *Mathematics and Statistics* in recognition of the usefulness and importance of statistics at all levels.

One of its features is the strong emphasis placed at all ages on statistical problem solving using real and meaningful data. The table below gives the statistics requirements at levels five and six, typically covered by the same age of students as would be preparing for GCSE in this country.

Level 5	Level 6
Statistical investigation	
Plan and conduct surveys and experiments using the statistical enquiry cycle: determining appropriate variables and measures; considering sources of variation; gathering and cleaning data; using multiple displays, and re-categorising data to find patterns, variations, relationships, and trends in multivariate data sets; comparing sample distributions visually, using measures of centre, spread and proportion; presenting a report of findings.	Plan and conduct investigations using the statistical enquiry cycle: justifying the variables and measures used; managing sources of variation, including through the use of random sampling; identifying and communicating features in context trends, relationships between variables, and differences within and between distributions, using multiple displays; making informal inferences about populations from sample data; justifying findings, using displays and measures.
Statistical literacy	
Evaluate statistical investigations or probability activities undertaken by others, including data collection methods, choice of measures, and validity of findings.	Evaluate statistical reports in the media by relating the displays, statistics, processes, and probabilities used to the claims made.
Probability	
Compare and describe the variation between theoretical and experimental distributions in situations that involve elements of chance. Calculate probabilities using fractions, percentages, and ratios.	Investigate situations that involve elements of chance: comparing discrete theoretical distributions and experimental distributions, appreciating the role of sample size; calculating probabilities in discrete situations.

An extract from the New Zealand Mathematics curriculum

In a number of places in this report the needs of end-users and of the various subjects are emphasised. When these are compared with the content of these two years of the New Zealand curriculum a close match is found.

The statistics specification within the New Zealand Mathematics and Statistics curriculum reflects a joint design and writing exercise between statistical education researchers at Auckland University, Statistics New Zealand and the Department for Education. They utilised evidence of how best to engage young people with the lifeblood of the subject – real data which are for and about themselves – and made those data core for the learners to practise becoming 'data detectives'. The data produced by the New Zealand version of the international CensusAtSchool project, which was conceived first in the UK and has been running here since 2000, is embedded in teaching and learning resources as well as in the professional development material used to improve the skills and knowledge of the teachers.

Professor Neville Davies, Advisor

A feature of the mathematics provision in New Zealand is the high proportion of young people who continue with mathematics beyond the stage at which it is compulsory. This is described in the 2013 report *Towards universal participation in post-16 mathematics: lessons from high performing countries*[4.1].

This report features seven countries: England, Germany, Hong Kong, New Zealand, Scotland, Singapore and the United States. Among these New Zealand has the highest rate of uptake of *Advanced Mathematics* and England the lowest; the New Zealand rate is over three times that in England. New Zealand also has the highest uptake of *Some Mathematics* among those countries in the study where it ceases to be compulsory at a certain stage; England again has the lowest uptake.

The differences between New Zealand and England are striking, the more so given the similarity in culture between the two countries. Many people attribute New Zealand's success to the motivation and engagement fostered by the emphasis on problem solving using statistics in the compulsory mathematics curriculum.

A likely further factor is that there are attractive options for post-compulsory students. At that higher level there are two syllabuses, Mathematics with Calculus and Mathematics with Statistics. The latter is very popular.

In New Zealand … The availability of advanced mathematics options focused on statistics and modelling appears to be a key factor in increasing participation to one of the highest levels internationally. These options are widely available, attract a critical mass of students and are widely recognised by higher education and employers.

Dr Jeremy Hodgen et al[4.2]

It seems very likely that there are important lessons to be learnt from New Zealand and so one of the recommendations of this report is that the reasons for their success should be investigated closely.

4.2 Teaching

In all the subjects covered, concern was expressed that a minority of teachers were outside their comfort zones with the statistics and mathematics requirements of the existing A levels. Such teachers clearly need professional development but too often, it was said, this is not available to them, either because of a lack of suitable provision or as a result of inadequate funding, or both.

While lack of CPD is clearly a general problem, it would seem to be more pressing in some subjects than others; the worst situations appear to arise in those subjects, like psychology and economics, where in many schools there are not enough lessons to fill a teacher's complete timetable. The situation is exacerbated by the fact that using statistics is only one of the requirements of any of the subjects and so is in danger of being tacked on to the end of a programme of CPD.

The recommendations of this report are designed to improve the quality of learning in the various subjects considered, but most teachers would have to extend their skills to cover some new ideas and techniques.

- Some teachers would find themselves having to reconsider the way they present aspects of their subjects, moving to an approach where the evidence presented is more often explicitly derived from data and students are encouraged to consider the data behind the facts they learn. This would involve more direct interaction with the data than is currently common.
- There would be an increase in students' individual investigational work. This is always likely to take unexpected directions and so to present teachers with unpredictable demands. This can be intimidating for any teacher who lacks confidence.
- Teachers would find themselves having to learn some new techniques, not least those relating to the use of software to interrogate large data sets.

Across the various subjects, there are likely to be many teachers in any school or college who need professional development in these areas. This could be seen as a problem by senior management but one way of dealing with it could be through Recommendation 5 in *The Future of Statistics in our Schools and Colleges*[4.3].

School and college mathematics departments should ensure they have the expertise to be the authorities on statistics within their institutions. Mathematics departments should be centres of excellence for statistics, providing guidance on correct usage and good practice.

Implementing this recommendation would enable this aspect of the institution's CPD needs to be carried out internally. Someone in the mathematics department would know just what statistics is used in the various subjects and be able to run training for colleagues in other departments as well as to give day-to-day advice. Such a person would, of course, need CPD to be in a position to carry out such a role.

A second strand to an internal programme of CPD can be provided by online tutorials, typically held in twilight hours. This is already being carried out to some extent, as described below, so what is required is not something new but an extension of what is already in place.

CPD online

Some organisations run online professional development for teachers using a virtual classroom. Participants can communicate with the presenter, and with each other, by talking, using a typed ‘chat’ facility, and writing on the shared whiteboard.

Mathematics in Education and Industry, a curriculum development body, provides professional development like this, mainly for teachers of mathematics and statistics. Teachers taking part in an A level Statistics course attend an online session each week; each session lasts about an hour. This allows them to learn gradually without having to travel or take time out of school. It is possible to share software with participants; statistics teachers especially appreciate seeing software such as Autograph or Excel demonstrated for statistics teaching. Recordings of the online sessions allow participants to go back to the session at a later date to refresh their memories.

Some examination boards run similar training and/or feedback sessions across a range of subjects including those requiring knowledge of statistics. Teachers view a live presentation on the internet, displayed on a computer monitor or using a digital projector. An examiner or trainer goes through the presentation using the visual display and audio. Teachers are able to ask questions and a discussion ensues that is targeted at their precise needs. These training sessions are often attended by groups of teachers in schools and colleges so that colleagues can benefit by working together to improve their understanding of problems associated with the teaching of an A level subject.

This type of provision is evaluated very highly by teachers as an effective and economic way of passing on useful information.

4.3 Accountability

In every group it was emphasised that teachers would be extremely reluctant to try out anything new or creative unless it was required in the formal assessment. The pressure on them to produce results, in the form of examination grades, is just too great. They feel compelled to teach for the test, even when they know it is not in the best long term interests of their students.

This situation is a direct result of the current accountability regime, with its almost exclusive emphasis on examination results.

Other accountability systems are possible in which emphasis is placed on the quality of students’ educational experience and how well they are prepared for their future lives.

The introduction of an accountability system that emphasised the aspects of teaching and learning that are of long term importance would provide a major opportunity to enthuse teachers to take part in CPD.

Devising and implementing such a system is itself a major opportunity to improve the quality of work in our schools and colleges.

Notes and references

4.1 Hodgen J., Marks R. and Pepper D (2013) *Towards universal participation in post-16 mathematics*, Nuffield Foundation

4.2 ibid., page 7

4.3 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, page 2, The Royal Statistical Society

Advisors for Section A of the report

Roeland Beerten	Director of Professional and Public Affairs, The Royal Statistical Society
Catharine Darnton	Headteacher, Gillotts School
Professor Neville Davies	The Royal Statistical Society Centre for Statistics Education, Plymouth University
Dr Janet de Wilde	Assistant Director and Head of STEM, The Higher Education Academy
Stella Dudzic	Mathematics in Education and Industry
Professor Harvey Goldstein	The University of Bristol
Dr Dawn Hawkins	Senior Lecturer, Anglia Ruskin University
Thomas King	Statistician, Centre for Research Excellence in Child Language, University of Newcastle upon Tyne
Professor Xiaohui Liu	Director, Centre for Intelligent Data Analysis, Brunel University
Dr Kathleen Maitland	Senior Lecturer (Computing) and Director, SAS Student Academy, Birmingham City University
Dr John Pullinger	President, The Royal Statistical Society and Director-General Information Services, House of Commons
Hetan Shah	Executive Director, The Royal Statistical Society
Rob Sharpe	Training and Education Services Manager, Esri UK
Neil Sheldon	The Royal Statistical Society Centre for Statistics Education, Plymouth University
Dr Neil Spencer	The University of Hertfordshire

Section B

Subject findings

Biology

End-user requirements

Higher education

Well over 10,000 students study biological sciences each year in UK universities in courses with a variety of titles, including biology, botany, zoology, microbiology, molecular biology[1]. Others take biology in combination with other disciplines. In addition, many of those who took biology as an A level go on to study medicine and related subjects.

No international benchmarking has been carried out recently for UK research in biosciences. At degree level, eight UK universities were rated among the top 50 in the world for Biology in the 2012 QS rankings[2].

Biology has become a much more mathematical subject over recent years in higher education and beyond. Statistics and quantitative methods are pervasive and there is extensive use of mathematical modelling, as described in the following two extracts.

Virtually no research in the biosciences can be published without some form of statistical analysis.

Dawn Hawkins[3]

The concepts of rate of change modeling, equilbria and stability, structure of a system, interactions among component, data and measurement, visualizing and algorithms are among those most important to the curriculum.

National Research Council[4]

Around the world these changes have led to questioning about the content and teaching methods of biological science degree courses; these are the subject of a 2013 report published by the Higher Education Academy, *International Perspectives on Integrating Mathematics into the Teaching and Learning of the Biological Sciences in Higher Education*[5]. This report pays particular attention to the effects of the BIO 2010 programme[6] in the United States.

A key factor everywhere is the level of mathematics of students joining degree courses; this varies between and within countries, so that care needs to be taken when considering ideas from elsewhere. However, there can be no doubt about the overall direction of travel; in the UK this was described in the Strategic Plan for 2010–2015 of the Biotechnology and Biological Sciences Research Council.

As bioscience becomes increasingly quantitative, there is also an urgent need to raise the mathematical and computational skills of biologists at all levels.

BBSRC[7]

In almost all universities, biology undergraduates attend courses in statistics or quantitative methods, and then use a suitable software package to analyse data they have generated and also secondary data. The pace of most such courses is considerably faster than students would encounter during A level.

Some of those who enter higher education with little or no background knowledge end up able to enter data into a computer but with very little understanding of what the computer is doing or how to interpret the outputs and assess their validity.

By contrast, those who arrive with basic skills in statistics (and mathematics) are in a better position to benefit from their university courses.

Important skills for new biology undergraduates

- They are confident with data:
  - they know about different types of variable and measurement;
  - they understand about natural variability, experimental error and sampling error, and the differences between them.
- They understand the basic principles of statistical inference:
  - they are able to judge which test or procedure is the most appropriate in a particular situation;
  - they are able to interpret the results of a test;
  - they appreciate that modelling assumptions are involved.

Those students who arrive at university to start biology courses expecting them to be essentially descriptive are thus in for a shock. Instead they will meet a subject, often called bioscience, built around the rigour of scientific method.

There is a philosophical mismatch between the practice of biology in higher education and the experience of many A level students. To an extent this is true of all subjects, but the disparity would seem to be particularly great in biology and in large measure to derive from differing perceptions of the role of statistics.

All students should understand that biology is often analyzed through quantitative approaches. Developing the ability to apply basic quantitative skills to biological problems should be required of all undergraduates, as they will be called on throughout their lives to interpret and act on quantitative data from a variety of sources.

American Association for the Advancement of Science[8]

The Biomaths Education Network[9]

The array of statistical techniques used by bioscientists in research and employment has been increasing dramatically. Examples include randomisation tests, effect size, the generalised linear model, meta-analyses and social network analyses. Many of these techniques allow or require a Bayesian approach.

This presents a considerable challenge to educators in higher education, the more so given the expectations, attitudes and skills of many students starting undergraduate programmes in biosciences. Teaching statistics within biology requires not only a sound understanding of mathematics and statistics but also a good all-round knowledge of biology, together with an appreciation of the pedagogy of both disciplines for mature learners. It is essential that this interdisciplinary skills set and knowledge base is developed and supported in higher education.

Recognising this, the *Biomaths Education Network* was formed with the support of the Higher Education Academy and the Nuffield Foundation. There has been significant interest in the Network[10] and it is a model that could be followed in other sciences. Its remit could also be extended to help those teaching statistics to biologists in schools.

Employment

Many of those who take A level biology go on to use their knowledge at university but in other subjects. This is true of degrees in medicine, veterinary studies, pharmacology, pharmacy and dentistry, and there are well-trodden routes into professional employment for graduates of all these subjects.

It is important for students to appreciate the 'big picture' as much as to be able to carry out specific tests. One of the key things that a pharmacologist, medic or vet needs to understand is the concept of a mathematical or statistical model and the assumptions that are used to build them since these models underpin our understanding of how a drug is dealt with by the body and how it affects the body. An understanding of how variability can be determined and expressed is perhaps equally important.

Dr Jenny Koenig, Biology advisor

By the time they enter employment, whatever biology graduates of these subjects learnt in A level has long been superseded. The same is not, however, necessarily true of skills and attitudes that they acquired during those formative years.

Important skills for new biology graduates entering employment

- They are confident in using data, for example:
  - they can understand data regarding risk-benefit of treatments or diagnostics (such as screening tests);
  - they can explain bio-statistical concepts (such as a the significance of a clinical study) to colleagues or clients who do not have a scientific background.
- They can interpret and communicate statistical information, for example:
  - they can interpret and explain the results of medical investigations;
  - they understand and can critically appraise the quantitative information in a research paper.

Once in the workplace, graduates may also be faced with and expected to understand more general business and economic data.

Thus future employees will need statistical intelligence. A rich experience at A level can establish a relationship with data that will provide a sound basis for developing it.

In a global workplace, it is important that UK graduates have at least the same level of skill and confidence in statistics as their colleagues from other countries, in order to be able to communicate and work effectively.

Dr Sheuli Porkess, Biology advisor

A level Biology: The current situation

Biology is among the most popular A level subjects. In 2012 it was taken by 63,074 candidates of whom 43.5% were male and 56.5% female[11].

Current (2012) A level biology syllabuses are bound by the Subject Criteria for Science which specify some statistics within this list of required mathematics.

Statistics required by the A level Subject Criteria for Biology[12]

In order to be able to develop their skills, knowledge and understanding in science, learners need to have been taught, and acquired competence in …

(a) Use an appropriate number of significant figures.

(b) Find arithmetic means.

(c) Construct and interpret frequency tables and diagrams, bar charts and histograms.

(d) Understand simple probability.

(e) Understand the principles of sampling as applied to scientific data.

(f) Understand the terms mean, median and mode.

(g) Use a scatter diagram to identify a correlation between two variables.

(h) Use a simple statistical test.

Most of these items are covered in GCSE mathematics and so should already be familiar to students. However, their use within the context of biology may be unfamiliar, the more so since people commonly compartmentalise knowledge and do not easily transfer it from one subject to another.

This list is not without its critics among biology teachers and lecturers. They suggest that it would benefit from being reconsidered, and that the items should be exemplified within biology.

For students who have just taken GCSE, the only essentially new items are about sampling and null hypothesis significance testing. These are major topics that could introduce students to ideas in experimental design and statistical inference. However, they are often tied to the coursework required for the assessment rather than pervading the whole A level course.

Often minimal time is devoted to teaching statistics and its importance, particularly if a teacher feels insecure about statistics. The tests taught tend to be confined to those included in the specification. Students learn how to put numbers into a test and interpret the outcome using a table but I would question if they really understand why they are doing it. How much statistics is taught will vary between specifications and the nature of coursework assessment. I suspect many students learn 'how to do' but don't appreciate 'why to do'.

Ian Harvey, Biology advisor

In this situation, it is perhaps understandable that there is still a widespread belief among A level students and others, including some teachers, that biology is essentially a descriptive subject.

Opportunities within A level Biology

It is clear from both higher education and employment that students taking A level biology would be much better prepared for the future if they had more experience of working with data, to the point that the skills required start to become second nature.

Some work covering the Statistics Cycle[13] already happens in A level biology, but its extent is limited. Expanding on what is, essentially, already in place offers major opportunities both for better learning of the biology and for greater experience of working with data.

The Subject Criteria include the statement:

Understand the principles of sampling as applied to scientific data.

In most current A level syllabuses, the requirement is limited to using transects and quadrats, usually to assess biodiversity.

Consequently, when it comes to their own data, most students' experience is very limited; it may be restricted to only one source. So students are denied the benefit of meeting data from a variety of contexts and of different types.

The distinctions between experimental error and natural variability are critical to an understanding of biological data but many students are not currently presented with opportunities that will allow them to understand their importance at first hand, or how they cause sampling error. Students may well, for example, never have to make decisions about outliers and missing data. With such a deficit, students' learning is inevitably impoverished, and with it their understanding of the nature of biology.

Furthermore, many students do not meet a variety of available sampling techniques, even when these are relevant to the syllabus content. Knowing a variety of sampling techniques is important for good experimental design. Some examples of opportunities that might arise for A level students are given in the following table.

Sampling techniques: examples of opportunities	
Technique	**Examples of opportunities**
Opportunity sampling	A sample of flying insects is collected by placing a trap under a night-time light.
Stratified sampling	For a test of reaction times among young people, a sample is selected from the students in a school. The numbers chosen from the different year groups are in proportion to the numbers in those years.
Cluster sampling	A number of quadrats are used to collect information about the different plant species living in a field.
Quota sampling	Each member of a class is required to collect a specified number of plants of various species from a given habitat.
Systematic sampling	The trees in a plantation are numbered and every tenth tree is checked for fungal infection.
Simple random sampling	A survey is being carried out into an aspect of young people's health, such as allergies. Each student in a school is assigned a different number and 50 numbers are selected at random to give a sample of students.

An important opportunity for better statistics teaching and learning in A level Biology arises with experimental design. Neither the principles not the techniques involved are addressed to any great extent in the current A level, even though they are very important in higher education and research and, even at a relatively elementary level, can be a rich source of learning.

Experimental design fits naturally within the Problem Analysis stage of the Statistics Cycle. It requires students to think about the variables they are dealing with:

- their levels of measurement and whether they are categorical, ordinal or nominal;
- whether they are discrete or continuous;
- their likely distribution;
- whether an independent variable is natural (random) or manipulated (non-random).

The design stage is easily overlooked when a standard experiment is involved.

A level students are often criticised for collecting data without knowing what they are going to do next with them. A key part of experimental design is knowing just this. However, the design for an investigation may involve two or more cycles: an exploratory or pilot survey leading to biological hypotheses, followed by a second cycle in which data are collected specifically to test those hypotheses.

The first cycle may well involve only Data Presentation whereas the second is likely to result in Data Analysis and may involve a null hypothesis significance test. This is illustrated in the following example.

Problem analysis

What factors promote or retard the development of brine shrimp cysts?

There are many ways in which this problem could be approached. Here are some of the questions that could be asked[14].

1 Does temperature affect the rate at which brine shrimp eggs hatch?
2 Do different concentrations of salt affect the rate at which brine shrimp hatch?
3 Does increased acidity (acid rain) affect the hatching rate of the brine shrimp?
4 Do increased amounts of light increase or decrease hatching rates?
5 Do pollutants (oil, etc.) have an effect on hatching rates?

These are discussed as part of the problem analysis and as a first stage (or cycle), pilot experiments are designed and carried out. The results are then shared and biological hypotheses are formed.

A second cycle then begins with the design of experiments that will allow those hypotheses to be tested. By the end of the problem analysis stage in this cycle, it is known what data will be collected and what data analysis techniques will be used. This is likely to require the use of particular null hypothesis significance tests.

The Subject Criteria include the requirement to use *a simple statistical test*. This wording has profound consequences. The word ‘a’ is interpreted in many syllabuses as meaning ‘one’ and so most students are expected to know just one particular test.

As a result, they are never required to select the appropriate test for a given situation; nor do they have to consider any modelling assumptions. The person who set the examination question or the teacher who set up the coursework task has already done all that for them.

These limitations would be largely overcome if the word ‘a’ were replaced by, say, ‘at least three’. This would have the very considerable additional advantage of establishing null hypothesis significance testing as a general process in students’ minds rather than a one-off technique that is confined to the particular test that happens to be in their syllabus.

The tests needed in any syllabus would need to be defined; it would be quite unfair to spring a new test on a student in an examination question. However, having at least three opens up many teaching opportunities. There are, of course, many tests that could be used in biology at this level; the following are the most common.

- Spearman's rank correlation
- Product moment correlation
- Normal test for a mean
- *t*-test for a mean
- χ^2 test
- Mann–Whitney *U*-test
- Wilcoxon signed-rank test

It is not, however, suggested that A level Biology students should be required or expected to know all these tests.

Formal null hypothesis significance testing is not the only means that can be used for inference in biology at this level. One example is the capture–recapture method for estimating population size.

Null hypothesis significance testing is well suited to individual or small group investigative work. It involves using small data sets to make inferences about the populations from which they are drawn.

However, large data sets are becoming increasingly available in forms that allow them to be used in biology classrooms. As a result it is possible to investigate questions, such as the following examples, with the rigour provided by accompanying data.

- Are deaths from malaria decreasing?[15]
- Does the owl sing at a different frequency in the presence of greater background noise?[16]
- Why is Grandma wheezing? Is it the forest fires, the heat or the high ozone levels?[17]

Greater emphasis on large data sets in UK schools and colleges would provide an opportunity for them to work together with those in higher education to develop resources. A model for this is already in place with the BioQuest workshops[18] in the United States. They bring university lecturers together to develop teaching resources for the biosciences based on large data sets. While this work is mainly at the higher education level, some of those involved are school teachers. Those from higher education have experience of using the statistics and mathematics in a research context and teaching many of the same concepts.

Constraints

Several of those consulted commented that it would be helpful if the statistics taught in mathematics was better coordinated with the needs of biology. It was regretted that so little use was made in mathematics classrooms of the rich biological data that is available. The same point was also made about other techniques that are taught in mathematics but not in ways that allow students access to them in biology lessons.

There is manifestly much to be gained by closer cooperation between mathematics and biology teachers. However, people have been saying that for many years and it has not happened in many schools and colleges. There is a clear need for a systemic approach to ensuring that the skills learnt in mathematics classrooms are more transferable.

The main impact of the opportunities opened up for biology by the increasing use of statistics in higher education and employment may well be on the style of teaching rather than the topics covered in A level Biology. This may require some teachers to reconsider the way they present aspects of the subject, moving to an approach where the evidence presented is more often explicitly derived from data, and students are encouraged to consider the data behind the facts they learn. Such an approach also involves finding more opportunities for students to collect, think about and analyse their own data. However, a large number of teachers will need to take part in professional development if this opportunity is to become a reality.

Notes and references

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2 Source: QS Quacquarelli Symonds Limited, www.topuniversities.com

3 Hawkins D. (2011) *Maths and stats*, Chapter 7 in Adams D. (editor) *Effective learning in the biosciences*, Wiley Blackwell

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7 Biotechnology and Biological Sciences Research Council, *The Age of Bioscience: Strategic Plan 2010–2015*, page 15

8 American Association for the Advancement of Science (2011) *Vision and Change in Undergraduate Biology Education Final Report*, page 14

9 Biomaths Education Network: http://biomathed.wordpress.com

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15 Data about deaths from malaria available from the World Health Organization at www.who.int

16 Data on birdsong available from ArcGIS Explorer Online at www.arcgis.com

17 Data on air pollution data available from Bioquest at http://bioquest.org

18 BioQuest: http://bioquest.org

Biology advisors

Peter Bowen-Walker	Former biology teacher, The Manchester Grammar School
Dr Gemma Garrett	The Biochemical Society
Dr Angela Hall	Formerly of the Nuffield Foundation
Ian Harvey	Head of Biology, Hills Road Sixth Form College, Cambridge
Dr Dawn Hawkins	Senior Lecturer, Anglia Ruskin University
Dr Jenny Koenig	Lucy Cavendish College, University of Cambridge
Dr Rachel Lambert-Forsyth	Society of Biology
Dr Sheuli Porkess	Global Head of Quality Management (Medicine and Regulatory), Boehringer Ingelheim GmbH
Damian Riddle	Senior Product Manager for Science, Pearson Edexcel

Business studies

End-user requirements

Higher education

Business studies is not really a discipline in its own right but an umbrella term that is applied to degrees covering, to varying extents, a number of areas, including the following.

Accounting	Human resources
Administration	Management
Business	Marketing
Finance	Operations management

There is a diversity of degree titles and some graduates associate themselves more with their particular specialism than with business as a whole. Overall, business studies lacks the internal coherence and professional identity associated with most other subjects.

Some programmes offer more relevant labels to encourage students worried about mathematics, e.g. operational research, management science, finance, accounting, market research, econometrics, using those different descriptors to also indicate the multidisciplinary nature of 'business studies'.

Richard Atfield, Business studies advisor

The total number of students in any year is about 80,000, by far the largest of any subject area in higher education[1]. In some universities the annual cohort is over 1000 students. Many of the students are from overseas, with strong contingents from several Asian countries.

Several colleges of further education are franchised by universities to provide degree courses in business studies. In some cases this leads to a Foundation Degree or HNC/HND Diploma which can then be topped up to a degree at the university.

A particular feature of many, but not all, degree courses is the possibility of a work placement, often a sandwich year, in which students are paid by employers to do genuine jobs. Although these extend the duration of the degree courses, they are popular; students recognise that the experience makes them better able to benefit from their degree programmes and more employable once they graduate.

The diverse nature of Business studies means that overall international comparisons are not available for higher education in the UK. However, in the recent QS subject rankings[2], Oxford, Cambridge and the London School of Economics were placed in the top four universities for Finance and Accounting, and five other UK institutions were ranked in the top 50.

Almost all of the subject areas given above require the use of data and so there is a considerable amount of statistics in most business studies degree courses. In some universities this is taught through dedicated courses; in others statistics is embedded in the rest of the course and taught as and when it arises. Most degree courses involve a final year project and many of these require some statistics.

For most business studies degree courses, admission is not dependent on any particular subjects at A level, Highers or other qualifications; a prior qualification in business studies is not required. Some are also less demanding in terms of grades than most other subjects. Consequently some new undergraduates have done no mathematics or statistics since GCSE, and as a result may find themselves lacking in data handling skills; while this is true for 18- and 19-year-olds entering higher education, the problem may be even greater for mature students.

The diversity of educational backgrounds and workplace experiences (or not) of students entering business studies programmes provides a complexity which is often a surprise to those students; also to early career academics in business schools, many of whom were educated outside the UK.

Richard Atfield, Business studies advisor

Business studies students are expected to suggest ways of responding to opportunities and to find the evidence to support their proposals. The evidence is often based on data which they need to be able to obtain, analyse and present. They thus need to be comfortable working with data.

Important skills for new business studies undergraduates

- They are confident with data:
  - they are able to decide what data are appropriate to support a particular business case, consultancy or research project;
  - they know how to obtain relevant data;
  - they are comfortable working with data;
  - they are able to interpret data and to present their conclusions, orally and in writing, including appropriate visual representations.

Employment

There is considerable variability in the employability of those with business studies degrees.

This is in part due to the diversity of the content of degrees in this subject area, with some disciplines more sought by employers than others, but the large numbers of overseas students on business studies courses makes this difficult to quantify. The reputation of the university that awarded the degree also seems to have a large influence on a graduate's job prospects.

Degree level study is not the only route to a qualification in this area. Some people take apprenticeships and obtain BTEC qualifications. Some employers have been reported to express preference for those who take this route[3], particularly those who do the apprenticeship with their organisation and so have been trained to their standards and ways of working.

The fact that, given the choice, some employers prefer to employ non-graduates may provide a view into what it is they want from graduates and do not think they are getting.

Important skills for new business studies graduates entering employment

- They have a working knowledge of statistics:
  - they understand those statistical techniques that are relevant to the post to which they have been appointed;
  - they can use statistical software packages appropriately;
  - they can explain statistical concepts to colleagues without any background in statistics;
  - they can use data to provide evidence that is relevant to the needs of the organisation;
  - they can interpret trends.
- They understand the nature of risk:
  - they can carry out the risk-benefit analysis for a proposed course of action.

A level Business studies: The current situation

The number of students taking A level Business studies is currently just under 30,000[4]. It has decreased slightly over the last decade.

A level Business studies syllabuses (but not the Scottish Higher) are bound by the Subject Criteria for Business studies. No specific mathematics or statistics is specified. There are, however, some statements that effectively require the use of data.

Extracts from the Subject Criteria for Business studies[5]

Aims and objectives

1. AS and A level specifications in Business studies should encourage learners to: …

- acquire a range of relevant business and generic skills, including … the quantification and management of information.

Subject content

6. Knowledge, understanding and skills set out in the AS and A level specifications must: …

- enable learners to:
  - identify business problems;
  - plan appropriate investigations into such problems
- make justifiable decisions using both qualitative and quantitative methods …

9.

Area of study	**Amplification**
Business analysis	Forecasting Data analysis Market analysis Measures of performance: financial and non-financial

It is thus the case that if the criteria were followed strictly, there would be investigational work in A level classrooms which would require the use of statistics and demonstrate its relevance.

The assessment of the current A level includes questions based on pre-release material. There is, however, no coursework.

Business studies is fundamentally about strategic decision making. The subject comes to life when students are able to confidently use data to make evidence based decisions. When students can manipulate, interpret and analyse data, they begin to understand that business decisions are not black and white. This enables critical thinking: the ability to see shades of grey, spot inconsistencies and identify cause and effect.

Sandra Donnelly, Business studies advisor

However, anecdotal evidence suggests that the situation in many classrooms is rather different. Many people do not perceive Business studies as a particular high status A level and it attracts students of varied abilities including many who are not at all strong. A proportion of those taking this subject are planning to go directly into employment rather than higher education on completing the A level.

Research with stakeholders has shown that some students perceive mathematics as a stand-alone subject and are not always able to link the mathematical concepts with the real life context they are presented with, therefore leading to a perceived skills gap.

Isla Billett, Business studies advisor

In common with Business studies courses in higher education, the A level syllabus is very diverse in its content. Many of those teaching it have experience, for example from working in industry, of some aspects of it but not of the rest. While a background of working in the real world is in many ways ideal, it does often need to be supplemented by appropriate CPD and this is not always available. Consequently the teaching is often rather patchy. This is exacerbated by a lack of places in Initial Teacher Training[6].

Opportunities within A level Business studies

There are many opportunities within the current A level to improve students' learning through the use of data and statistics. Some of these would require small changes to the Subject Criteria but others would amount to little more than realising opportunities that are already there.

Current AS and A level Business studies syllabuses have no coursework requirement. Investigative work in Business studies usually follows a cycle which is very similar to the Statistics Cycle[7]. The introduction of coursework would provide an opportunity for such work to be carried out routinely. This would enhance students' learning of the syllabus and at the same time give them experience of working with data.

There are substantial advantages in students collecting their own data in any investigation: they have ownership and they are forced to consider issues relating to the suitability and quality of the data. However, the nature of the subject makes this difficult in A level Business studies, and so secondary data are almost always used instead.

Consequently there is a need for suitable up-to-date data sets that students can access. These should be regarded as tools of the trade in much the same way as laboratory equipment in science.

An example of a possible task is given below.

Task: Understanding macroeconomic data Evaluate the economic growth of the UK.
Problem analysis Understand measures of economic performance. Manipulate and present macroeconomic data. Interpret (describe trends) in economic data. Analyse and evaluate economic growth.
Data collection Use the office of national statistics (www.statistics.gov.uk), to source time series data for each of the following variables: • GDP per capita • Unemployment rate (claimant count summary) • Inflation (CPI and RPI Indices)
Data presentation Copy and paste the raw data into an Excel spreadsheet. Use these data to create a separate line graph for each data series separately and label each graph carefully.
Data analysis Identify the type of data series used, for example real or nominal values, index numbers or percentage changes. Label the graph accurately to identify periods of rapid growth, slower growth and negative growth. For each graph interpret the data by describing significant short term fluctuations and long term trends in the data. Be very careful to explain where GDP is growing or declining, and whether the rate of decline or growth is slowing/speeding up. (Use figures within these descriptions.) Use your class notes about GDP, Inflation and Unemployment to analyse (explain) what each graph shows has happened to each economic variable. Explain what impact the changes in these macroeconomic variables are likely to have had on consumer demand and capital investment by UK businesses. Compare the graphs and identify possible correlation, for example exploring similarities and differences, possible cause and effect.
Conclusion What does the data tell us about the health of the UK economy? Can these data be used to make a prediction of future trends?

The use of computers need not be confined to working with large data sets. They open up many other teaching opportunities of a broadly statistical nature.

- A more thorough approach to existing topics, such as forecasting.
- More interactive forms of teaching, such as using business games.
- The introduction of new ideas, such as Business Analytics.

An overall conclusion from the roundtable discussion is that the current Business studies A level would benefit from being refreshed. It was suggested that it could move on from the current approach of telling stories to one which is about using evidence that has often been derived from data.

The quality and depth of argument is significantly improved where students are able to use data based evidence confidently.

Sandra Donnelly, Business studies advisor

Constraints

There are two major constraints: the attitude of many students to any form of mathematics and the limited experience of some teachers.

Many of the students who opt for Business studies are not particularly good at mathematics, are frightened of it and are reluctant to engage with it. They see statistics as a part of mathematics and so something to be avoided. Clearly changes are needed to GCSE Mathematics to ensure that it gives students a more positive experience. In addition the Business studies A level should be designed in such a way that students work with data, en passant, on the way to finding results that they really want to know.

The subject criteria for Business studies state that students should develop skills in decision making, problem solving, challenging assumptions and the quantification and management of information. Statistics can have an important role in building these skills and, where appropriate, should be embedded in teaching and learning to demonstrate its relevance to the subject: for example decision making arising from data collection and analysis.

Isla Billett, Business studies advisor

It is already the case that some Business studies teachers do not have the breadth of experience to teach the whole syllabus confidently. The introduction of new ideas could make their situation worse, and so might well not be viewed with the enthusiasm that would be needed for these ideas to be successful. An essential condition for any of the opportunities to become a reality is that teachers should be provided with CPD to allow them to embrace the new ideas involved.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 Source: QS Quacquarelli Symonds Limited, www.topuniversities.com

3 www.apprenticeships.org.uk/News-Media/Latest-News/Article314.aspx

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5 Ofqual (2011) *GCE AS and A Level Subject Criteria for Business studies*

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Business studies advisors

Richard Atfield	Higher Education Academy
Isla Billett	Product Manager for Business and Economics, Pearson UK
Sandra Donnelly	Chief Executive, Economics, Business and Enterprise Association (EBEA)
Sara Furness	Higher Education Vocational Assessment Manager, Pearson UK

Chemistry

End-user requirements

Higher education

Chemistry is taken as a degree subject by about 5,000 undergraduates per year in UK universities[1]. There are also several fairly closely related subjects such as biochemistry and material science. A minimum content for chemistry degrees is recommended by the Royal Society of Chemistry and contained in the standards laid down by the Quality Assurance Agency[2].

A review of chemistry research in UK universities in 2009 was summarised as follows.

In brief, the overall health of chemistry research in the UK is good. … There are pockets of truly outstanding (world-leading and world-class) work going on and numerous examples of very well-supported research groups. … Importantly, the top-level research is not confined to just one location. There are excellent examples of international collaboration, especially via EU programmes and a number of good examples of cooperation with industry. Multi-disciplinary research efforts are expanding. Pockets of excellent multidisciplinary research are being nucleated via Doctoral Training Centres (DTCs). Chemists in the UK have definitely shed their ivory tower attitudes and are better prepared than in the past to tackle society's challenges.

EPSRC[3]

In higher education subject demarcations can be misleading with respect to chemistry, which is often the link between different disciplines. This is true of many of the new and developing areas which advisors identified.

- Green chemistry
- Renewable energy
- Sustainability and rare metals replacement
- Systems and predictive modelling
- Materials and formulation
- Industrial biotechnology
- Chemical biology and medicinal chemistry
- Synthetic biology
- Nanotechnology

Another feature of many of these areas is that they are data rich and so require the application of statistics. While some of them may well always remain the preserve of higher education, others, such as green chemistry and renewable energy, are likely to impact on A level.

In a few universities almost all first year chemistry undergraduates arrive with A level Mathematics or its equivalent. However, in most this is far from the case. Overall only just over 60% have done A level Mathematics[4]. Those students who have not done any mathematics and statistics in the two or more years since they took since GCSE are seriously disadvantaged.

Maths is an extremely important part of nearly all chemistry degree courses. Although an A-Level in maths is not always an entry requirement, you will find some aspects of the course more difficult if you have not studied maths to this level. You may also be required to do a 'catch-up' course in maths once you reach university.

Royal Society of Chemistry[5]

Even those who have done A level mathematics may find themselves struggling, particularly those who have concentrated on the questions likely to be set in the examinations at the expense of developing transferable skills.

One of the issues for chemistry undergraduates is that many of them find it difficult to relate quantitative skills to real world problems. As a result, even students with A level Mathematics find statistics challenging when it relates to chemistry experiments. Their lack of understanding of data, critical analysing of data, error analysis and interpreting the data in order to plan future work is problematic for them. They should also be able to record and analyse pooled experimental data during their practical courses.

Dr Gita Sedghi, Chemistry advisor

Clearly competence in basic mathematics is important for new undergraduates. The same is true of confidence with data and an appreciation of their relevance to scientific enquiry.

Beneficial statistics skills for new chemistry undergraduates

- They are confident with data:
  - they understand the value of observation;
  - they are able to describe, present and report on data;
  - they know about different types of variable and measurement;
  - they know about experimental and systematic error and appreciate the need for error analysis.
- They understand the basic principles of scientific investigation:
  - they are able to engage with quantitative procedures;
  - they are able to judge which procedure is the most important in a particular situation;
  - they are able to interpret the results;
  - they understand the importance of patterns in data
  - they can judge when modelling assumptions are involved.
- They are able to process information:
  - they are able to translate information from one form to another: tabular, graphical and narrative;
  - they are adept at data visualisation.

Employment

Chemistry provides the link between many disciplines and as a consequence a wide variety of career paths are open to those chemistry graduates who wish to use their technical knowledge. However, they have developed considerable analytical skills which are transferable so many find employment in quite different areas.

For those whose careers are based on their knowledge of chemistry, workplace practice is evolving to keep pace with what is a complex, data-rich and competitive environment. There is an ever-increasing reliance on data generation, visualisation and manipulation to drive decision-making. As the range of experimental options grows, chemists are having to apply predictive modelling techniques that capitalise on existing data to inform future experiment design. As research becomes more collaborative, spanning geographical and cultural boundaries, there are new challenges associated with consolidating data from a variety of sources, using a range of methodologies. In particular, it is critical that researchers are able to assess the quality and integrity of the data critically to ensure that the conclusions drawn are based on sound information.

This way of working could be used much more in A level classrooms, albeit with much more elementary content. This would allow students to develop critical analysis skills and collaborative behaviours that will make them valuable employees later in their lives. The use of work experience placements in companies could do much to provide students with the necessary context to develop these capabilities.

A critical part of the process is the way in which data are used. This will require students to learn techniques that are not difficult but are not currently practiced at A level, for example using spreadsheets, graphical visualisation of data sets and being able to move seamlessly from one format to the other.

The demands of employment mean that new graduates require statistical skills as well as their knowledge of chemistry.

Important skills for new chemistry graduates entering employment

- They are competent and confident in using relevant mathematics and statistics:
  - they have a basic understanding and awareness of statistical significance testing and an appreciation of experimental error and uncertainty;
  - they are able to plot basic graphs (either using computer programs or by hand);
  - they are confident with inter-conversion of units, rough estimates and order-of-magnitude calculations;
  - they can work with and interpret models that are expressed in mathematical and statistical terms;
  - they can use data to construct models;
  - they can explain concepts linking chemistry, business and statistics to colleagues;
  - they understand and can critically appraise quantitative information, for example in a research paper, a government report or a pilot study.

Chemistry is a key enabling discipline for a wide variety of science and technology sectors. As a result, chemists need to understand how their expertise can be brought to bear on complex problems that span discipline boundaries. Invariably, this will involve the generation, analysis and manipulation of data; to be successful in this multidisciplinary environment, chemists need to be competent and confident in their use of data in unfamiliar situations and to draw conclusions that form the basis of well-informed decisions.

Dr David Fox, Chemistry advisor

A level Chemistry: The current situation

The number of students taking A level Chemistry has risen from 36,648 in 2002, the first year of the Curriculum 2000 syllabus, to 49,234 in 2012[6]. A level Chemistry syllabuses (but not the Scottish Higher) are bound by the relevant part of the Subject Criteria for Science and these specify the following minimum demands for mathematics and statistics content.

Statistics required by the A level Subject Criteria for Chemistry[7]

In order to be able to develop their skills, knowledge and understanding in chemistry, learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject.

Arithmetic and numerical computation

1 Recognise and use expressions in decimal and standard form.

2 Use ratios, fractions and percentages.

3 Make estimates of the results of calculations (without using a calculator).

4 Use calculators to find and use power, exponential and logarithmic functions.

Handling data

1 Use an appropriate number of significant figures.

2 Find arithmetic means.

Algebra

1 Understand and use the symbols: $=$, $<$, $<<$, $>>$, $>$, $\propto$, $\sim$.

2 Change the subject of an equation.

3 Substitute numerical values into algebraic equations using appropriate units for physical quantities.

4 Solve simple algebraic equations.

5 Use logarithms in relation to quantities that range over several orders of magnitude.

Graphs

1 Translate information between graphical, numerical and algebraic forms.

2 Plot two variables from experimental or other data.

3 Understand that $y = mx + c$ represents a linear relationship.

4 Determine the slope and intercept of a linear graph.

5 Calculate rate of change from a graph showing a linear relationship.

6 Draw and use the slope of a tangent to a curve as a measure of rate of change.

Geometry and trigonometry

1 Appreciate angles and shapes in regular 2D and 3D structures.

2 Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects.

3 Understand the symmetry of 2D and 3D shapes.

In addition, one of the statements in the overarching requirement *How science works* is:

- Analyse and interpret data to provide evidence recognising correlations and causal relationships.

Statistics does not feature very prominently in this list. The following items, which are included in the overall Handling data list in the science criteria, are not required for chemistry.

Topics in the Science criteria but not those for chemistry[8]	
3	Construct and interpret frequency tables and diagrams, bar charts and histograms.
4	Understand simple probability.
5	Understand the principles of sampling as applied to scientific data.
6	Understand the terms mean, median and mode.
7	Use a scatter diagram to identify a correlation between two variables.
8	Use a simple statistical test.
9	Make order of magnitude calculations.

The current A level Chemistry specifications contain very little specifically about statistics. However, they do include some statements relating to the collection and presentation of results in general, usually within an investigative cycle, and they all mention data in this context. This provides ample scope for error analysis but, in contrast to physics, little is done on this in chemistry.

The position of mathematics within other A levels, including Chemistry, changed when syllabuses were revised for Curriculum 2000.

For Curriculum 2000 A levels, each A level became 'stand-alone', so that there could be no assumption that students taking A level Chemistry were taking A level Mathematics and content was arranged so that there was no built-in disadvantage to students without mathematics at A level.

Damian Riddle, Chemistry advisor

Recently (in 2012) there has been criticism that the expected mathematical content is not well covered in A level examinations.

For … chemistry … the mathematical requirements that were assessed concentrated on a small number of areas (e.g. numerical manipulation) while many other areas were assessed in a limited way, or not at all.

SCORE[9]

Such statistics as is required is largely assessed within the practical work and so fell outside the examinations investigated in the SCORE research. However the statistics could also be covered in written examinations and that would probably add to its impact.

Opportunities within A level Chemistry

Although data handling is required extensively by chemists in higher education and employment, most A level students encounter very little of it within chemistry. Increasing their experience of working with data, and thereby ensuring they are better prepared for their futures, is clearly a major opportunity. Such work will often be associated with the Statistics Cycle[10].

Chemistry students already use an investigative cycle as part of their practical work (assessed or not), so no fundamental change is required in this respect, more a change of emphasis to ensure that more of the work is quantitative and the data are more often central to the tasks. A suitable task is shown in the example on the next page.

This would encourage more attention to be given to the statistics involved in collecting, processing and interpreting experimental data, including the following topics.

- Different types of variable
- Issues surrounding bivariate data including lines of best fit
- Time dependent variables, including reaction rates
- Error analysis, including combining errors

Some mathematical models, such as the Maxwell-Boltzmann distribution, are used in physical chemistry at A level. However, there are opportunities to improve the way such models are presented. Current treatment lacks the underlying mathematics that would allow students to explore the relationships between the variables, other than at a superficial graphical level.

Models such as the perfect ionic model for an ionic solid are considered without any of the underlying mathematics (inverse square law of electrostatics). This is an indictment of the way in which relatively simple mathematics could be used to further understanding but it is not!

Dr John Bentham, Chemistry advisor

There are opportunities for the increased use of data in determining appropriate values for the inputs to models. This naturally leads to an introduction to sensitivity analysis, where the effects of small changes to the inputs are investigated.

A related opportunity is for students to use data to construct models. While this would be breaking new ground in A level chemistry, it would be a first step in developing a skill, and the associated way of thinking, that has been identified as important in the workplace.

Another opportunity would involve the introduction of a mathematical formula for entropy as an A level topic. At the moment entropy is linked to disorder only by word association. It would be a relatively straightforward step to introduce the equation $S = k\ln(W)$ where W is the number of ways of arranging particles in the available energies. This would enable the use of computer graphics to show how entropy linked mathematically to states of matter and to temperature.

Task: Rate of evaporation investigation[11]

Evaporation is the conversion of liquid to vapour without the boiling point necessarily being reached. In this experiment, the time taken for a drop of propanone to evaporate is measured under a number of different conditions and compared.

Problem analysis

Liquids evaporate below their boiling point. This is because as the particles move around and collide, some have more energy than the others allowing them to escape from the rest of the liquid as vapour. This results in the overall energy of the liquid (and therefore its temperature) decreasing.

Students should be able to observe that warmth, air flow and spreading out the drop all increase the rate at which it evaporates.

Having observed this, students can then be asked to decide on which data should be gathered to demonstrate the effects of the various influences on the rate of evaporation and how the data should be presented.

Data collection

a Put a drop of propanone onto a microscope slide and time how long it takes to evaporate.

b Change the conditions and repeat the experiment, ensuring that you record the conditions used and the time taken for each one. For example: warm the microscope slide by holding it in your hands, or by placing in warm water and then drying; spread the drop out with the tip of the dropper pipette; for a cool air flow, fan with a book or similar; for a warm air flow, blow across the drop.

Data presentation

Presenting the data in ways that help understanding of the effects of the variables on the rate of evaporation of propanone.

Data analysis

Create suitable tables and graphs to explain the effects.

Conclusion

Decide whether further experiments need to be done to explain the findings.

Constraints

Capitalising on the teaching opportunities accompanying the greater use of statistics in chemistry will involve overcoming similar constraints to those in other subjects but with possibly rather different emphases.

Chemistry is intrinsically mathematical and so both the non-transferability of GCSE skills and the removal of mathematics from recent A level syllabuses constitute serious constraints to the successful learning of the subject; the introduction of more data related work is likely to be hard to achieve until these general mathematics issues are resolved, although it could be a step towards their solution.

Some chemistry teachers know little statistics and so could find themselves being asked to teach topics that they do not know themselves. However, their ability to think analytically means that this should not be as serious a problem in chemistry as it is in some other subjects. Given suitable CPD, most chemistry teachers should be able to make up their skills gap

Textbooks and new teaching materials will be required. In the past this would have been a bigger constraint than it is now because materials can be made available online.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 The Quality Assurance Agency for Higher Education: www.qaa.ac.uk

3 EPSRC (2009) *Chemistry for the Next Decade and Beyond: International Perceptions of the UK Chemistry Research Base*, page 3

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5 Royal Society of Chemistry Response to Towards Level 3 Mathematics in 2016 (ACME, 2009)

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8 ibid.

9 SCORE (2012) *Mathematics within A-level Science 2010 Examinations*, page 4

10 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

11 Adapted from Practical Chemistry, www.nuffieldfoundation.org/practical-chemistry

Chemistry advisors

Dr John Bentham	Chief Examiner for A level Chemistry, AQA
Dr David Fox	Vulpine Science and Learning
Nicole Morgan	Royal Society of Chemistry
Damian Riddle	Senior Product Manager for Science, Pearson Edexcel
Dr Gita Sedghi	Lecturer, University of Liverpool
Annette Smith	Chief Executive, The Association for Science Education

Computing

End-user requirements

Higher education

Approaching 25,000 students a year take computing degrees[1]. Several different course titles are currently used, such as *Computing*, *Computer science*, *Information systems* and *Business information technology*. There is a strong gender bias among the students with fewer than 15% female[2].

An international review of computing research in UK universities[3] in 2001 raised concerns.

Computer science in the UK has traditionally been of the highest quality. However, while the UK remains a world leader in some research areas and is a strong participant in many others, this position is by no means assured. Declines in certain fields are already evident; more will follow, given the current levels of support and the nature of today's university research environment. The consequences could be far-reaching. Computer science is not only an academic discipline offering deep intellectual challenges; it is also a discipline where research results can translate into competitive advantage and economic well-being on a local, national, and international scale.

A subsequent review, *International Perceptions of the UK Research Base in Information Communications Technologies*[4], five years later, in 2006, was much more reassuring.

The Panel was impressed with the breadth and quality of ICT research throughout the UK. There have been significant improvements in ICT research and attitudes since the last review in 2001. Morale in the ICT community was perceived to be high and the excitement of the institutions and individuals at each of the week's events was refreshing and contagious.

The UK ICT community is doing exciting, high quality, world class research across the spectrum of CS and EEE. The Panel agreed that the UK is in the premier league in many research areas.

The UK, through its Interdisciplinary Research Collaborations (IRCs) and e-Science programmes, has made great strides in interdisciplinary research and in some areas this is attracting new talent into the ICT community. Both programmes have brought together groups that did not traditionally collaborate.

The Panel saw evidence of substantial and pervasive knowledge transfer from universities to industry. There is substantial IPR creation and numerous small company spin-outs.

Internationally UK first degrees are well regarded as providing a balanced programme for those who are likely to work subsequently in the industry. Many UK universities offer computing degrees in Computer science and Business information technology. The former is a more technical degree and the later focuses more on the business side of computing. In contrast, many computing degrees in India, Pakistan and China focus more on the technical and theoretical side of the subject area. Some universities in the UK are now introducing Masters degrees in relatively new areas of computing, such as data analytics, building on experience in data mining modules and corresponding research activities in this area.

Subject benchmarking by the Quality Assurance Agency for Higher Education[5] was first introduced for Computing in 2000 and revised in 2007. Most UK degree courses conform to these benchmarks and most are accredited by the British Computer Society and/or the Institute of Engineering and Technology. The requirements include some compulsory mathematics but no statistics. A degree from an accredited university makes it easier for a graduate to progress to professional recognition.

In practice there is considerable variation in the coverage of statistics in UK degrees. A few include separate statistics courses; in others it is included in mathematics courses, or in those on data analysis or research methods. Typically final year undergraduates are required to submit projects and degree programmes which include enough statistics to support them.

A particular development, *Big Data*, relates to very large data sets.

Big Data

As a result of the development of digital collection methods, very large sets of data and databases are now common. The Big Data initiative is designed to develop techniques for unlocking the information that is undoubtedly available in them. The requirements of these techniques are classified under four headings.

Volume

They must be able to handle the vast size of these data sets.

Velocity

They must be able to do so quickly, especially for real-time applications.

Variety

They must be able to handle a large variety of data types, including unstructured data.

Veracity

They must be able to establish trust in the data.

Computing departments in higher education around the world are now involved in *Big Data*. In the UK it is becoming a major research and teaching area in many universities.

Information extracted from Big Data must be presented in a format that is available and understandable by users. Whilst statistical methods form the basis for data analytics, the visualisation of results is important to organisations; they need the results to be available via a variety of output devices, such as ipads and other mobile devices, as well as more conventional means via the internet.

For some time the UK computing departments have been running MSc courses in business intelligence, data mining and machine learning to accommodate the growing need for graduates with data analytical skills. More recently new MSc courses in data science, Big Data and data analytics have been set up to respond to the huge challenges of Big Data.

These courses incorporate statistical methods to extract information from data sets and require students to have a working knowledge of statistics and a good level of mathematics. Increasingly these courses are jointly run with mathematics or statistics departments. Much of the content of these courses is now being moved into undergraduate programmes in recognition of the need for more emphasis on data analytics.

Many courses expect students to have an A level in Mathematics. However some, such as business intelligence, accept students with just a GCSE in Mathematics and provide additional support for students in gaining further knowledge in statistics.

Expertise in computing is currently a serious skill shortage in the UK and so it is predictable that undergraduate enrolment in computing courses will increase in the years ahead. It will be important that new undergraduates arrive with appropriate skills.

Computing students need to be able to analyse situations and problems, and to break them down into a number of steps, using techniques such as functional decomposition. New undergraduates who have taken mathematics beyond GCSE, for example at A level, are more likely to have developed an analytical and logical way of thinking about data, and so are likely to be better equipped for computing degrees.

Important skills for new computing undergraduates

- They have good analytical skills.
- They have a sound knowledge of basic mathematics which they are able to apply in new contexts.
- They are comfortable working with data.
- They are familiar with different types of data and ways of displaying them.
- They are able to interpret data and to communicate their conclusions, orally, visually and in writing.

Employment

Most computing graduates use the technical knowledge they have acquired when they enter employment. Their skills are highly sought and so they have little difficulty in finding jobs. Some large companies and public sector organisations have their own systems departments; others use the services of software houses or contractors.

While the current UK skills shortage in this area may be good news for computing graduates, it is certainly not in the national interest. The particular problem of companies being unable to obtain information from large data sets was highlighted in a recent report from the software provider, SAS.

The single barrier to unlocking the data that derived in those organisations was the lack of skills that existed, and actually inertia was created through people not having the necessary skills to derive some value out of the data. This is a problem that we're seeing in our clients, that there are a lack of skills in organisations to help drive the use of that data.

Mark Wilkinson[6]

Much of the development work that computing graduates do for their organisations is intended to provide evidence on which decisions will subsequently be made. Consequently, they can find themselves with an open door into management, making this a natural career progression, often via an MBA.

New computing graduates entering employment will need not just their technical skills but a background understanding of how to handle data when the occasion demands.

Important skills for new computing graduates entering employment

- They know how to store data in an appropriate format.
- They can interpret and explain the results of processing data.
- They can relate data to the needs of the organisation and can explain this to their colleagues.
- They can critically appraise data from any source.

In terms of future employment, many of the most interesting, challenging and financially rewarding careers over the next 10, 20 or 30 years will be in companies which don't exist today. Even more interestingly, lots of these careers will be in industries which don't exist today. What all these companies will have in common is the need for computer-literate employees who have the statistical ability to analyse data and turn it into useful information.

David Cross, Computing advisor

A level Computing: The current situation

The number of students taking A level Computing has decreased steadily over recent years, from 7242 in 2005 to just 3809 in 2012, with girls accounting for less than 8% of them. A similar but less marked decline has occurred in the less technical A level in Information and Communication Technology, down from 14,883 in 2005 to 11,088 in 2012; in this case the proportion of female candidates is much higher, nearly 40%[7].

A possible explanation for the decline in the uptake of A level Computing is that some universities did not recognise it for admissions purposes, claiming that it was insufficiently rigorous. This situation was taken into account in the design of a new syllabus introduced for first teaching in 2008. Along with some other more recently developed computing courses, this is now recognised by universities, including those in the Russell Group.

A level computing syllabuses (but not the Scottish Higher) are bound by the Subject Criteria for Computing. No specific mathematics or statistics is specified. However all the syllabuses do include binary and hexadecimal arithmetic, and in addition the criteria include the following requirements relating to data.

Extracts from the Subject Criteria for Computing[8]

Software

- Data types, data structures and algorithms.

Information

- The methods of capturing, selecting, exchanging and managing data to produce information for a particular purpose.

Design

… the methods of solving the problem include where appropriate …

- the algorithms, data types, data structures and other requirements of the solution;
- the method of testing the solution and the selection of test data; …

The view is sometimes expressed that it would be better if more mathematics and statistics were to be specified.

At present, a student who is not also studying A level Mathematics can be disadvantaged when applying for degree courses at university. During research for the development of the new A level specification, a number of parties have related their fears that there are no specific mathematics and statistics bullet points in the current A level Computing subject criteria.

Mark Judge, Computing advisor

Opportunities within A level Computing

Current Computing syllabuses have a requirement for coursework. This provides an opportunity for work using a format similar to the Statistics Cycle[9], as below.

Task

Aggregate the sales information for the UK, China and India. Analyse the results using appropriate statistical techniques and present the results in a report that can be viewed online via a variety of mobile devices.

Problem analysis

Deciding what data are relevant, where they reside and their format, and what appropriate statistical analysis can be performed on them. For example:

- sales data for the UK may exist on a UK server in a Oracle database;
- sales data for China and India may exist in Excel spreadsheets on servers based in each country.

Analyse what information can be extracted from the data.

Data need to be integrated into a new data set before analysis can be performed.

A common format will be required and all data translated into it.

Analysis will be performed by the application of statistical methods and outputs generated in the format as required.

Outputs are required in a variety of formats, such as those required for viewing via the internet or specified mobile devices.

Data collection

Understanding the data is essential in this context. Activities involved in data collection include finding the sources of the data, where the data resides i.e. the address of the server, the format of the data files and the data types within the data files.

Data presentation

Presenting the data and analysis performed in ways that are relevant to understanding sales in the UK, China and India.

Data analysis

Use appropriate statistics methods or mathematical models and produce outputs into an appropriate format e.g. graphical output for viewing via the internet or tabular output in Excel.

Describe and interpret the outputs.

Providing a written analysis of the data supported by graphical outputs.

Conclusion

Deciding whether the data correctly merged into a new data set will impact on the data analysis. The data will need to be presented in a format in which statistical analysis can be performed. Selecting appropriate statistical methods to perform on the data will influence what information can be extracted from it. Finally, the results need to be presented in the required format.

Work like this presents an opportunity for making use of statistics to improve the relevance of the work students do within A level Computing. Suitable new wording of the Subject Criteria, with appropriate emphasis on the importance of handling quantitative data, would ensure that it is done routinely.

A different opportunity arises from the importance now being attached to *Big Data*. So far the impact of this has been felt in employment and in higher education but not in schools and colleges. However, if 16- to 18-year-old students are to be presented with courses that are up to date, their syllabuses must be subject to frequent review and new topics, such as *Big Data*, introduced and made accessible.

The importance of data analytics, which is primarily statistics, has been recognised by large organisations but this has not filtered down to A level syllabuses. The world of statistics is changing into a world of data analytics and Big Data

Dr Kathy Maitland, Computing advisor

Computing should be the fastest developing subject in the whole curriculum.

Constraints

An essential condition for any of the opportunities to become a reality in any subject is that teachers should become familiar with the new ideas involved. This necessity is given added poignancy in computing because many students will embrace changes as they occur and so there is a danger of teachers being left behind in newly developing areas.

Consequently it is essential that relevant CPD is available for teachers and that the conditions surrounding it, including the cost, ensure that in practice it is accessible. Otherwise there is a real danger of the subject stagnating in schools and becoming progressively more removed from what is happening in higher education and employment.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 Source: UCAS, www.ucas.ac.uk

3 Schneider, F. and Rodd, M (Eds) (2001) *International Review of UK Research in Computer Science*, page iv, EPSRC, IEE and BCS

4 *International Perceptions of the UK Research Base in Information Communications Technologies*, page 1, (2006), EPSRC, BCS, Intellect and IET

5 The Quality Assurance Agency for Higher Education: www.qaa.ac.uk

6 Private communication: Mark Wilkinson, Managing Director for SAS UK & Ireland, speaking at the launch of the SAS report *Big Data: Lessons from Leaders* (2012)

7 Source: Joint Council for Qualifications, www.jcq.org.uk

8 Ofqual (2011) *GCE AS and A Level Subject Criteria for Computing*

9 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

Computing advisors

David Cross	Langley Grammar School
Mark Judge	Technology Qualifications Manager, OCR
Dr Kathy Maitland	Senior Lecturer (Computing) and Director, SAS Student Academy, Birmingham City University
Bill Mitchell	Director, British Computer Society Academy
Professor Xiaohui Liu	Director, Centre for Intelligent Data Analysis, Brunel University
Dr Mark Ratcliffe	Discipline Lead (Computing), Higher Education Academy

Economics

End-user requirements

Higher education

Economics is taken as a degree subject in its own right by about 10,000 undergraduates per year in UK universities[1]. In addition, it is a subsidiary part of many other degree courses so that the number of students who learn some economics while at university is considerably greater. Numbers of students have increased in recent years, at least in part as a result of high uptake from some Asian countries with a culture which holds economics in high esteem.

There is a growing demand from school leavers for degree courses in Economics. Not all will have studied the subject at A level but they are clearly attracted by the relevance of the subject in the global economy and the opportunity for securing a meaningful job on graduation.

Professor Colin Bamford, Economics advisor

Economics research in UK universities is highly regarded internationally, as evidenced in the recent ESRC international benchmarking exercise[2].

First and foremost, the research achievements of United Kingdom scholars are exceptional by world standards; the UK economics profession is more prominent than any other country's except for the United States. UK scholarship has been very influential in a number of important fields, such as labour economics, public economics, and economic development, and it has attained world leadership in microeconometrics.

A large part of the methodology of economics involves the application of real data to economic models and then interpreting the outcomes in terms of what is actually happening and any implications it may have for policy. So the use of data, and consequently statistics, lies at the heart of the subject.

The data are usually secondary and economics students are expected to develop a good understanding of the different available sources. It is often the case that only summary measures are available, rather than the raw data, making it particularly important for students to understand how they were compiled and any possible sources of inaccuracy or misrepresentation.

In recent years it has become clear that some economics issues are best addressed using qualitative methods or that a mixture of qualitative and quantitative methods is required.

All economics students are taught statistics or quantitative methods. After the first year it is common for such work to be embedded within the economics teaching. There is extensive use of suitable software packages. The pace is considerably faster than students would encounter during A level and consequently those students who arrive as new undergraduates without appropriate backgrounds in mathematics and statistics often struggle.

Students on undergraduate economics degree programmes at British universities who lack basic understanding of concepts such as probability and algebra are often at a disadvantage during their first year of undergraduate economics degree work compared to their peers with sound mathematical backgrounds. This adversely affects their learning experience and engagement in teaching rooms.

Meena Kotecha, Economics advisor

By contrast, those who arrive with basic skills in statistics (and mathematics) are in a better position to benefit from their university courses.

Beneficial skills for new economics undergraduates

- They have a sound knowledge of basic mathematics which they are able to apply in new contexts.
- They are comfortable working with data.
- They are able to interpret data and to communicate their conclusions, orally and in writing.
- They have analytical skills.

Employment

There is considerable diversity in the careers followed by economics graduates. Many are related to business or to policy within the private or public sector. The largest single employer is the Government Economic Service.

So what do government economists actually do? Last year 85 per cent had synthesised evidence, 75 per cent produced briefing material, 70 per cent provided policy advice, 70 per cent had used cost-benefit analysis, 55 per cent had been involved in policy evaluations, 55 per cent had used mathematics and 50 per cent econometrics, and 15 per cent had used game theory.

Deputy Director, Government Economic Service[3]

The value placed on economic research in policy making is summarised in the concluding words of the 2008 international benchmarking report[4].

Economic research has a substantial impact outside academia in the UK, through publications, seminars, commissioned studies, and movements of people between universities and public institutions. These interactions appear to be very fruitful, and they benefit research and public policy alike.

By the time they enter employment, whatever economics graduates learnt at A level has long been superseded; indeed many never took the subject at A level. The same is not, however, necessarily true of skills and attitudes relating to mathematics and statistics that they acquired during those formative years, or even earlier in their education.

It is now almost standard practice that the application process for the types of jobs to which economics graduates typically aspire begins with an online screening test. These tests include some mathematics and elementary statistics, usually under time pressure. Those who fail are not allowed to proceed with their applications.

Important skills for new economics graduates entering employment

- They are competent in basic mathematics and statistics and willing to engage with problems that require their use:
  - they can work with and interpret economic models that are expressed in mathematical and statistical terms;
  - they can explain concepts linking economics and statistics to colleagues.
- They are confident in using data, for example:
  - they can decide what data are appropriate in a given situation and know where they are available;
  - they can interpret and explain the results of applying real data to an economic model;
  - they understand and can critically appraise quantitative information, for example in a research paper, a government report, a pilot study or a news story.

When you are applying for jobs in this economic climate, being able to demonstrate quantitative skills is one of the most positive and effective ways of differentiating yourself from the other candidates.

Joe Twyman[5]

A level Economics: The current situation

The number of students taking A level Economics has risen from just over 16,000 in 2001 to 24,327 in 2012, with particularly strong growth in recent years[6]. However, the uptake is still quite low when compared with some other countries. College students in Singapore are required to study economics to at least AS level; elsewhere, especially in Pakistan, China and India, economics is a particularly popular subject.

A level Economics syllabuses (but not the Scottish Higher) are bound by the Subject Criteria for Economics. No specific mathematics or statistics is specified but the criteria include the following requirements.

Extracts from the Subject Criteria for Economics[7]

- Select, interpret and use appropriate data from a range of sources
- Interpret and evaluate data from multiple sources

Mathematical models are used extensively in A level Economics. Students are expected to be able to process data into measures which are relevant to these models. Many of these models are designed to explore the consequences of the variability of economic data, for example for elasticity. Time series are widely used.

Current A level examinations often include a question on data interpretation.

There is a GCSE in Economics but its uptake is small and many institutions do not offer it. Consequently in some schools and colleges with limited A level numbers there are not enough economics lessons to fill a full timetable. In some such cases specialist economics teachers are employed and their timetables are filled up with other subjects, often business studies, but in others the economics is taught by a non-specialist. Those consulted expressed concern that not all A level students have access to specialist teaching and it may be that this is being exacerbated by the limited availability of teacher training in economics.

Opportunities within A level Economics

It is clear from both higher education and employment that the more experience A level students have in working with economics data, the better they will be prepared for their futures. Ideally they will be presented with problems that are so interesting that they really want to know the answers. Such problems are likely to fit broadly within the Statistics Cycle[8], as illustrated in the following example.

Task: Analyse growth forecasts for India

Analyse growth forecasts for India over the next 30 years.

Problem analysis

Deciding what data are relevant and important, for example:

- GDP/GNP, annual projected growth per annum;
- as above but in terms of per capita;
- population growth, age distribution projections;
- data related to sustainability, such as: oil and metals demand and supply; skills requirements; food supply and demand-forecasts.

Data collection

Finding the sources of the data and the required figures

Data presentation

Presenting the data in ways that are relevant to understanding India's predicted growth.

Data analysis

If necessary, substituting the data into relevant (mathematical) growth models and interpreting the outputs.

Providing a written analysis of the data.

Conclusion

Deciding whether the question has been answered adequately or whether more data are required and so the cycle needs to be repeated.

In contrast to the International Baccalaureate, there is no tradition of coursework or internal assessment in A level Economics. So the assessment has been more stable in recent years than that of most other subjects covered in this report.

So the statistics opportunities in teaching economics at A level can probably be described in three different categories. These are not mutually exclusive; indeed tomorrow's lessons may well include features of all three.

- Carry on as at present but try to ensure that common misunderstandings in the use of statistics are eliminated, as in the following examples.
  - Emphasise the meaning of rate of change, including cases where it is a rate, such as inflation, that is changing.
  - Emphasise the main sources and types of economic data.
  - Give students greater practice in inspecting data to pick out the main trends and features.
  - Emphasise why some data are estimates.
  - Include more data response questions in the assessment.
- Extend current practice to include new areas of study.
  - Include, for example, development economics. This requires data to be collected and processed.
- Break into new territory, as in the following examples.
  - Make use of forecasting models.
  - Using ICT, construct indices from raw data.
  - Use business games.

Statistics may be most effectively understood in the context of real world application. A level Economics provides an opportunity to do this as many topics, such as development economics, focus on content developed by statistical analysis. Experiencing statistics in this way can have the added advantage of helping students to engage with other mathematical processes and so appreciate their importance in Economics.

Anna Gibbs, Economics advisor

Constraints

An essential condition for any of the opportunities to become a reality is that teachers should become familiar with the new ideas involved, whether they amount to a change in emphasis, the introduction of new areas of syllabus content, or the development of completely new skills.

Consequently it is essential that relevant CPD is available for teachers and that the conditions surrounding it, including the cost, ensure that in practice it is accessible. Otherwise there is a real danger of the subject staying the same in schools while the world moves on.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 The Economic and Social Research Council (ESRC) and the Royal Economic Society (2008) *International Benchmarking Review of UK Economics*, page 1

3 *Message to Applicants from Deputy Director GES*; available at www.civilservice.gov.uk/networks/ges

4 ibid. 2, page 28

5 The British Academy (2013) *Stand out and be counted*, quoting Joe Twyman, Director of Political and Social Research, YouGov

6 Source: Joint Council for Qualifications, www.jcq.org.uk

7 Ofqual (2011) *GCE AS and A Level Subject Criteria for Economics*

8 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

Economics Advisors

Professor Colin Bamford	Associate Dean of The Business School, The University of Huddersfield
Joseph Fidler	Economics Qualification Leader, OCR
Anna Gibbs	Westminster School
Moussa Haddad	The Royal Statistical Society
Dr Meena Kotecha	Departments of Management and Statistics, The London School of Economics
Professor Rebecca Taylor	Dean, The Open University Business School

Geography

End-user requirements

Higher education

In higher education geography is a broad subject, spanning the humanities, social and natural sciences. This variability occurs both between and within universities. Students graduate with either a BA or BSc. The total number of students taking geography degrees each year is between 7000 and 8000[1]. The vast majority of geography undergraduates have studied geography post-16, for example through A level, Highers or the International Baccalaureate.

UK research in Human Geography was highly praised in a recent (2013) international benchmarking exercise led by the ESRC[2].

UK human geography ranks first in the world. Findings also showed it as an empirically and conceptually innovative, diverse, vibrant discipline that in many areas sets the intellectual agenda.

The UK publishes more than its share of major disciplinary journals; bibliometric indicators reveal international primacy both in volume and citation impact; and a large number of the seminal publications (books as well as articles) continue to have a UK origin.

UK human geography is radically interdisciplinary and with the spatial turn in the humanities and social sciences has become an exporter of ideas and faculty to other disciplines.

There was confidence that research in human geography had substantial impact on policy and practice and would successfully meet the challenges of the current impact agenda.

At undergraduate level, more attention to statistics and other quantitative methods typically might be included in a BSc degree, although many BA courses also draw on extensive use of quantitative methods. However, on either degree most students take a statistics or quantitative methods course in their first year. Beyond the first year most students tend to specialise within the social or physical sciences; in some cases this may lead to more extensive exposure to statistics, in others less so. After the first year, quantitative methods are taught as stand-alone courses in some degrees but in others they are embedded within other thematic courses.

While there is some discussion about the relative importance of quantitative and qualitative methods in the discipline, there is clear acknowledgement of the importance of a range of statistical techniques. Students on geography courses commonly use and analyse primary and secondary data, including data collected through field and laboratory work. The Quality Assurance Agency for Higher Education (QAA) Geography Benchmarking Statement for undergraduate courses identifies what should be covered.

All geographers should be conversant with a substantial range of analytical and observational strategies, including most or all of the following: social survey and interviewing methods; geographical field research; laboratory-based analysis (both scientific and computational); quantitative analysis; qualitative analysis; and modelling strategies. Students should also be familiar with the developing technology associated with these strategies, such as computer packages for statistical and qualitative analysis, specialist computing and remote sensing.

QAA[3]

Much of the statistical work undertaken by geography undergraduates involves primary data they have collected, often in field courses or for their dissertations; they also work with secondary data, including large sets. Whatever the size of the data set, and its source, the work is virtually always done on a computer, using a suitable software package. The pace of most university courses is considerably faster than students would encounter during A level.

Some statistical work is a requirement in all the A level Geography specifications, and of similar post-16 courses, and so virtually all new entrants to a geography degree course have already encountered some statistical techniques. There is a clear expectation amongst new undergraduates (85% in a recent survey[4]) that quantitative methods will feature in their courses, particularly within their undergraduate dissertation research.

However, some students' confidence in their ability to use statistics may be limited and such students may end up able to enter data into a computer but without much understanding of how to interpret the outputs from the computer or to assess their validity.

Some students arrive at university with little background knowledge of statistics. Typically such students have done no formal mathematics or statistics in the two (or more) years since they took GCSE Mathematics and whatever knowledge they had then has since atrophied. (Currently, about one-fifth of undergraduates have studied mathematics as part of their overall A level course.)

By contrast, those who arrive with more developed skills in statistics (and mathematics) are likely to be in a better position to benefit from their university courses.

Geography brings theory down to earth. And in a world where 80 per cent of information is referenced to locations, it provides spatial awareness.

Dr Rita Gardner[5]

Beneficial skills for new geography undergraduates

- They are confident with data:
  - they are able to present and report on data;
  - they know about different types of variable and scales of measurement;
  - they are comfortable with a variety of data sets, large and small, primary and secondary;
  - they understand about natural variability and experimental error.
- They are able to visualise spatial data.
- They understand the basic principles of statistical inference:
  - they are able to judge which test or procedure is the most appropriate in a particular situation;
  - they are able to interpret the results of a test;
  - they appreciate that modelling assumptions are involved.

Employment

While there are few well-defined career pathways for geography graduates, it is nonetheless the case that they find they have among the lowest levels of graduate unemployment of all subject disciplines[6]. They are recognised to have skills that are well regarded in the workplace.

The nature of geography, partly a science and partly about people, means that its graduates have a wider range of skills than those of most other subjects. At A level, geography is a broadening subject for many students, either a part science among humanities or a part humanity among sciences. Consequently geography acts as a bridge to a wider range of ways of thinking at a formative stage in students' intellectual development.

Many workplace decisions, for example those taken in a planning department, are about how society interacts with different environments (be they natural, managed or built), and the different perspectives relevant to such decisions. Decision making in these contexts needs to be rigorously based on as much evidence as possible, drawing on both information from the social and physical sciences. The evidence is often statistical, but it is common for decision makers to have only a limited appreciation and understanding of the relevance of statistics.

Most geography graduates arrive in employment with many of the skills to address such situations, as described in the following paragraph from a report on a survey conducted by Esri UK in 2010[7].

The survey of 200 business leaders across the public and private sectors showed that the skills they are looking for in future employees are critical thinking (nominated by 78 per cent of businesses' leaders as key for graduates), advanced analytical skills (76 per cent), understanding and interpreting complex data (71 per cent), advanced technology skills (57 per cent) and understanding socio-economic environments (54 per cent) – all of which can be gained through a geography degree.

Thus over 70% of the respondents said they were looking for *understanding and interpreting complex data*. Elsewhere in this report this is described by the term *statistical intelligence*.

The list below takes this idea further, identifying relevant skills for those entering employment; many of the skills are generic but some, particularly those relating to spatial data, are specific to geography graduates.

These are not skills that can be acquired overnight. Rather they will be built up over many years, ideally starting in the years of A level study.

Important skills for new geography graduates entering employment

- They are confident in using data, for example:
  - they can understand a variety of forms of data, including spatial data;
  - they can interpret data trends;
  - they can explain concepts linking workplace decisions to statistics, for example the significance of a test result.
- They can interpret and communicate statistical information, for example:
  - they can interpret and explain the results of investigations;
  - they can write reports that draw on statistical information;
  - they understand and can critically appraise the quantitative information in a research paper.

Once in the workplace, graduates may also be faced with and expected to collect and understand more general business and economic data, such as gathering and analysing market research data.

It is the geographical analysis and presentation of spatial and other data that underpins the use of Geographical Information Systems. Many statistics packages that analyse consumer classification, such as Mosaic UK[8], draw on demographic and spatial data.

Steve Brace, Geography advisor

A level Geography: The current situation

Geography is a popular A level. In 2012 it was taken by 32,005 students[9]. Almost all of those opting for A level Geography have previously taken the subject at GCSE, and so know to expect some mathematics and statistics.

A level specifications are bound by the Subject Criteria for Geography but these do not include any explicit requirement for statistics or mathematics. However, the criteria for geography include the following requirements, all of which provide opportunities for the use of quantitative methods, including statistics.

Extracts from the Subject Criteria for Geography[10]

AS and A level specifications in Geography should require learners to: …

- become adept in the use and application of skills and new technologies through their geographical studies both in and outside the classroom
- use a range of skills and techniques, including the use of maps and images at different scales necessary for geographical study
- carry out research, and out-of-classroom work including fieldwork, as appropriate to the topics selected
- use modern information technologies, including geographical information systems, as appropriate to the content
- analyse and synthesise geographical information in a variety of forms and from a range of sources

The criteria for those subjects defined by Ofqual as sciences include lists of mathematics and statistics topics that are specifically required. There are those, including the Royal Geographical Society (with IBG), who would welcome an explicit identification of the quantitative and other geographical skills that should be a required element of all A level geography courses.

In the absence of any formal requirements, there is considerable variation in the statistical demands of the specifications from the different awarding bodies, and also how these demands are expressed in the assessment of the different geography A levels. Consequently, students can have different experiences and arrive at university with quite different skills according to which geography A level they have been taught. Furthermore, some new undergraduates have come through other routes, such as Highers and the International Baccalaureate, and they too have different statistics requirements.

The value of fieldwork for A level students is widely acknowledged. Until 2008, candidates were required to submit coursework, often based on fieldwork they had carried out. However, this is no longer the case and, as a direct result, some students are less well prepared for university courses in terms of their fieldwork, data collection and analysis skills and writing up a piece of individual research at length. Those teaching Geography in higher education have noted these trends and Ofqual's research into standards in A level Geography in 2001 and 2010 included the following statement.

Reviewers judged A2 to be less demanding because of the removal of the coursework element. Coursework – typically a 4,000-word investigation – was an effective way to assess skills by, for example undertaking and reporting on investigative fieldwork. While awarding organisations now assess skills in a variety of ways within the four-unit, external examination structure, reviewers found that they were not as effective at assessing skills as coursework.

Ofqual[11]

In this review Ofqual made the following recommendation.

… we recommend that consideration is given to the following: …

whether assessing geographical skills through external examinations is sufficient for future A level geography specifications or whether coursework should be reintroduced.

Ofqual[12]

Some schools and colleges continue to organise fieldwork for their geography students, seeing it as of the essence of the subject, although the range, duration and focus of the fieldwork varies from one institution to another. The Royal Geographical Society (with IBG) has argued strongly for the return of coursework at A level to ensure that all students experience fieldwork[13] .

Fieldwork generates data which then have to be processed. So how much fieldwork is undertaken has an influence on students' experience of statistics at this level, and consequently how well they are prepared for proceeding to a geography degree.

Geographers develop their geographical understanding through fieldwork and other forms of experiential learning, which helps to promote curiosity about the social and physical environments, discerning observation and an understanding of scale.

QAA[14]

A recent survey by the Royal Geographical Society (with IBG) showed general acceptance among teachers of the role of quantitative methods in A level Geography.

Some findings from a survey of A level geography teachers[15]

- Over 90% of teachers agreed or strongly agreed that quantitative methods were an important skill to learn, although less than half the teachers agreed it was something they enjoyed teaching.
- The majority of teachers thought the quantitative methods content coverage in the Year 12 and 13 curriculum and unseen examinations was about right.
- 80% of teachers taught mathematical statistics in their geography classes.
- Over 80% of the teachers agreed that putting quantitative methods in a geographical context helps students understand them better.

New teachers entering the profession, who may have studied for a geography degree containing relatively little statistics, may find a mismatch between their skills, confidence and understanding of statistics and the A level requirements. Unless they have access to suitable professional guidance, they may find it more difficult to teach those parts of the A level syllabus.

A good number of recently qualified teachers delivering the statistical components of the current A level specifications lack the confidence to deliver these skills to their classes, as shown by the popularity of CPD courses, run by various organisations, including the exam boards. This was evident to me when I was involved with the delivery of one of these courses.

Amanda Dawson, Geography advisor

Opportunities within A level Geography

It is clear from both higher education and employers that the more experience A level students have in working with data, the better they will be prepared for their futures.

Gaining such experience is likely to be most effective when students have to use data to address problems that are so interesting that they really want to know the answers. This is often the experience of students carrying out geography fieldwork where they have the opportunity to become immersed in problems, and form and test hypotheses. Typically such work requires data to be collected, analysed and interpreted within a cycle of activity, such as the Statistics Cycle[16].

Those consulted felt that the assessment system could do more to ensure that students do undertake some fieldwork, seeing this as integral to the discipline of geography and its relationship to statistics. The reintroduction of coursework would provide an opportunity for students' fieldwork, and its associated quantitative and statistical methods, to contribute to their final grades at A level.

While coursework was in place, most students were provided with an experience which led them naturally through the Statistics Cycle. This would often end with a formal null hypothesis significance test, and so the rationale for it made sense to them. However, without such hands-on work it is all too easy for the statistical techniques to become no more than mathematical exercises, disconnected from the rest of students' learning of geography. So a prerequisite for improved teaching opportunities is to fill the vacuum created by the absence of coursework.

This applies particularly to the early stages of the Statistics Cycle. Students need the opportunity to think through a problem, to decide what data are required and how to obtain them, and then to do the actual data collection. All this activity is intimately linked to their building up an understanding of the geographical ideas involved, and indeed to the very nature of the subject.

The following example illustrates the sort of work that might be involved.

> **Analysing the bid-rent gradient in cities**
>
> The economic geography theory of bid-rents states that land values decrease with increasing distance from a city centre. This can be tested by analysing how house prices change with distance from the city centre (house price will capture the value of the land the house occupies). By selecting a sample of properties along a transect from the city centre outwards, it is possible to quantify the effect of distance on price, provided that the sampled properties are very similar in size and style and are located in comparable areas (e.g. three bedroom semis in leafy neighbourhoods).
>
> The null hypothesis of no association between price and distance is tested against the alternative hypothesis of a decrease in price with distance using Spearman's rank correlation coefficient.
>
> This investigation is likely to show up some cases where the theory does not hold and these raise important geographical issues relating to how cities work.

The considerable variation between the statistical demands of the different A level specifications was identified by those consulted as a weakness in the present provision. It has been suggested that additional support focusing on mathematics and statistics in geography, such as through resources and CPD training, would be a useful addition for geography teachers.

Levelling up would involve all specifications requiring some experimental design together with data collection and sampling techniques. Three hypothesis tests are commonly required: Spearman's rank correlation test, the χ^2 test and the Mann–Whitney *U*-test. However, a danger to be guarded against is that the situations that students are given to investigate are determined by the tests in the syllabus rather than by the natural development of the subject.

Teachers can encourage their students to consider how these particular tests allow examples involving difference and correlation to be covered. The tests that a student actually uses are, to a large extent, dictated by the type of data available; it is important for students to know how these concepts are transferable to different context and settings.

These tests tend to focus on the collection of firsthand data through fieldwork. This is to be encouraged, as it gives students direct and firsthand experience of geographical fieldwork and the resulting analysis. However, if this is the only situation where students encounter statistical techniques they are missing out on the opportunity to address analysis of big data sets as well; these are a particular feature of many undergraduate geography courses.

In recent years, it has been recognised that Geographic Information Systems (GIS) can often do much to provide students with insight into the subject, and so GIS has been incorporated into A level and GCSE syllabuses. The use of data within GIS provides significant opportunities to engage students with quantitative methods and statistical approaches in relation to how different data sets are used, presented and analysed within a spatial context. Whilst there are many outstanding examples of the use of GIS within schools, its use at the appropriate level is not widespread across the school cohort, as noted by Ofsted in 2011.

Geography also offered opportunities to develop a wide range of skills and knowledge. This was particularly the case with information and communication technology (ICT) and where the enormous potential of geographical information systems (GIS) was used to give students insights into areas such as cartography, statistical analysis and natural resource management. In strong secondary school geography departments many students were inspired by challenging and engaging questions; with diverse sources and data; and with more in-depth and detailed descriptions and explanations of contemporary changes. … However, more limited use was made of … geographical information systems to engage pupils in learning in geography.

Ofsted[17]

Geographical Information Systems present many opportunities for use of the real-world application of geography in the classroom. One example is the increased emphasis on quantifying risk in the workplace across a wide range of contexts such as planning, insurance, environmental management, infrastructural development and business and commercial planning.

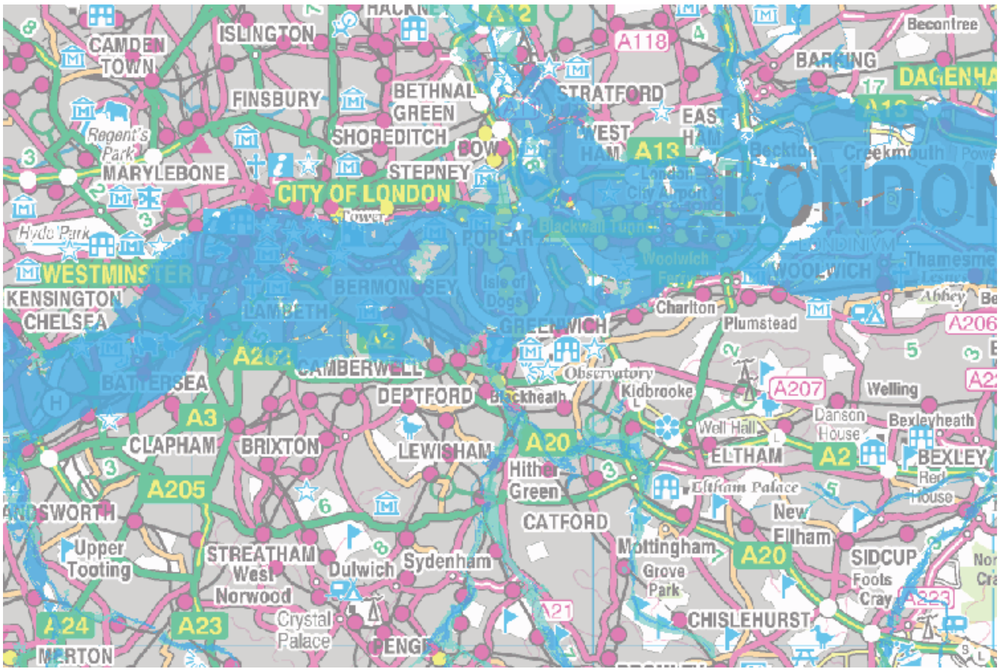
Business leaders across the UK are telling us that they need more employees who can help them maximise key technologies such as GIS but who also understand their business needs in these tough economic times.

Richard Waite[18]

The Geographical Information System in the example on the next page is a flood map for London but such maps are available from the Environment Agency's website[19] by post-code or location. Each map is a representation of an extremely large data set.

Flood maps

One example is how the likelihood of flooding is expressed; this is illustrated by the flood map below, provided by the Environment Agency. Such maps identify the likelihood of flooding as a 1:100 or 1:200 year flood event i.e. a 1% or greater, or a 0.05% or greater chance of happening each year.



Map legend

Click on the map to see what is the Risk of Flooding at a particular location.

Flood Maps

- Flooding from rivers or sea without defences
- Extent of extreme flood
- Flood defences (Not all may be shown*)
- Areas benefiting from flood defences (Not all may be shown*)
- Main rivers

This synthesis, and online visualisation, of geographical and statistical information reveals both the likelihood and the extent of a potential flood. It draws and combines hydrological and rainfall data, mapped against topographic, land use and other spatial data. In this way students are able to better understand flood risk in their local areas, or elsewhere in England, and are able to investigate how different locations respond to the potential risk.

It is not only in the classroom where this combined analysis brings greater precision and understanding to a geographical process and its impact on people and the environment. It is also at the heart of the insurance industry's response to flood risk, helping to determine the cost of premiums or indeed whether certain areas are uninsurable.

Constraints

Major constraints on the further development of statistical approaches in A level Geography fall into two categories: those that are consequences of the current Subject Criteria and those relating to teachers' professional development.

The lack of any specific statistical requirement in the Subject Criteria is exacerbated by the absence of coursework in the assessment. These constraints could be overcome at the stroke of a pen.

Fieldwork is important in itself but the preparation for it and the work that follows from it have a deep effect on the way that the subject is taught. Following a cycle of activity, in which appropriate use of statistics is embedded, occurs naturally in those classes where fieldwork is carried out. By contrast, where fieldwork has been reduced, it is hard to avoid the statistics being something of an add-on to the rest of the syllabus.

In some schools and colleges, the recommendations in this report would result in little, if any, need for change in pedagogy, but in others teachers would need to reconsider their approach quite fundamentally.

Teachers need to understand the opportunities raised by using and interrogating different data sets, such as those relating to census, crime, environmental and developmental information. As well as the direct use of these data sets many of them can also be integrated into Geographic Information Systems. Different data can be presented, compared and visualised in a spatial context through these. While many teachers are very proficient in teaching about and using such materials others will require professional development to derive the maximum benefit from them in the classroom and the field.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 The Economic and Social Research Council (ESRC), the Royal Geographical Society (with IBG) and Arts and Humanities Research Council (2013) *International Benchmarking Review of UK Human Geography*, Press release

3 The Quality Assurance Agency for Higher Education (QAA), (2007) *Subject benchmark statement: Geography*, paragraph 3.12

4 Research undertaken by the Royal Geographical Society (with IBG)

5 *Introduction to the National Curriculum for Geography*, Dr Rita Gardner, Director, The Royal Geographical Society

6 Source: HESA survey of university graduates, www.hesa.ac.uk

7 Esri UK press release (17/11/2010) Research conducted amongst 200 business leaders by Vanson Bourne in 2010

8 Mosaic UK is a classification based on demographic data set. For more information see: www.experian.co.uk/business-strategies/mosaic-uk.html

9 Source: Joint Council for Qualifications (JCQ), www.jcq.org.uk

10 Ofqual (2011) *GCE AS and A Level Subject Criteria for Geography*

11 Ofqual (2012) *Review of Standards in GCE A Level Geography 2001 and 2010*, page 3

12 ibid., page 20

13 Response from the Royal Geographical Society (with IBG) to the Ofqual consultation on A level reform, available at: www.rgs.org/NR/rdonlyres/8F86D3F6-49C7-4041-BC10-851723875B20/0/OfqualConsultationonAlevelreformRGSIBGresponse.pdf

14 The Quality Assurance Agency for Higher Education (QAA), (2007) *Subject benchmark statement: Geography*, paragraph 2.2

15 Source: Royal Geographical Society (with IBG) survey of Geography teachers

16 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

17 Ofsted (2011) *Geography: Learning to Make a World of Difference*, pages 5 and 6

18 Private communication: Richard Waite, Managing Director, ESRI UK

19 www.environment-agency.gov.uk/homeandleisure/37837.aspx

Geography advisors

Steve Brace	Head of Education and Outdoor Learning, The Royal Geographical Society (with IBG)
Amanda Dawson	Stowe School
Dr Scott Orford	Senior Lecturer in GIS and Spatial Analysis, Cardiff University; Wales Institute of Social and Economic Research, Data and Methods (WISERD)
Rob Sharpe	Training and Education Services Manager, Esri UK
Dr Catharine Souch	Head of Research and Higher Education, The Royal Geographical Society (with IBG)
Dr Nicholas Tate	Department of Geography, University of Leicester
Jon Wolton	Geography Subject Advisor, Pearson Edexcel

History

End-user requirements

Higher education

History evolved as a university subject in the second half of the 19th century, placing it among the longest established disciplines. The Royal Historical Society was founded in 1868 and the Historical Association in 1906.

The subject is not readily accessible to formal international comparisons. Consequently no benchmarking exercise, for example by the ESRC, has been carried out on history research in UK universities.

Approaching 15,000 students a year take degrees in history or closely related subjects in the UK[1]. The traditions established in UK universities command international respect. Evidence for this is provided in the recent QS subject rankings[2], where Oxford and Cambridge Universities come top of the table and nine other UK institutions are ranked in the top 50.

Subject benchmarking for undergraduate history was introduced by the Quality Assurance Agency for Higher Education in 2000 and revised in 2007. Most UK degree courses conform to these standards. Below is an extract from them.

Some programmes, for example economic and social history, incorporate the methodologies of other humanities and social science disciplines. A number of specific skills are thus essential to particular types of programme, and desirable though not obligatory in others. Departments or institutions are strongly recommended to make provision, where appropriate, for the development of at least one of these: visual and material culture; languages; the use of information and communication technology (ICT) in learning or analysis; numeracy and quantitative methods; archaeological fieldwork; archival study; or skills associated with the study of other disciplines with which history has close links. Fieldwork and field trips may play an integral role within a history course or programme.

QAA[3]

Substantial amounts of quantitative work are present in economic and social history.

Economic history is the study of economic phenomena in the past and readily links in with social history and fields such as demography and the history of health. Economic historians tend to compile large sets of information that are usually abstracted from primary sources that allow a numerical coding or offer up figures outright. Statistical methods are then applied, usually cautiously to allow for the fuzziness of the data used. Examples of sub-fields are business history and the history of finance. At the very end of the spectrum lie cliometrics, which exclusively focuses on quantitative methods in its approach to the past.

None of the above dominate 'History' but the findings from economic and social history approaches often provide a platform from which the more cultural approaches can then take off, such as the context of depression in which political parties either gained or lost power in the 1930s. Since they provide the foundation for the context to 'events', which are most often studied, history students at A level would certainly benefit from an understanding of some of the more basic techniques (though not necessarily the ability to apply such techniques) that lie behind these syntheses, to be able to make sense of what they read.

Dr Karin Dannehl, History advisor

Over recent years, many historical documents have become available in digitised form and this process will doubtless continue; some of these are sources of data. This work is being carried out in programmes at national and local archives; as well as through major funded programmes, some of it is being carried out by local history and genealogical societies. Consequently large data sets are now available to historians in electronic form, with all the opportunities for new insights that come with such information.

Data sets from National Archives

The National Archives has an increasing number of data sets available, generated from digitisation and cataloguing projects with specific record series. Details of the datasets can be accessed through The National Archives Labs page – the development area for The National Archives online services[4].

Web developers are encouraged to experiment with new applications, online tools and ways of visualising data.

Datasets available online include the following[5].

- **Government Films** – A list of over 4800 government films accessioned by The National Archives and held as public records in the BFI's National Film Archive including wartime and documentary classics such as *Night Mail* and *Listen to Britain* and Colonial films such as *Amenu's Child* and *Morning on Mount Kenya*.
- **Papal Bulls (SC7)** – Official correspondence from the Pope (some with attached metal 'bullae') between the 1130s and the break with Rome 400 years later.
- **Poor Law Union and Workhouse Records** – Extremely detailed, name rich record descriptions of a wide range of correspondence between central government and selected regional Victorian Poor Law Unions across England and Wales.
- **Medieval Petitions 1189–1577** – Petitions to the Crown and other state officials from across the medieval period, listing the petitioners and the nature of their request as well as related place names, addresses and other data.

There are, however, uncertainties surrounding historical data. The conditions under which the data were collected are unlikely to be known, and so their accuracy and reliability cannot be guaranteed; there are often gaps in the data. When data have been collected over a long period, the relevant definitions may well have changed causing discontinuities in any patterns. It is, of course, not possible to go back in time and question those involved in collecting or giving the data, or to carry out experiments to replicate the data.

Consequently considerable interpretation is needed when analysing historical data and in some cases large margins of error may be appropriate. So working with historical data is often less easy than might be expected at first sight, and the conclusions that can be drawn may be more tentative. The availability of data reinforces the need for other historical skills particularly questioning.

A particular problem in UK history departments is that many of the students are reluctant to engage with mathematics or statistics. Consequently some branches of history, for example economic and demographic history, are effectively closed to them. By contrast those undergraduates who are confident in working with data are potentially able to access any of the options available in their degree courses.

Desirable skills for new history undergraduates

- They are confident using data as a source of evidence:
  - they are able to present and report on data relating to people and events;
  - they are able to present their evidence orally, visually and in writing;
  - they are able to comment on the strength of their evidence.
- They are familiar with different types of data and ways of displaying them.
- They are willing to question other people's work.

Employment

Apart from teaching and lecturing, there are few career opportunities for history graduates that are based on their subject knowledge. However, the broader skills they have traditionally developed are widely recognised by employers. Particularly important among these are being able to write well, to extract evidence from sources and in so doing to evaluate them critically. The main careers for history graduates are described under the following headings on the Historical Association's website[6].

- Museums and galleries
- Heritage sites and historic houses
- Heritage organisations and charities
- Record offices and archives
- Libraries
- Universities
- Archaeology
- Horticulture and nature conservation
- The media
- Architecture
- The conservation of buildings and artefacts
- National and local government
- The civil service and the diplomatic service
- The armed forces and the police

However, the workplace is changing with more emphasis on being able to interpret data and so it is predictable that in the future those history graduates who can be described as statistically literate will be more employable.

Acquiring the appropriate skills typically involves experience of working with data over a period of years. On the previous page a list of desirable skills for new undergraduates has been identified. Those entering employment would benefit from having built on this foundation while at university so that they are able to apply similar skills in much more sophisticated contexts.

Valuable skills for new history graduates entering employment

- They know how to extract information from data and to present it as evidence.
- They can read, understand and evaluate a variety of types of documents that contain data, for example media stories, government reports and research papers.
- They can assess the quality of data from any source.
- They can detect when false conclusions are being drawn from data.

A level History: The current situation

The number of students taking A level History in 2012 was 51,652, split almost equally between males and females[7].

A level History syllabuses (but not the Scottish Higher) are bound by the Subject Criteria for History. No mathematics or statistics is specified. The criteria do, however, refer to evidence, sources and information in the extracts below; these can be based on data but the wording of the criteria is designed to ensure that this is not a requirement.

Extracts from the Subject Criteria for History[8]

Knowledge, skills and understanding

7. A2 learners will build on their learning at AS by drawing on and evaluating a greater depth and range of increasingly more sophisticated content and evidence, demonstrating a more complex understanding of historical concepts, producing responses that are more analytical and judgements that are more effectively substantiated.

Historical enquiry

10. A level specifications should require learners to:

- investigate specific historical questions, problems or issues;
- use historical sources critically in their context, deploying appropriate information and reaching substantiated conclusions.

The current examination papers for A level History do not include questions that are based on data.

The assessment involves coursework in which students undertake an investigation and report on it; the work could be motivated by data but in practice this rarely happens.

Opportunities within A level History

Since 2008, A level History syllabuses have had requirement for compulsory coursework; before that it had been optional. This provides an opportunity for investigational work using a format similar to the Statistics Cycle[9], as in the example below.

> **Development in Russia**
>
> An example of this approach involved evaluation of the impact of industrial development on Russia's economy and society in the 19th and 20th centuries. It was based upon an analysis of published economic data such as output and population statistics.
>
> This approach not only required engagement with statistical evidence and related concepts, but also allowed the student to explore the complexity and provisional nature of statistical evidence and its place within the historiography of the period.

Work like this presents an opportunity for using statistics to improve students' understanding of particular issues within history.

Although many data sources are available in digitised form online, they are often not immediately suitable for use by A level students. Reasons for this include the time required to understand the context in which they were collected and the caveats that accompany the data. Consequently, several lessons' teaching would be required before anything useful could be done.

Students typically find it hard to draw meaningful conclusions from large sources of data without careful guidance; they are less familiar with the kind of questions which should be addressed than they are with textual sources.

Katherine Brice, History advisor

One way round these problems is to have dedicated teaching and learning materials to accompany particular digital archives. This approach has been taken in a project involving The National Archives, University of Sussex and local teachers.

The National Archives and University of Sussex Teacher Scholar Project

The Dawn of Affluence was a teacher education programme run as part of the ESRC funded project The Living Standards of Working Households in Britain, 1904–1960. This developed data sets based on government Household Expenditure Surveys conducted in 1904, 1937–8 and 1953–4. The data sets provide academic historians with an insight into Edwardian, inter-war and post-war living standards[10].

In order to support dissemination and impact The National Archives Education Service developed a CPD programme for eight teachers based on its proven teacher–scholar methodology. In this teachers become experts on a particular topic through academic input, archival research, experiential field study and pedagogic training. They then develop classroom resources for publication on The National Archives education website to be shared with other teachers.

The programme ran for 14 weeks and involved online and on-ground delivery including a seminar weekend at The National Archives where teachers were introduced to the data sets and began to develop enquiry questions for investigation. There was also a field study weekend to Liverpool and the Black Country to set the archival material and data sets in the context of real living conditions from the 1930s and 1950s.

The teachers then each produced a set of lesson plans with resources and pedagogic rationale and wrote a Master's level essay for the question *Explain how your work with the data set(s) illuminates the debate about living standards in Britain from c1900 to c1955*[11].

The resources have been further demonstrated and promoted to teachers through workshops at the Historical Association Conference and Schools History Project Conference.

To allow such work to achieve its potential, it is important that students are introduced to the concept of working with data as early as possible in their school careers and certainly before they complete Key Stage 3 at the age of 14. The National Archives have made a number of investigations available which enable students to become familiar with historical data in a manageable form. An example of this aimed at Key stages 2 and 3 is *What happened at the Trimdon Grange Mining Disaster?*[12]

The use of statistical evidence can be a very effective device for encouraging GCSE or A level students to think independently and develop inferential skills. For example, analysis of regional electoral statistics or party membership lists in Weimar Germany can give students the opportunity to formulate their own views on the growth of Nazism and a relatively accessible portal to engagement in informed historical debate.

Michael Charman, History advisor

Students also need to be taught how statistics can be used to manipulate the truth, for example by selective use of percentages. They should be given the tools to assess the reliability of statistics in the same way as they are taught how to identify bias and distortion in the written or spoken word.

Katherine Brice, History advisor

A different teaching opportunity arises from the possibility of displaying large amounts of information graphically as is done with Geographical Information Systems. Some displays have already been developed for history; an example is the historical mapping of London[13]. Such displays have the potential to allow students to understand and interact with issues in ways that were previously not possible.

Constraints

A major constraint to the greater use of data in history is the fear of mathematics, and so statistics, felt by many students. Consequently, certain aspects of the subject, for example social and economic history, can be the source of some trepidation.

This problem clearly also extends to some teachers who would lack confidence in their ability to teach quantitative aspects of history well. It is essential that relevant CPD is available for teachers and that the conditions surrounding it, including the cost, ensure that in practice it is accessible to them.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 Source: QS Quacquarelli Symonds Limited, www.topuniversities.com

3 The Quality Assurance Agency for Higher Education (QAA), (2007) *Subject benchmark statement: History*, paragraph 3.2

4 http://labs.nationalarchives.gov.uk/wordpress/

5 The data The National Archives have made available through Labs is licensed under the Open Government Licence. For more information see: data.nationalarchives.gov.uk/records/

6 www.history.org.uk/resources/public_resource_2914_76.html

7 Source: Joint Council for Qualifications, www.jcq.org.uk

8 Ofqual (2011) *GCE AS and A Level Subject Criteria for History*

9 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

10 For more information see: www.sussex.ac.uk/britishlivingstandards/

11 The essays and resources were then assessed by an editorial board and following subsequent revision will be published on The National Archives website at www.nationalarchives.gov.uk/education/cpd/sussex.htm

12 Available at: http://nationalarchives.gov.uk/education/lessons/lesson21.htm

13 www.locatinglondon.org/

History advisors

Katherine Brice	Head of History, City of London School for Girls
Professor Arthur Burns	Professor of Modern British History, King's College London and Vice-President (Education Policy), Royal Historical Society
Michael Charman	Qualifications Manager, AQA
Dr Karin Dannehl	Research Fellow in History, University of Wolverhampton, Chair of the Schools and Colleges Committee of the Economic History Society
Andrew Payne	Head of Education and Outreach, The National Archives
Alf Wilkinson	CPD Manager, The Historical Association

End-user requirements

Higher education

Physics is taken as a degree subject by about 4000[1] undergraduates per year in UK universities. Almost all of these have taken physics and mathematics at A level, or similar qualifications such as Highers. A minimum content for physics degrees is recommended by the Institute of Physics and contained in the standards laid down by the Quality Assurance Agency[2].

In 2008 the Wakeham Review[3] reported on the state of physics in the UK. The extract below is taken from the report's Executive Summary.

Educationally, the discipline faces enormous challenges. The numbers of students taking the subject at school level have fallen over many years, with A-level numbers a particular cause for concern. The number of physics departments has also declined over the last 10 years meaning that the discipline is primarily concentrated in the older traditional research-based universities. The low percentages of female and ethnic minority students are a worry.

The Panel concludes that physics research in the UK is in a generally good state of health, with departments performing curiosity-driven research of the highest international quality …

Many of those who take A level Physics go on to read engineering at university. Approximate numbers taking the most popular are given below[4]. Not all of these students have taken either A level or Higher Physics.

Type of Engineering	Undergraduates (nearest 1000)
Aeronautical	2000
Chemical	2000
Civil	5000
Electronic and Electrical	7000
General	3000
Mechanical	7000

Much of the research currently being carried out in physics involves collecting and analysing very large quantities of data.

Research into generating electrical power from nuclear fusion requires the recording of large amounts of data. Several hundred sensors are digitised at rates from MHz to GHz for a few seconds at a time, yielding about a terabyte of data several times per hour, and this is rising all the time. Statistics plays a part in analysing and displaying these data.

Andrew Darke, Physics advisor

In degree courses, Statistical Physics is a core discipline and statistics features strongly elsewhere, for example in astronomy and particle physics. However, it is rarely, if ever, taught as a stand-alone subject but is embedded within the physics.

Physicists are as competent as anyone at handling data, but in many cases wouldn't recognise this activity as having anything to do with statistics.

Dr Paul Yates, Physics advisor

Scientific method is central to physics and so knowing how deal with the uncertainty of experimental data is an essential requirement. Many students learn some statistics in this context, typically within an experimental methods course. All of those who take a four-year degree and most of those who take a three-year BSc undertake an extended project in their final year and this usually requires them to learn some statistics.

In higher education subject demarcations can be misleading with respect to physics and this is illustrated in the following extract from the Wakeham Review[5].

Physicists can be found working in areas of fundamental research pushing forward the heartland of the discipline, but also in other areas applying their skills and expertise in interdisciplinary teams across science, engineering and medicine. Often this work is performed outside the environment of a physics department and it is very important to appreciate that the pursuit of curiosity-driven, fundamental research in physics is not confined to physics departments.

The list below gives new and developing areas of physics which advisors identified; many of these are interdisciplinary.

Biological physics	Renewable energy
Medical physics	Astrobiology
Nanotechnology	Photonics
Quantum information	Econophysics
Complex systems	

Many of these areas are data rich and all require the application of statistics. While some of them will probably always remain the preserve of higher education, others, such as nanotechnology and photonics, may well become relevant at A level.

University physics is highly mathematical and so competence in mathematics is essential for new undergraduates. It is also advantageous for them to be confident in using data, particularly those arising out of their experimental work.

Quantifying the accuracy of experimental results and the certainty with which data may be said to confirm or refute a theory is central to physics. Early exposure to these ideas is vital to the development of a student's appreciation of the complementary roles of experiment and theory.

Dr Paul Kyberd, Physics advisor

Beneficial statistics skills for new physics undergraduates

- They are confident with data:
  - they understand the value of observation;
  - they are able to describe, present and report on data;
  - they know about different types of variable and measurement;
  - they are aware of the uncertainty attached to experimental results and its possible causes;
  - they can estimate the accuracy of experimental results.
- They understand the basic principles of scientific investigation:
  - they are able to engage with quantitative procedures;
  - they are able to judge which procedure is the most important in a particular situation;
  - they are able to interpret the results;
  - they understand the importance of patterns in data;
  - they can judge when modelling assumptions are involved.
- They are able to process information:
  - they are able to translate information from one form to another: tabular, graphical and narrative;
  - they are able to visualise data.

Physics is the most mathematical of the sciences and it plays an underpinning role to much of engineering and the other sciences. Quantitative measurement is right at the heart of the subject so it is absolutely essential that students understand experimental uncertainty. Similarly, highly sophisticated data processing, often from huge data sets, is central to many research applications, particularly those involving international facilities.

Professor Peter Main, Physics advisor

Employment

Along with mathematics, physics underpins many other disciplines. Consequently physics graduates can be found in many walks of life doing things that appear to be unrelated to their university degrees but in fact are enabled by the way of thinking in which they have been trained. Even those who are doing technical work are often using knowledge that they acquired after leaving university.

You will find physicists working across a huge range of areas, bringing technical expertise and analytic problem solving to subjects as diverse as pharmacy and nuclear engineering; physics is less defined by its content than by a way of thinking, which has broad application way beyond the usual confines of the subject.

Professor Peter Main, Physics advisor

Undoubtedly many physics graduates use statistics frequently in a variety of contexts. It is part of the training which provides a background to so many careers.

Statistics is an important transferrable skill. It enables physicists to be aware how the uncertainties in observations impact on a line of theoretical reasoning, even where those uncertainties may not allow as precise a quantification as is often possible in physics.

Dr Paul Kyberd, Physics advisor

Many of those who are working as engineers find themselves using statistics in ways that they probably did not learn about at university, such as:

- Risk assessment
- Quality control
- Reliability
- Reproducibility
- Material characterisation

Statistics is an important area for engineering as it impacts on design, characterisation and validation processes which are key activities in engineering. The Royal Academy of Engineering sees statistics as such an important topic as to arrange a joint project and meeting to raise the profile of statistics in undergraduate degree courses.

Professor Bernard Weiss, Physics advisor

Overall, the demands of employment mean that many new physics and engineering graduates are likely to require some statistical skills.

Important skills for new physics and engineering graduates entering employment

- They are competent and confident in using statistics together with relevant mathematics:
  - they have an appreciation of experimental error and uncertainty;
  - they are confident with dimensional analysis, rough estimates and order-of-magnitude calculations;
  - they can build and refine models that are expressed in mathematical and statistical terms;
  - they can explain concepts linking physics and engineering data to colleagues and can relate them to the needs of their organisation;
  - they understand and can critically appraise quantitative information, for example in a research paper, a government report or a pilot study.

Problems in the workplace are not optional and are not marked for a personal examination grade. It is common that colleagues cannot give you a ready answer; it is your responsibility to find one.

Dr Chris Robbins, Physics advisor

A level Physics: The current situation

Following a period of decline, culminating in a low of 27,368 in 2006, the number of students taking A level Physics has risen steadily for the last six years reaching 34,509 in 2012. There is a strong gender bias in the uptake of physics at this level; only 21.3% of the 2012 entry were female.[6]

A level Physics syllabuses (but not the Scottish Higher) are bound by the relevant part of the Subject Criteria for Science and these specify the following minimum demands for mathematics and statistics content. The few statements that are relevant to statistics are given on the next page.

Statistics required by the A level Subject Criteria for Physics[7]

In order to be able to develop their skills, knowledge and understanding in physics, learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject.

...

Handling data

Use an appropriate number of significant figures.

Find arithmetic means.

Make order of magnitude calculations.

…

Graphs

…

Plot two variables from experimental or other data.

…

In addition, one of the statements in the overarching requirement *How science works* is:

Analyse and interpret data to provide evidence recognising correlations and causal relationships.

The following items are included in the overall list for Handling data in the science criteria but are not required for physics.

Topics in the Science criteria but not those for Physics[8]

Construct and interpret frequency tables and diagrams, bar charts and histograms.

Understand simple probability.

Understand the principles of sampling as applied to scientific data.

Understand the terms mean, median and mode.

Use a scatter diagram to identify a correlation between two variables.

Use a simple statistical test.

The current A level Physics specifications contain statements about collecting and recording experimental results, and estimating their error or uncertainty.

The position of mathematics within other A levels, including Physics, changed when syllabuses were revised for Curriculum 2000. A new regulation came into force that required subjects to be freestanding; there could be no assumption that students were taking any other subjects, for example mathematics. That made it almost impossible to include calculus in A level Physics, or more than the most elementary statistics.

Recently (in 2012) there has been criticism that the expected mathematical content is not well covered in A level examinations.

… a large number of the mathematical requirements listed in the … physics specifications are assessed in a limited way or not at all … The mathematical requirements that are assessed are covered repeatedly and often at a lower level of difficulty than that required for progression into higher education and employment.

SCORE[9]

The assessment for A level Physics includes practical work and this is usually where any statistics is assessed. It fell outside the scope of the SCORE research which looked only at the examination papers.

Opportunities within A level Physics

Although statistics is used quite extensively in physics degrees, and even more so in research, most A level students encounter very little of it within physics. Increasing their experience of working with data, and thereby ensuring they are better prepared for their futures, is clearly a major opportunity. Such work will often be associated with the Statistics Cycle[10].

Physics students already use an investigative cycle as part of their practical work (assessed or not), so no fundamental change is required in this respect, more a change of emphasis to ensure that more of the work is quantitative and the data are more often central to the tasks. A suitable task is shown in the example on the next page.

More such work would encourage greater attention being given to the statistics involved in collecting, processing and interpreting experimental data. As well as enriching the physics they are learning at the time, such work would provide students with a better background for higher education and subsequent employment. The skills involved should become second nature to students so that engaging with data comes naturally to them.

In many areas of physics research large data sets are commonplace. Obtaining the required information from them involves the use of statistical techniques; detecting elementary particles is often done statistically, working with both large and small data sets. Working with the raw data is not easy and experience has shown that they need to be cleaned if they are to be used successfully by undergraduates. Where appropriate this has been done.

This raises two questions.

- Could A level students work with such ‘undergraduate’ data?
- Would it be a good use of their time to do so?

Task: Measuring the half-life of protactinium-234[11]
Background Radioactive materials are unstable and transmute from one element to another by emitting radiation. This decay from a parent to a daughter is a spontaneous, random event which cannot be predicted. However, when considering a large number of radioactive nuclei, a statistical analysis can be used to show that the number of radioactive nuclei that decay in a given time period is proportional to the number of nuclei present.
Outline of the task In this experiment a Geiger–Müller tube is used to measure the decay activity of a radioactive material. To find the decay rate, it is also necessary to measure the background level of radioactivity and subtract this from the measured counts. The measurements show how the decay activity changes with time.
Results The count rate is plotted against time on a graph. It is seen to decrease and should follow an exponential pattern, with the best fit curve always taking the same amount of time to halve. However, the curve will not be a perfect match for all the data points; there are inherent as well as experimental uncertainties. The graph is then used to estimate the half-life of protactinium.
Commentary This experiment not only shows how statistics can be used within an experiment, it also shows how statistics can be fundamental to the behaviour of physical systems. The background count will fluctuate around a mean value, the decay activity will not always follow the line.

The consensus view of those consulted was that a further level of cleaning would be needed to make the data usable, but that in most cases the work that students would be carrying out would be beyond what is appropriate for A level anyway. The point was made that whatever is included should be comprehensible to typical students. There was criticism of the inclusion of some items, such as the Higgs boson, in current syllabuses even though students have no hope of understanding them at a level deeper than reports in the mass media.

However, there is a distinction between work that students actually do for themselves and the explanations that are given by their teachers. There are topics where the use of carefully designed teaching materials that draw on large data sets could be very stimulating; possible examples are the search for exoplanets, particle physics and energy usage.

A number of data-rich areas of physics may well be incorporated into A level Physics in the foreseeable future. These would provide opportunities to use more statistics and so to convey a more accurate impression of the subject in higher education. Examples include nanotechnology, photonics and molecular dynamics.

There are also topics in the existing A level syllabus, such as radioactivity, simple harmonic motion and the superposition of waves, that would benefit from treatment in which data play a more prominent role.

Another opportunity within the current A level arises with uncertainty and experimental error, where the treatment compares unfavourably with that in the International Baccalaureate[12]. Possible changes to the A level would involve:

- inclusion of the precision of the measuring instrument as part of the results table header;
- percentage error columns for input variables and both percentage error and error value columns for calculated columns that are to be plotted on a graph;
- the use of error values for each data point to generate error bars;
- the use of the error bars to generate the steepest and shallowest fit and thus a gradient value that has an inherent spread error.

Constraints

The major constraint identified comes from the current accountability system and the pressure it places on teachers to prioritise examination results even if this undermines the quality of their students' learning. It is predictable that many classrooms will be characterised by a reluctance to try anything new; the focus of teaching will be typical examination questions.

A different constraint arises from the nature of the discipline. In many other subjects, data are often measurements of quantities that exhibit considerable natural variability, like the height of an adult male human. A different source of variability arises from the way the measurements are carried out. Many of the topics in the physics taught at A level are presented deterministically with no place for natural variability, only that due to measurement. Consequently, students need to understand that the use of statistics can sometimes be rather different in physics from that in their other subjects.

Some physics teachers know little statistics but their ability to think analytically and mathematically means that this should be something that, at a technical level, they can easily remedy. However, they also need to appreciate the differences in the use of statistics between physics and other subjects; otherwise they may inadvertently confuse their students.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 The Quality Assurance Agency for Higher Education: www.qaa.ac.uk

3 Professor Bill Wakeham (Chair), (2008) *Review of UK Physics* (The Wakeham Review), page 6, Research Councils UK

4 Source: HESA, www.hesa.ac.uk

5 ibid. 3, page 12

6 Source: Joint Council for Qualifications, www.jcq.org.uk

7 Ofqual (2011) *GCE AS and A Level Subject Criteria for Science*

8 ibid.

9 SCORE (2012) *Mathematics within A-level Science 2010 Examinations*, page 11

10 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

11 Adapted from Practical Physics, www.nuffieldfoundation.org/practical-physics

12 International Baccalaureate: www.ibo.org

Physics advisors

Andrew Darke	Formerly of Culham Centre for Fusion Energy
Simon Hunt	Head of Physics, The Manchester Grammar School
Dr Paul Kyberd	Senior Lecturer in Particle Physics Informatics, School Of Engineering and Design, Brunel University
Professor Peter Main	Director, Education and Science, Institute of Physics
Stephen Nugus	Science Advisor, Pearson Edexcel
Dr Chris Robbins	Owner, Grallator Consulting
Professor Bernard Weiss	Royal Academy of Engineering
Dr Paul Yates	Discipline Lead for the Physical Sciences, Higher Education Academy

Psychology

End-user requirements

Higher education

Psychology is a popular degree subject with about 25,000 undergraduates per year in UK universities[1].

Psychology research in UK universities is highly regarded internationally, as evidenced in the recent international benchmarking exercise led by ESRC[2].

UK Psychology research when compared with the world's best psychology research is very strong: overall second only to the USA and in many areas clearly the best in the world.

At degree level, psychology is a vibrant subject and one that has significant reach given the interest in the subject at A level and the incorporation of psychology in other routes of pre-university study such as BTEC in health and social care.

It is no surprise to find that UK psychology degrees draw strong interest from overseas students who wish to take a British degree in psychology.

Professor Mark Davies, Psychology advisor

There has long been extensive use of statistics in psychology in higher education. Its central importance is reflected in The British Psychological Society's curriculum requirements that are part of the professional society's accreditation criteria that enables graduates from an accredited programme to secure graduate basis for chartership[3].

In recent years it has become clear that the use of qualitative methods or a mixture of qualitative and quantitative methods sometimes provides the best way to address relevant psychological questions[4]. Consequently some degree courses have redesigned their research methods provision to include a broader range of techniques. This has led to a small reduction in the time devoted to teaching statistics in some degrees.

All psychology undergraduates attend courses in statistics or quantitative methods; typically this accounts for about 25% of their time. This includes extensive use of a suitable software package to analyse data they have generated and also secondary data. The pace of most such courses is considerably faster than students would encounter during A level.

About 70% of those starting psychology degree courses have taken the subject at A level or in Scottish Highers. Those students have had some prior exposure to statistics but the same need not be true of the other 30%. They may have used statistics in another subject but some of them have not done any since they took GCSE Mathematics, typically at least two years previously; some are also weak in basic mathematics.

There is clearly a need for sensitivity on the part of university lecturers teaching first year undergraduates but this can be in conflict with the need to complete the course content in the available time. Over recent years, with the increased role of sophisticated software packages a noticeable proportion of students are able to enter data with only limited understanding of what the software is doing or how to interpret the outputs and assess their validity. Many of these students entered higher education with little or no relevant background knowledge of statistics.

By contrast, those who arrive with basic skills in statistics (and mathematics) are in a better position to benefit from their university courses.

Beneficial skills for new psychology undergraduates

- They are confident with data:
  - they understand the value of observation;
  - they are able to describe, present and report on data;
  - they know about different types of variable and measurement;
  - they understand about natural variability, experimental error and consequent sampling error, and the differences between them.
- They understand the basic principles of statistical inference:
  - they understand the importance of patterns in data;
  - they are able to judge which test or procedure is the most appropriate in a particular situation;
  - they are able to interpret the results of a test;
  - they appreciate that modelling assumptions are involved.

Employment

There is considerable diversity in the careers followed by psychology graduates. Popular options include fields in health and social care, teaching, the voluntary sector and market research[5]; between about 15% and 20% become professional psychologists, registered with the Health and Care Professions Council. The variety of applications of psychology in the workplace is illustrated by the number of different descriptions that may be precede the word ‘psychologist’ in a job title: clinical, forensic, sports, educational, counselling, environmental and so on.

It is widely recognised that psychology provides students with a valuable skill set for future employment[6]. On the one hand they experience the rigour of a scientific and analytical discipline while on the other hand they learn about communication and ethics. A psychology graduate is thus able to frame a question, collect and analyse the data and communicate the findings effectively.

By the time they enter employment, whatever psychology graduates learnt at A level has long been superseded. The same is not, however, necessarily true of skills and attitudes that they acquired during those formative years. Employers would hope to see the core elements of psychology instilled into its A level students. Psychology is concerned with the study of the human mind and human behaviour but it is a science, requiring evidence that is often obtained by analysing data.

Within an organisation, a psychologist is often involved in convincing managers that particular decisions are, for psychological reasons, in their interest. The evidence is often statistical, but the manager in question may well have only a limited appreciation and understanding of statistics. So, to be effective in the workplace, a psychologist must be able to communicate statistical ideas effectively. Such ideas could be derived from a variety of sources, including research papers and investigations within the organisation.

Important skills for new psychology graduates entering employment

- They are confident in using data, for example:
  - they can understand data, for example interpreting individual differences in psychometrics;
  - they can interpret data trends;
  - they can explain concepts linking psychology and statistics (such as the significance of a test result) to colleagues without a background in either discipline.
- They can interpret and communicate statistical information, for example:
  - they can interpret and explain the results of investigations;
  - they can make judgements about interventions related to people's behaviour in areas such as education, health, parenting and crime;
  - they understand and can critically appraise quantitative information, for example in a research paper, a government report, a pilot study or a news story.

The demands of modern society include the use of evidence and this often requires data to be collected and interpreted. Thus, once in the workplace, psychology graduates may also be expected to work with more general social and business data: for example gathering and analysing market research data; conducting surveys among clients, students or service users.

Thus future employees will need statistical intelligence. A rich experience at A level can establish a level of self-efficacy when encountering data that will serve them in good stead throughout their lives. Conversely a poor experience at this age can foster anxiety and a disinclination to engage with data.

Statistics and insight are two vital ingredients in psychology. It is amazing how much more insightful you become when you know how to analyse data.

Dr Craig Knight, Psychology advisor

A level Psychology: The current situation

Psychology is a popular A level, particularly in colleges. In 2012 it was taken by nearly 56,500 students[7]. Psychology has been shaped by the tradition of experimental design and analysis common to the other sciences, resulting in considerable emphasis on statistics in higher education. This is reflected in the requirements of A level and the Scottish Higher.

A level psychology syllabuses (but not the Scottish Higher) are bound by the Subject Criteria for Science which specify some statistics within this list of required mathematics . However, the current A level syllabuses contain considerably more statistics than this minimum requirement.

Statistics required by the A level Subject Criteria for Psychology[8]

In order to be able to develop their skills, knowledge and understanding in science, learners need to have been taught, and acquired competence in …

Arithmetic and numerical computation

(a) Recognise and use expressions in decimal and standard form

(b) Use ratios, fractions and percentages

(c) Make estimates of the results of calculations (without using a calculator)

Handling data

(a) Use an appropriate number of significant figures.

(b) Find arithmetic means.

(c) Construct and interpret frequency tables and diagrams, bar charts and histograms.

(d) Understand simple probability.

(e) Understand the principles of sampling as applied to scientific data.

(f) Understand the terms mean, median and mode.

(g) Use a scatter diagram to identify a correlation between two variables.

(h) Use a simple statistical test.

(i) make order of magnitude calculations

Algebra

(a) Understand and use the symbols $=$, $<$, $<<$, $>>$, $\propto$, $\sim$.

(c) Substitute numerical values into algebraic equations using appropriate units for physical quantities.

Graphs

(a) Translate information between graphical, numerical and algebraic forms.

(b) Plot two variables from experimental or other data.

Sampling and null hypothesis significance testing are included in all the A level syllabuses and the Scottish Higher. These topics are essentially new to all students. Most of the other items listed in the Subject Criteria are covered in GCSE Mathematics and so, in theory, should present few problems to students. In practice that is often not the case. Many of those opting to take psychology as an A level have not had an entirely satisfactory experience of mathematics at GCSE; some have had only limited success and others, while superficially successful, have not understood how to transfer their mathematics skills into other subjects, such as psychology.

Consequently successful psychology teachers at this level not only cover the various statistics topics in the syllabus, but also help many of their students to overcome mathematical weaknesses from GCSE and the lack of confidence that comes with them.

Given the popularity of psychology courses in schools, teaching stats in psychology at this level has excellent potential for building confidence in numeracy skills and reducing anxiety about them; however, to ensure such benefits are fully realised, we need increased provision of teacher training for psychology.

Morag Williamson, Psychology advisor

A particular problem in the provision of pre-university psychology is that in many institutions there are not enough lessons to fill a full-time psychology teacher's timetable. In some cases the psychology is taught by a non-specialist, for example a biologist. While many such teachers have an appropriate background to develop the necessary expertise and take great trouble to do so, there are stories of psychology being landed on teachers with no knowledge of science or statistics. Overall there is concern that some A level students do not have access to specialist teaching.

This situation is exacerbated by the absence of psychology from initial teacher training courses and the lack of training opportunities for non-specialists who find themselves teaching it.

Opportunities for CPD are very limited, whether for specialist or non-specialist teachers. Consequently those who are having difficulty teaching the required statistics and the necessary mathematics do not have easy access to good advice.

A key issue in psychology relates to the lack of training places available for psychology teachers in the UK. Some psychology teachers at A level have come from degrees in other subjects, and many of them find the statistical element of psychology difficult to grasp. The quality of statistics teaching at A level in psychology is therefore variable.

Dr Julie Hulme, Psychology advisor

Opportunities within A level Psychology

It is clear from both higher education and employment that the more experience A level students have in working with data, the better they will be prepared for their futures.

Psychology is a subject which engages students scientifically with issues that relate to their own lives, and to solving problems in the real world. That is why it is such an immensely popular subject at A level. As such, it is very well placed to engage students with numeracy and statistical literacy in a way that demonstrates the relevance of data to real life.

Dr Julie Hulme, Psychology advisor

This is likely to be most effective when students have to use data to address problems that are so interesting that they really want to know the answers. In psychology such problems are typically of their own devising and require data to be collected, analysed and interpreted within the Statistics Cycle[9].

For many years the coursework requirements ensured that such work was carried out in A level Psychology. However, since 2008 there has been no externally assessed coursework in A level Psychology. (By contrast it is required in Scottish Highers and in the International Baccalaureate.)

While coursework was in place, most students were provided with an experience which led naturally to formal null hypothesis significance testing, and so the rationale for it made sense to them. However, without such problem solving work there is a real danger of the statistical tests becoming no more than mathematical exercises, disconnected from the rest of students' learning of psychology.

Some of the current psychology specifications include experimental design techniques, and between them they cover the following sampling methods and null hypothesis significance tests.

Sampling methods	**Hypothesis tests**
Random	Spearman's rank correlation
Stratified	Product moment correlation
Volunteer and self-selecting	χ^2 test
Opportunity	Mann–Whitney *U*-test
	Wilcoxon signed-rank test
	Sign test
	t tests

However, there are those who feel that in the absence of coursework, or its equivalent, the syllabus has now become fragmented with connections no longer always being made between the various elements that should fit together within a complete cycle. It is argued that unless greater emphasis is placed on students doing practical work on real problems, there is only limited value in many of the statistical techniques that are in current specifications.

Because A level psychology specifications tend to be 'content-heavy', and assessment tends to focus on recall of facts, there is a tendency for practical work to be limited to small scale studies which generate small data sets, and thus the opportunity for students to learn how to apply statistical tests is reduced. Added to this the examination questions do not usually require, or indeed credit, thorough understanding of the Statistics Cycle.

Dorothy Coombs, Psychology advisor

Thus in psychology the greatest opportunity may be to restore the balance between students' own investigations and the techniques that will be needed to process and analyse the outcomes. If it is necessary to reduce the long list of hypothesis tests in some current specifications to make time for this to happen, this could be a net gain for statistics. However, all students should continue to meet some tests.

There is no lack of suitable questions to be investigated, such as the two examples below.

Attractiveness of married couples[10]

Is there a correlation between the physical attractiveness (scored on a scale of 1 to 10) of men and women in married couples?

Wedding photographs are selected from the internet (an **opportunity** sample) and the males and females are scored for physical attractiveness by a group of judges (students). The data are **ordinal**. The test is **Spearman rank**.

The effect of an audience on sports performance

Do sports people perform better with or without an audience?

Students who are interested in taking part in the experiment are recruited by posting adverts in a school or college (a **volunteer sample**). The sport is basketball and they are asked to attempt to score ten baskets in two different conditions. Half perform with the audience first and half without. The 'audience' is a class of students who are told to cheer and shout as they might at a real match.

The data are converted into **ordinal** and the statistical test is the **Wilcoxon paired-sample signed-rank.** It is repeated measures design.

In common with many investigations that are suitable for A level students, both of these require non-parametric tests. This is sometimes criticised in higher education.

When they start a psychology degree at university, some students are told that the non-parametric tests they learnt in A level were a waste of time, and now they will be taught the real thing (i.e. parametric tests). A better approach would obviously be to tell them they are now going to extend their knowledge to further techniques.

Dorothy Coombs, Psychology advisor

Students' investigational work usually results in small sets of primary data and so they meet statistical techniques for processing such data. However there are also many large secondary data sets that are relevant to A level Psychology such as the following examples.

- Re-offending rates
- Mental health disorders
- Workplace stress
- Suicide rates around the world
- Public health
- Social attitudes
- Parenting and child care in relation to health and school attainment

Psychology teachers can use such data as evidence to illustrate the points they are making. Where data visualisation techniques have been applied to such sets, they can become powerful teaching resources. If suitable tools are available the data can be interrogated to investigate particular questions as they arise. However, advisors felt strongly that the opportunities provided by the availability of large secondary data sets should not be seen as reasons to reduce the amount of individual investigative work that students undertake.

Psychology is unusual among the various subjects taken in higher education in that the increase in the use of statistics happened quite some time ago and has largely stabilised since then, with consequent knock-on effects on the development of the A level syllabus. So, in some ways psychology is in the lead; certainly those responsible for A levels in other subjects can learn lessons from psychology. However, there are important differences, not least in the particular difficulty psychology teachers have in obtaining access to professional guidance, something that must impact on the development of suitable pedagogical models.

Constraints

Three issues emerge as being particularly important for those deciding how to teach the statistics embedded in the subject: the need for students to engage in problem solving, the difficulties arising from their lack of success in mathematics, typically at GCSE, before starting the psychology course, and the need for suitable CPD for teachers.

Students own investigative work is particularly important now that there is no longer any coursework. Teachers need to find opportunities for them to collect, think about and analyse their own data. This may require some teachers to reconsider the way they present aspects of the subject, moving to an approach where the evidence presented is more often explicitly derived from data, and students are encouraged to consider the data behind the facts they learn.

Several of those consulted commented on the lack of numeracy of typical psychology students, some of whom are frightened of elementary mathematics. In addition the way that techniques are taught in mathematics often does not allow students access to them in psychology lessons, even some of those with good grades in GCSE Mathematics. This is seen as limiting the amount of statistics which can currently be taught successfully within A level psychology.

Teachers need to be confident in the guidance they provide students about the subsequent analysis. Anecdotal evidence suggests that many psychology teachers need help in this area but are unable to obtain it.

Appropriate CPD needs to be made available to A level psychology teachers to support them in delivering statistical content. Further, the statistical content in A level psychology should not be too challenging for the teachers to manage confidently.

Dr Julie Hulme, Psychology advisor

CPD can introduce psychology teachers to resources which can enable them to improve their students' understanding of statistical methods.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 The Economic and Social Research Council (ESRC), The British Psychological Society, the Association of Heads of Psychology Departments and the Experimental Psychology Society (2011) *International Benchmarking Review of UK Psychology*, page 30

3 Accreditation criteria are available at: www.bps.org.uk/careers-education-training/accredited-courses-training-programmes/what-accreditation/what-accreditat

4 The Quality Assurance Agency for Higher Education (QAA), (2007, 2010) *Subject benchmark statement: Psychology*

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8 Ofqual (2011) GCE AS and A Level Subject Criteria for Science

9 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

10 Based on the work of Murstein, B.I. (The Matching Hypothesis, 1972)

Psychology advisors

Elin Angharad	Subject Officer, GCE and GCSE Psychology, WJEC
Dorothy Coombs	Chair of the Association for the Teaching of Psychology
Professor Mark Davies	The Association of Heads of Psychology Departments
Dr Julie Hulme	The Higher Education Academy
Matt Jarvis	The British Psychological Society
Dr Craig Knight	Prism – Identity at Work Research Group, University of Exeter
Morag Williamson	Psychology lecturer, West Lothian College; Committee member of the Association for the Teaching of Psychology (Scotland)

Sociology

End-user requirements

Higher education

Sociology became established in higher education in the UK in the years following World War II. It became a popular degree subject in the 1960s and remains so with slightly over 7,000 undergraduates per year in UK universities, and a similar number taking closely related subjects, like Social policy and Social work[1].

The British Sociological Association was established in 1951 and described the new subject in these terms.

Sociology is the scientific study of society … [its] purpose is to investigate the working of society in order to enable it to work better.

British Sociological Association[2]

Thus sociology is defined as a social science and sociologists employ rigorous scientific research methods in their work. However, there is ongoing debate over the appropriate relationship between quantitative and qualitative methods in sociology.

As social scientists, sociologists are often revered as the guardians of high quality qualitative research but, to use the words of Google's chief economist, Hal Varian, they also need quantitative skills to be able to process, extract value from, visualise and communicate their findings[3].

Judith Mudd, Sociology advisor

There has always been some use of statistics in sociology degrees but in recent years the trend has been for it to diminish. For example, in contrast to the United States, the proportion of UK journal publications that contain reference to quantitative methods has decreased from 58% in the 1960s to a current level of 27%[4].

In the recent international benchmarking, UK universities were praised for their qualitative research but criticised for the lack of quantitative work[5].

The main conclusion we have arrived at is that sociology in the UK is overall in a healthy state, despite the many difficulties both of externally imposed and internally generated origin. It continues to be intellectually innovative and vibrant and shows many reassuring signs of a strong and lively engagement with the contemporary world and its manifold problems. In a comparative international perspective the capacity of UK sociology for new developments and intellectual innovation remains very high.

…

While the Panel was unanimous in acknowledging the pioneering role of UK sociology in developing qualitative methods and various method 'mixes', the figures we were given showed that only one fifth of End of Awards reports from ESRC sociology projects were quantitative. As a consequence, the training in quantitative methods, while itself at a high level where it is offered, remains too restricted compared to international standards.

In all universities sociology undergraduates attend courses in research methods and these contain some statistics or quantitative methods and also qualitative methods. They then use a suitable software package to analyse data they have generated and also secondary data. The pace of most such courses is considerably faster than students would encounter during A level.

A problem in many sociology departments is the low proportion of lecturers, estimated at about 10%, with the skills needed to teach quantitative methods[6].

I teach quantitative research methods on sociology degree courses at an elite, research intensive university; it is the easiest sociological subject to get a job in since there are so few who are qualified to do it.

University sociology lecturer[7]

A new programme sponsored by the Nuffield Foundation, ESRC and HEFCE in social science quantitative methods training[8], is being established in 15 university centres of excellence. This should reverse the overall trend but its effects will take some years to work through.

Many of those starting sociology degree courses have not taken the subject at A level or in Scottish Highers but done other subjects, for example psychology, which include some statistics. However, some new undergraduates have not done any statistics since they took GCSE Mathematics, typically at least two years previously; some are also weak in basic mathematics and fear the subject.

You wouldn't believe how freaked out many of them can get if you give them data in the form of numbers.

University sociology lecturer[9]

It is sometimes suggested that a vicious circle is at work. In order to accommodate students who are weak at mathematics, the quantitative demands of a degree course are reduced. This is then rationalised by claiming that the course reflects the true nature of the subject. This is then reinforced by graduates from such courses who become the next generation of teachers and lecturers.

The employment of highly skilled, inspirational teachers of quantitative methods at all levels of the taught sociological life-course, from pre-University to postgraduate level, would, in my view, be a desirable way to improve the prospects of the next generation of sociology students and to enhance the communication of sociology.

Judith Mudd, Sociology advisor

Some of those who enter higher education with little or no background knowledge end up able to enter data into a computer but with very little understanding of what the computer is doing or how to interpret the outputs and assess their validity. This is particularly important for sociology which often involves working with derived measures, such as those for social class.

Those who arrive with basic skills in statistics (and mathematics), as in the table below, are in a better position to benefit from their university courses.

Beneficial skills for new sociology undergraduates

- They are confident with data:
  - they are able to present and report on data relating to people;
  - they understand about the measurement errors inherent in data collected from people;
  - they understand about natural variability and experimental error.
- They understand the basic principles of statistical inference:
  - they are aware of the difference between observation and experiment.
- They are willing to question other people's work.

It is right that sociology continues to nurture its highly prized mastery of qualitative skills but it is also important that we equip sociology students with the necessary level of quantitative skills that they will need to access quantitative data effectively, to engage with a variety of researchers, and to communicate their own findings in the range of delivery styles required to address audiences with different learning styles. To send sociology students out into the world lacking confidence in quantitative skills is to send them out with an Achilles' heel; they are always in danger of being tripped up, whether going for job interviews, teaching in the classroom, doing research, or responding to academic enquiry or media enquiry.

Judith Mudd, Sociology advisor

Employment

There is considerable diversity in the careers followed by sociology graduates but with the common theme that most of them are about people, social justice and social policy; examples are charities, the probation service, teaching and the police.

By the time they enter employment, whatever sociology graduates learnt at A level has long been superseded. The same is not, however, necessarily true of skills and attitudes that they acquired during those formative years.

Important skills for new sociology graduates entering employment

- They are confident in using quantitative data:
  - they can understand and interpret data and associated summary measures, including trends;
  - they can explain concepts linking sociology and statistics (such as the statistical significance of a study) to colleagues without a background in either discipline.
- They can interpret statistical information and communicate it to non-specialists:
  - they are confident with the principles of sampling, population and inference, validity and reliability, and survey design;
  - they understand and can critically appraise the quantitative information in a report or a research paper.
- They can identify trends.

Thus future employees will need statistical intelligence. A rich experience at A level can establish a relationship with data that will provide a sound basis for developing it.

I co-convene the Sociologists Outside Academia group for the British Sociological Association, so took the opportunity to talk to some of my colleagues about their experiences with statistics. We all agreed that some knowledge and confidence with statistics is essential, both to improve your employment opportunities and also to engage with current debate and research. Statistical knowledge for social scientists is, as one of my colleagues put it, 'a no-brainer'.

Phil Jones, Sociology advisor

A level Sociology: The current situation

Sociology is a popular A level, particularly in colleges. In 2012 it was taken by 31,357 students[10].

Current A level Sociology syllabuses (but not the Scottish Higher) are bound by the Subject Criteria for Sociology. These do not specify any particular mathematics or statistics. As a result there is considerable variability in the statistical demands from one syllabus to another.

However, the Subject Criteria contain a number of statements which make it clear that such work is intended.

Extracts from the GCE Subject Criteria for Sociology[11]

Aims and objectives (include)

- Understand and evaluate sociological methodology and a range of research methods through active involvement in the research process.

Subject content (includes)

- Methods of sociological enquiry
  - the collection of primary and secondary data;
  - the analysis of quantitative and qualitative data using appropriate concepts;
  - factors influencing the design and conduct of sociological research;
  - practical, ethical and theoretical issues arising in sociological research.
- Interpretation and evaluation of evidence (includes)
  - interpret qualitative and quantitative data;
  - identify and evaluate significant social trends shown in evidence.

Until 2008 the assessment of A level Sociology included coursework. Typically this gave students some firsthand experience of the sociological research referred to in the Subject Criteria, and to the analysis and interpretation of data.

However that is no longer the case and something of a vacuum has resulted. Many of those opting to take sociology as an A level have not had a particularly satisfactory experience of mathematics at GCSE; some have had only limited success and others, while superficially successful, have not understood how to transfer their mathematics skills into other subjects, including sociology. The removal of coursework has made a bad situation worse for many such students.

A particular problem in the provision of pre-university sociology is that in many institutions there are not enough lessons to fill a full-time sociology teacher's timetable. Consequently it is often taught by a non-specialist. Opportunities for CPD are very limited, whether for specialist or non-specialist teachers.

Opportunities within A level Sociology

The current discussion within higher education about the appropriate balance between quantitative and qualitative methods is likely to influence what happens in many A level classrooms. Teachers who experienced little, if any statistics, in their sociology degrees are unlikely to emphasise it in their own lessons.

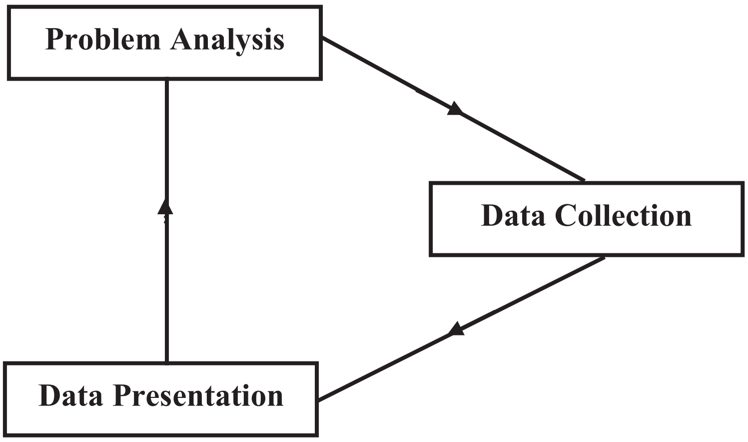
However, it is clear from both higher education and, particularly, employment that the more experience A level students have in working with data, the better they will be prepared for their futures.

Sociology without data is like Wuthering Heights *without Heathcliffe. Sociology ultimately depends upon the analysis and interpretation of evidence. Learning the logic of how to collect, organise and present that evidence scientifically are essential statistics skills that students need to develop from the start.*

Professor John MacInnes, Sociology advisor

This is likely to be most effective when students have to use data to address problems that are so interesting that they really want to know the answers. In sociology such problems are typically of their own devising and require data to be collected, presented and interpreted.

This will often occur within a version of the Statistics Cycle[12], from which the data analysis (typically a formal null hypothesis significance test) has been removed.



Typical cycle for sociology

For many years the coursework requirements ensured that such work was carried out in A level Sociology. However, in 2008 the coursework requirement was removed.

While coursework was in place, most students had some experience of sociological research, together with relevant statistical procedures and techniques. There is, of course, no formal reason why a teacher should not continue to require students to undertake such work but the pressure from examinations and the accountability structure mean that in many classrooms it no longer happens.

Thus in A level Sociology, an important opportunity is to restore students' own investigations, and so their learning of the techniques that will be needed to carry them out. The choice of investigations should be informed by evolving good practice in higher education and employment.

The emphasis of the statistics is rather different in sociology from that in many other subjects. Typical types of data are given in the table below. They are mostly either large secondary data sets or small non-random samples. Consequently formal null hypothesis significance testing is seldom appropriate. It will be seen that some of the entries in the table are relevant to both quantitative and qualitative methods.

Types of data	Examples
Public statistics	Census 2011 (Office of National Statistics) Indices of multiple deprivation
National surveys	Labour Force Survey British Social Attitudes Survey
Transactional and administrative data	Housing rent data held by a local authority
Privately collected data	Data collected, for example for research, from samples and focus groups using measurement, interviews, questionnaires and observation
Social media data	Opinions expressed on Facebook and Twitter

A variety of sampling techniques are used, for example stratified, opportunity, cluster, quota and snowball.

Focus groups are used when trying to explore people's attitudes, beliefs or behaviour. This may involve the reasons subjects give for holding particular attitudes or displaying certain behaviour, and what other attitudes or beliefs may be associated with them.

It is common practice for sociological theory to be used to analyse case studies. Students need to be able to learn from these and so should be able to interpret any quantitative information in them. In some cases they may write up their own work in this format.

Case study involving snowball sampling

Snowball samples are usually used for hard to reach groups for which little information is available. Such subjects are often behaving in ways that are outside the law and so it is not appropriate for A level students to work with them directly. However, the use of suitable case studies can alleviate this problem.

An example might be a study illegal drug use. By finding one drug user, the researcher can be provided with access to others who in turn provide access to yet more. Thus a small group is gathered and forms the basis for a case study. While not drawn from a random sample or even a group that is representative of all illegal drug users, such a case study may still may contain sufficient data to allow useful insights.

An example of such a study is described in *A Glasgow gang observed*[13]. The researcher met one member of a gang who introduced him to others, allowing him to pose as a member and observe their behaviour.

In addition, longitudinal studies are rich sources of information. The UK has a world leading series of birth cohort and other longitudinal studies which collect data from the same respondents over many years and in some cases an entire lifetime. These have provided invaluable information about the impact of early years on later development. Given appropriate teaching materials, they have the potential to provide high quality learning opportunities for A level students; some of these will be based on data, for example investigating possible causality.

The Million Women Study[14]

The Million Women Study is a study of women's health based on National Health Service data (made anonymous) from more than one million women aged 50 and over.

Between 1996 and 2001, women were invited to join the study when they received their invitation to attend one of the participating Breast Screening Centres in the UK. Together with their invitation, they received a study questionnaire which they were asked to complete and bring with them when they attended the screening. Around 70% of those attending the programme returned their questionnaires and agreed to take part in the study. As a result over 25% of women in the target age group in the UK participated, making it the largest study of its kind in the world.

Results from the Million Women Study have influenced national policy, resulting in a rapid decline in hormone replacement therapy prescriptions throughout Europe and the US from 2003.

The programme in ongoing and a number of recent studies have shown that it continues to have an impact on women's health and patterns of behaviour in Europe.

A further rich new area for sociology students is in social media analysis, for example the digital traces left behind by users of Facebook, Twitter, etc.

Constraints

Two issues emerge as being particularly important for those deciding how to teach the statistics embedded in the subject: the need for students to engage in research, and the difficulties arising from their lack of success in mathematics, typically at GCSE, before starting the sociology course.

Students own investigative work is particularly important now that there is no longer any coursework. Teachers need to find opportunities for them to collect, think about and interpret their own data. This may require some teachers to reconsider the way they present aspects of the subject, moving to an approach where the evidence presented is more often explicitly derived from data and students are encouraged to consider the data behind the theories they learn.

Several of those consulted commented on the lack of numeracy of typical sociology students, some of whom are frightened of elementary mathematics. In addition the way that techniques are taught in mathematics often does not allow students access to them in sociology lessons, even some of those with good grades in GCSE Mathematics.

Teachers need to be confident in the guidance they provide students about the statistics they use. Anecdotal evidence suggests that many sociology teachers need help in this area but find it difficult to obtain. CPD can also introduce sociology teachers to resources which will they will find useful when teaching statistical methods.

Notes and references

1 Source: HESA, www.hesa.ac.uk

2 Official minutes, 1951, The British Sociological Association, described in Platt J. (2003) *The British Sociological Association: A Sociological History*

3 The British Academy (2013) *Stand out and be counted*, quoting Hal Varian, Google's Chief Economist

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5 The Economic and Social Research Council (ESRC), the Heads and Professors of Sociology (HAPS) and the British Sociological Association (BSA), (2010) *International Benchmarking Review of UK Sociology*, pages 40 and 41

6 MacInnes J. (2009) *Proposals to support and improve the teaching of quantitative research methods at undergraduate level in the UK*, page 6; available at: www.esrc.ac.uk/_images/undergraduate_quantitative_research_methods_tcm8-2722.pdf

7 Private communication from a university sociology lecturer

8 For more information see: www.nuffieldfoundation.org/quantitative-methods-programme

9 Private communication from a university sociology lecturer

10 Source: Joint Council for Qualifications, www.jcq.org.uk

11 Ofqual (2011) *GCE AS and A level Subject Criteria for Sociology*

12 Porkess R. (2012) *The Future of Statistics in our Schools and Colleges*, The Royal Statistical Society

13 Patrick J. (1973) *A Glasgow gang observed*, Eyre Methuen

14 For more information see: www.millionwomenstudy.org

Sociology advisors

Phil Jones	Sociologists Outside Academia, British Sociological Association
Pam Law	Joint-Convenor of the British Sociological Association Teaching Group
Joanna Lewis	Subject Officer, A level Sociology, WJEC
Professor John MacInnes	University of Edinburgh
Judith Mudd	Chief Executive, British Sociological Association
Dr Richard Waller	Associate Professor of the Sociology of Education, University of the West of England, Bristol

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getstats
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Royal Statistical Society

12 Errol Street
London EC1Y 8LX

Telephone 020 7638 8998
www.rss.org.uk

Institute and Faculty of Actuaries

Staple Inn Hall, High Holborn
London WC1V 7QJ

Telephone 020 7632 2100
www.actuaries.org.uk

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