Teaching Statistics in British Secondary Schools

Statistics Knowledge and Pedagogy in Secondary Mathematics Teacher Training Courses in British Higher Education Institutions

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CONTENTS

CONTENTS (APPENDICES)

Acknowledgements

We would like to thank the Teaching Statistics Trust for funding this research project. It is the first time that an investigation has been carried out into the extent and form of teaching statistics within British mathematics teacher training courses. These comprise the Post Graduate Certificate in Education (PGCE) in England, Wales and Northern Ireland and the Post Graduate Diploma in Education (PGDE) in Scotland.

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Executive Summary and Recommendations

The main aim of this project was to investigate the extent and form of the delivery of statistics content and pedagogy in British PGCE-type Mathematics courses. The methodology used was to survey a number of teacher trainees, their course leaders and newly qualified teachers by questionnaires, telephone interviews and focus groups, as appropriate.

The PGCE mathematics students taking part were graduates with degrees that contained a substantial mathematics component. A large majority of these graduates, nearly 80%, consider statistics to be part of mathematics.

Focus group discussions revealed that many of these students believed that they were taught statistics poorly at school by uninterested teachers. Their university experience was mixed, with a number saying it had changed their attitude to statistics positively but others felt their experience at university had been no better than school.

Nearly 70% of the focus group participants stated that less than 11% of their original degree courses comprised modules in statistics. Some of the few mature entrants who had work experience said their knowledge of statistics was poor, they either had little experience of being taught statistics or could not remember it.

Many believed statistics should be taught separately from mathematics at some point before the start of degree courses and that it should be taught as a practical subject. Many recognised that it is used within (indeed crucial to) a wide range of other subjects and a good number also acknowledged the wider importance of statistics in the community at large.

In responses to the questionnaire more than half of the PGCE students indicated that they knew about each of the itemised, individual topics, with more than 70% knowing about topics in the key stage 3 statistics curriculum.

When asked about teaching named individual statistics topics, fewer students expressed confidence in their abilities to do so, although high percentages of students were confident in the use of:

- the data handling cycle;
- sampling and surveys;
- data collection and data presentation.

The proportions dropped below 50% for the remaining topics, even where large numbers had indicated they knew about them. For example, at A level for Analysis of Variance (ANOVA), 76% knew about it but only 36% had any confidence in teaching it.

Very few PGCE mathematics students in the focus groups indicated that they had much pedagogical support in statistics and this was supported by evidence from the questionnaire in which a large majority (about 80%) said that very little (only just over 10%) of the content of their PGCE courses was devoted to helping to teach statistics. This contrasts with the response for mathematics with 72% of the students indicating that at least one quarter of the content was concerned with teaching mathematics.

Experiences of teaching statistics while on teaching practice and what constituted 'good teaching' of statistics was mixed. Some indicated that much of the statistics teaching they observed in school was lacklustre or even boring, even in classes given by experienced teachers. Few could give examples of observing good statistics teaching; nonetheless, the majority understood the data handling cycle (statistical problem solving approach) and 86% of those would use it in teaching 'at least sometimes'.

Most PGCE mathematics course leaders considered they had good knowledge of statistics and its pedagogy at a level which is appropriate for their teacher trainees. Just under a third thought statistics should be taught in a completely different way from mathematics and that, because it is an investigative subject, it does not always produce one clear answer. Some thought that when teaching statistics context needed to be emphasised. At the same time they believed it should be firmly embedded in mathematics.

PGCE courses generally provided, at least in theory, support for teaching statistics but very few monitored the trainee teachers' exposure to its teaching at school. Getting experience in teaching statistics in school was generally an ad-hoc process resulting in a great variation in the views of the role of statistics within the school curriculum.

The PGCE mathematics course leaders gave little support to increasing the time allocated to statistics knowledge or pedagogy enhancement. They commented that, while it might be desirable to do so, other topics within mathematics would suffer. In principle, at least, they felt that their students should gain some experience of teaching statistics through other subjects using real data, but could not see how to allocate time within the PGCE to do so. They pointed out that linking statistics to other subjects is not realised in practice in schools and they expressed the view that, as statistics is an application of mathematics, as such it could not, or should not, be separated from mathematics.

There is evidence that there is a need to create resources for PGCE course leaders, the trainee teachers and their mentors in schools that bring together the importance of statistics within other subjects, including mathematics, the use of real data in the learning and teaching of the subject and the data handling cycle. An improved attitude to the learning and teaching of statistics would enhance its status within British secondary schools and with the wider public.

The responses to an online questionnaire from a limited number of newly qualified mathematics teachers proved to be consistent with the views elicited from the PGCE students. In particular they indicated that much less time on their PGCE course was spent addressing statistical pedagogy than was the case for mathematics. It is also clear that studying a topic before teacher training does not necessarily lead to confidence in teaching the topic. For example, more than half of the teachers who responded confirmed that they knew about 'regression' and did not know about 'inference' on entry to the PGCE. However, more said that they were confident about teaching inference rather than regression.

From the evidence gathered in this research project, together with that provided in a previous research report (RSSCSE/QCA, 2006), we make the following nine recommendations. The first five recommendations are similar to those in the RSSCSE/QCA report. This is indicated below by, for example, 'RSSCSE/QCA 3' which refers to recommendation 3 in the 2006 report.

Recommendation 1
We recommend that a programme of CPD be developed for Heads of Mathematics in schools and colleges with particular regard to identifying how the problem solving approach (data handling cycle) can best be taught in statistics. This will also be necessary for Heads of Science, Geography, Economics, Psychology and so forth, if they, or their staff, are required to teach this material. (RSSCSE/QCA 3).

Recommendation 2
We recommend that a comprehensive range of teaching materials be developed and made available to Heads of Mathematics in schools and colleges to facilitate the teaching of all topics within the statistics and data handling content of the mathematics curriculum. These should be designed to use real data, including that from other subject areas, and should embrace the problem solving approach. (RSSCSE/QCA 4).

Recommendation 3
We recommend that the Department for Education should promote the development of a database of resources containing examples of the use of the statistical problem solving approach across the curriculum and make this database available to school teachers. (RSSCSE/QCA 7).

Recommendation 4
We recommend that the Department for Education should promote the development of online CPD designed to demonstrate the use of the resources in Recommendation 3 to school teachers. The CPD should be developed in tandem with the teaching resources. (RSSCSE/QCA 8).

Recommendation 5
We recommend that the Department for Education should give priority to the development of online CPD resources that will enable school teachers to take ownership of their CPD needs by facilitating the transformation of their own case studies and examples into further resources in the style of those in Recommendation 3. (RSSCSE/QCA 8).

The following recommendations are made to the Secretary of State for Education concerning the training of teachers who will be responsible for the teaching of statistics in schools and colleges.

Recommendation 6
We recommend that a programme of CPD be developed for PGCE Mathematics Course Leaders and teachers responsible for mathematics training in the proposed teaching schools with particular regard to identifying good practice in the teaching of the problem solving approach (data handling cycle) in statistics. This will also be necessary for Course Leaders in many other subjects, for example, Science, Geography and Social Science as their trainees will be required to teach statistics within their disciplines.

Recommendation 7
We recommend that a programme of CPD be developed for teacher trainees' school mentors in mathematics with particular regard to identifying good practice in the teaching of the problem solving approach (data handling cycle). This will also be necessary for school mentors in other subjects such as Science, Geography and Social Science as their trainees will be required to teach statistics within their disciplines.

Recommendation 8
We recommend that a comprehensive range of exemplar pedagogic materials be developed and made available to HE mathematics education, departments and all teaching practice schools to facilitate the teaching of all topics within the statistics and data handling content of the mathematics and statistics curriculum in schools. These should be designed to use real data, including that from other subject areas, and should embrace the problem solving approach.

Recommendation 9
We recommend that all teachers involved in teaching statistics, including school mentors, should undertake a certified CPD course in teaching statistics similar in content to the two Teaching Statistics modules provided in the International Masters Programme at Plymouth University *Teaching Statistics Pre-university Level Mathematics and Statistics*.

This report is divided into six parts. Part (I), sections 1-4, provides the background to the project and the detailed research specification agreed with the Teaching Statistics Trust. In part (II), sections 5-6, we report and discuss the findings from the focus groups with PGCE mathematics students that took place in five British universities. In part (III), section 7, we report and discuss the responses obtained from newly qualified teachers (NQTs). In part (IV), section 8, the results of telephone interviews with PGCE mathematics course leaders at 17 British universities are reported. In part (V), section 9, we draw some conclusions. Some quotes from the PGCE mathematics students in the focus groups are also given in part (V).

In view of the findings in Parts (I) – (V), in Part (VI) we take the opportunity to update the material and recommendations about the extent, level and form of knowledge of statistics that every school leaver should have. The RSSCSE first published these on its web site in 2009 (see RSSCSE, 2009). They can be regarded as statistical literacy benchmarks that are vital to every citizen being able to make sense of the world around them.

We also propose how the material should be taught to motivate and enable every learner to become more statistically literate and aware. These recommendations have ramifications for statistics knowledge and pedagogy for existing teachers of statistics and, of course, future students on British PGCE mathematics courses.

(I) Research Project Background

1. Introduction

The Inquiry into post-14 Mathematics Education (Smith, 2004) was set up by the UK Government to investigate the teaching of mathematics in schools. It highlighted a widespread concern with a perceived crisis in mathematics education and produced several recommendations. These included recommendations to reform and strengthen aspects of teacher training and professional development.

Following this inquiry, the Education Strategy Group (ESG) of the Royal Statistical Society (RSS) set up its own task force under the chairmanship of Professor Harvey Goldstein to explore the role of statistics in school education and to report with recommendations (Goldstein, 2005). Amongst its recommendations were:

- statistics should be part of the 14-19 core curriculum to which everyone has some exposure;
- appropriate continuing professional development programmes are required, and there are also important requirements for initial teacher training.

The task group's report also stated that 'At the heart of the debate is the notion of what it means to be statistically literate'.

These views are endorsed in the recent report by Roger Porkess (2012) on statistics in schools. He recommends that the increasing importance of statistics to our national life should be recognised in our evolving education system and that national education policy should ensure that all students are equipped with a working knowledge of basic statistics.

In 2010, the RSS launched its 10-year Statistical Literacy Campaign, *getstats,* (www.getstats.org.uk). Several different strands, covering statistical literacy in the general public, in the workplace and for school children and older learners, have been identified. One aspect of this is the way in which statistics is taught in schools, which is influenced by the content and delivery of the statistics curriculum in teacher training courses. This also means that a considerable amount of continuing professional development (CPD) will be needed for those teachers already in post who may not have adequate subject knowledge and pedagogical understanding in statistics, either through no fault of their own or through a resistance to changing the way they teach the subject.

Further, the Smith report suggested that the Qualifications and Curriculum Authority (QCA) should undertake a review of the place of statistics and data handling in the national curriculum. The QCA commissioned the RSS Centre for Statistical Education (RSSCSE) to carry out this review and its recommendations included that statistics should be retained within mathematics and that statistics should be taught through a problem solving approach (QCA, 2006, available from them through a written request from the RSSCSE). All eleven recommendations of the RSSCSE/QCA report can be found in Table 20 of the Porkess report (2012, page 56). It is noted here that, to date, none of these recommendations have been implemented by the QCA, its successor bodies or the Department for Education.

These issues are not solely a British concern – for example the Joint International Congress for Mathematics Education/International Association for Statistical Education Conference in 2008 had as its theme *Statistics Education in School Mathematics: Challenges for Teaching and Teacher Education* (www.ugr.es/~icme/iase_study). Further, the school level Guidelines for Assessment and Instruction in Statistics Education (GAISE) report (Franklin et al, 2005) from the US concurs with many of the conclusions with regard to statistical literacy and the problem solving approach of the RSSCSE/QCA report cited above.

In summary, many statistics educators, within the UK and elsewhere, believe that statistics should be taught within the mathematics curriculum (even though it is widely used elsewhere) through a data-driven, problem solving approach. This has many implications for teacher training courses in mathematics as well as CPD for serving teachers.

We are aware that statistical content (sometimes substantial in nature) is to be found in the school curriculum of other subjects and that there is also evidence (see RSSCSE/QCA, 2006) that the teachers of those subjects are also in need of CPD in statistics knowledge and pedagogy.

2. Scope of Project

Until now there have been no formally published details of the extent to which teacher training courses embed or even refer to training in teaching statistics in preparation for school teaching at any level. However, there is much anecdotal evidence that statistics has low priority in the content of many mathematics teacher training courses and is rarely delivered well, although the subject forms a key part of the mathematics national curriculum at both primary and secondary stages.

The RSSCSE/QCA project mentioned above surveyed Heads of Mathematics, Science and Geography as these are among the main school subjects up to KS4 where statistics is used. Some pertinent conclusions are that:

- just over 20% of Heads of Mathematics had qualifications that did not include statistics (over 50% for Heads of Science and 30% for Heads of Geography);
- only about two thirds of Heads of Mathematics thought that their knowledge of statistics was "excellent" or "very good" and about 25% declared themselves to be "not fully confident" at teaching statistics at KS3.

In-depth interviews of mathematics teachers revealed that they wanted more training in teaching statistics. Thus there is evidence that CPD in teaching statistics is both wanted and required for serving teachers. To this end the RSSCSE has produced materials leading to an RSS-accredited Certificate in Teaching Statistics up to pre-University Level. This now comprises a pathway within the International Masters Programme (IMP) at Plymouth University that can lead to, for example, the degree *MA Education (Teaching Pre-university Mathematics and Statistics)*. See www.plymouth.ac.uk/imp.

Statistics is a pervasive and ubiquitous subject that occurs not only in the mathematics curriculum, but in several other school subjects such as geography, science, psychology, social sciences, economics and business. Indeed, statistics is required in any subject that produces or uses data. Whilst all these routes for learning statistics are important, in the first instance, the focus of this investigation is on teacher training courses in secondary mathematics.

One reason for concentrating on mathematics is that each of the reports by the RSSCSE/QCA, Goldstein (2005) and Porkess (2011) recommended that statistics is best placed in the mathematics curriculum at school level. Furthermore Porkess recommended that school and college mathematics departments should ensure that they have the expertise to be the authorities on statistics within their own institutions.

There are several ways in which people can be trained as mathematics teachers, most commonly through Postgraduate Certificate of Education (PGCE) courses in England, Wales and Northern Ireland, or through the equivalent qualification called the Post-graduate Diploma in Education (PGDE) in Scotland. The PGCE can be taken after an extra year of study, for example a Mathematics Enhancement Course (MEC) or an Extended Mathematics Enrichment Course (EEC), for suitably qualified people. These are 6 month intensive, mainly taught, courses that are designed to develop deep

understanding of aspects of mathematics and to enable successful participants to go directly to the teacher training course (Bidgood, 2007).

PGCE students are recruited through the Graduate Teacher Training Registry (GTTR) to places mainly at Higher Education Institutions (HEI), although some follow a school-centred initial teacher training route (SCITT), where training is provided by a consortium of schools and education providers. As can be seen from Appendix 1, these have accounted for approximately 3% of the total PGCE mathematics places in the last 3 years.

Other routes at HEIs include a BA, BSc or BEd with qualified teacher status, although these courses have declining numbers. A few people are eligible for the school based graduate teacher programme or registered teacher programme, and there are programmes for those from overseas.

However, the vast majority of those training to become secondary mathematics teachers do so through a PGCE at an HEI. Hence this is the qualification considered here.

3. Mathematics Teacher Trainer Courses

There are 64 HEIs in England, five in Scotland and three in Wales that between them offer the majority of places in secondary mathematics PGCE/PGDE courses. The PGCE route through the SCITTs is only available in England. In Northern Ireland a PGCE can be obtained at Queen's University, Belfast or part-time through the Open University. A list of providers and the numbers of accepted applicants over the past 5 years is given in Appendix 1. Clearly there is a great deal of difference in numbers of students between and within institutions over the years. The numbers of mathematics PGCE students varies from year to year, with a slight decline since a peak in 2009.

All the subjects listed in Table A2.1 produce or use statistics to some extent and so although the statistics content of PGCE mathematic courses are the focus of this report, the investigation into the extent and form of statistics could be extended to other PGCE subject areas.

In summary, each year almost 2000 students are training to become secondary mathematics teachers, through the PGCE route. They have the choice of 72 HEIs in which to train and their experiences of the content and delivery of the statistics element of their course are likely to be varied.

4. Detailed Specification

We first list the aims and objectives of this investigation. The aims were to:

- survey the extent and form of British PGCE Mathematics courses with respect to the delivery of statistics content and pedagogy;
- survey a range of newly qualified teachers, trainee teachers and education lecturers about their attitudes to and knowledge of teaching statistics.

The objectives were to:

- identify and catalogue mathematics teacher training courses and highlight those that pay particular attention to statistics knowledge or pedagogy;
- classify the entry profiles of students to such courses, particularly their statistics backgrounds;
- identify how the statistics content is delivered and the nature of the attention paid to statistical thinking and reasoning (as opposed to mathematical thinking and reasoning) for British PGCE/MEC secondary courses in mathematics and other relevant subjects;
- identify and synthesise elements of good practice in statistics knowledge and pedagogy delivery within BRITISH PGCE/MEC courses and disseminate findings.

We also planned to review the content of BEd courses and other PGCE subject courses, but time and resources did not allow us to complete these aspects of the project.

Our strategy to conduct the research for this project was to:

- carry out desk research to review how many universities offered PGCE mathematics courses and report how many students had been on such courses in previous years;
- visit up to six universities and carry out focus-group activities with the PGCE mathematics trainee teachers who were currently in schools;
- survey newly qualified teachers (NQTs) concerning their knowledge of and attitude to statistics and its pedagogy;
- conduct interviews with PGCE mathematics course leaders concerning their knowledge of and attitude to statistics and its pedagogy, as well as the extent and form of these within the courses they manage.

By the end of the project we attended a student mathematics engagement day, visited five universities, conducted focus-group activities with over 120 students, surveyed NQTs and interviewed 17 PGCE mathematics courses leaders.

The rest of this report is organised as follows. In Part (II) we report and analyse the data and responses we obtained from the students that were involved in the focus group meetings. In Part (III) we report and interpret the data obtained from newly qualified teachers and in Part (IV) the data and information from PGCE course leaders. In Part (V) we discuss the results and collect together our recommendations. In Part (VI) we re-visit some recommendations the RSSCSE published in 2009 about the statistical knowledge and awareness British school leavers should have.

(II) Student Data and Information

We first report the feedback we obtained from participating in a student engagement day at the University of Birmingham. We used the opportunity to discuss with 25 mathematical sciences undergraduates their perception and knowledge of statistics.

5. Student Engagement Day

To augment the main investigation into statistics within PGCE mathematics courses we took advantage of a student engagement day hosted by the then Mathematics, Statistics and Operational Research Network at the University of Birmingham in April 2011. As part of this day a focus group meeting was held in which the student participants, all on mathematical science-type undergraduate degree courses, were invited to discuss aspects of their experience of statistics as part of their HE courses. Students were from universities at Coventry, Birmingham, Loughborough, Nottingham and Warwick. Not all of these students intended to become teachers of mathematics, but their views enabled us to obtain general feedback about school and undergraduate experiences in learning statistics.

Active, enthusiastic and frank discussions took place under the four general headings: the students' perceptions of statistics; the students' experience of statistics within their HE courses; what constitutes 'good teaching' of statistics; and feedback in statistics.

At the end of the discussions arising from the first two of these headings the participants were asked to record their views. This was repeated after the second pair of headings and the session ended with the participants completing a short questionnaire.

The majority of the students taking part (more than 70%) were on the second or third year of mathematics degrees that involved some statistics modules and the overwhelming majority of them (nearly 90%) considered statistics to be part of mathematics.

The students' exposure to statistics, both before and during their degree courses, was not as we had expected, with half of them indicating that much of their experience consisted of putting numbers into formulae, with context and relevance unclear. This was particularly tedious for them and tended to put them off the subject. We reported this unfortunate state of affairs in the RSSCSE/QC (2006) report. It serves to highlight

the failure by the appropriate authorities to follow up and carry through the recommendations we made in that report.

These discussions lead to our first two recommendations.

Recommendation 1
We recommend that a programme of CPD be developed for Heads of Mathematics in schools and colleges with particular regard to identifying how the problem solving approach (data handling cycle) can best be taught in statistics. This will also be necessary for Heads of Science, Geography, Economics, Psychology and so forth if they, or their staff, are required to teach this material. (RSSCSE/QCA 3).

Recommendation 2
We recommend that a comprehensive range of teaching materials be developed and made available to Heads of Mathematics in schools and colleges to facilitate the teaching of all topics within the statistics and data handling content of the mathematics curriculum. These should be designed to use real data, including that from other subject areas, and should embrace the problem solving approach. (RSSCSE/QCA 4).

6. PGCE Mathematics Focus Groups

The five HE institutions in which we carried out the focus group activities were selected from both pre and post 1992 university institutions. The focus group sessions were led by a facilitator who was one of the authors. The students were divided into groups of between four, five or six and sat around tables in an arrangement that allowed them to discuss issues among themselves when appropriate. Sessions lasted between 2 and 2.5 hours. Participants were invited to talk about their experience of statistics both before they graduated and as part of their PGCE courses – this led to active and enthusiastic discussion.

The focus group facilitator followed a script to enable discussion of four topics which are reviewed in detail in Sections 6.1 to 6.4 below. At the end of the discussions arising from the first two of these headings the participants were asked to record their views in writing. This was repeated after the second pair of headings. The session ended with the

participants completing a short questionnaire. Notes from the focus group discussions are presented in Appendices 3 - 10.

6.1 Topic 1 Perceptions of statistics

The questions posed were:

a) How do you perceive statistics? (Maths by another name/subject in own right?)
b) Does it need teaching separately to maths? (Why?)
c) How should it be taught? (Is it theoretical/practical/other?)
d) What is your attitude to statistics? (From their own studies at school and university).
e) What is the relevance of data within statistics teaching?

The following comprise the key comments relating to a) – e) in Topic 1 from students at all five universities. In appendices 3 – 6 we provide the rough (sometimes verbatim) notes made relating to the responses for topic areas 1(a) – 1(d).

The general perception is that statistics is a set of procedures, a branch of mathematics but could or should be taught separately, especially after GCSE level. It is not much use unless it is applied to other subjects and there must be a reason for doing statistics in the first place. In general, the students felt that one of the biggest challenges within mathematics is teaching the (statistics) skills without having the means to provide context. They felt that statistics is one of the areas of mathematics that is used in real life, but at the same time should be taught within mathematics.

Statistics needs to have a theoretical underpinning but should be taught as a practical subject. However real practical examples are hard to find. There should be examples to engage the pupils and, where possible, they should collect their own data for use in the classroom. Wherever possible a practical investigative approach should be employed in teaching and learning.

When being taught at school the students felt the subject was taught too much as a number crunching exercise and there was too much regimentation of questions related to *doing* statistics. There was a culture of 'pick the formula, drop the numbers in and out comes the answer'. There was not much enthusiasm for statistics at school and it was often taught as a dry and uninspiring subject. 'All you need to do is choose the right formula and put the numbers in' several said.

Those that studied statistics after GCSE felt that any practical aspects of the subject were lost when moving from that level to A level study. Some saw no practical reason for the subject (and did not enjoy it) but others saw it as useful, relevant and practical

(and did enjoy it). Also, there was little connection between GCSE and A level and it did not appear to build from the study for the former qualification - A level was all about statistical distributions and tests with little or no context for learning the tests.

The students felt they very much needed data they could relate to, maybe through problem solving. But they admitted that real data do not behave nicely! Many felt they had been taught statistics badly by uninterested teachers. The experience at university was more positive for some, but just the same for others.

6.2 Topic 2 Experiences within the PGCE

Questions posed were:

a) What is your knowledge of statistics on entry to the PGCE?
b) What is your level of knowledge of statistics in the national curriculum?
c) How much statistics have you picked up during your PGCE course?
d) Where do you get support for statistics pedagogy?
e) Is any differentiation offered in relation to statistical knowledge needs in different application areas?

The following are the key comments relating to a) – e) in Topic 2 from students at all five universities. In appendix 7 we provide the rough (sometimes verbatim) notes made relating to the responses for topic 2.

As is to be expected there is a large variation in knowledge of statistics on entry to PGCE mathematics, with many saying they had little or no statistics knowledge, but others had A level statistics. Of course, some students will have studied a number of statistics modules in their first degrees, but the extent of the practical nature of what they studied is not clear. Note that all students will have done GCSE mathematics, which should have included many practical aspects of statistics. However, many reported that statistics was a rather distant memory.

Several reported that on the PGCE course they learned little of statistics and its applications or indeed its pedagogy. There seemed to be relatively little time set aside for knowledge enhancement or pedagogical study or developments. There seemed to be a preference for algebra or other mathematical topics compared with statistics; statistics pedagogy was expected to be self-taught. Those that recognised this suggested that there should be more focus on training and practice in teaching statistics.

6.3 Topic 3 Experiences on Practice in school

Questions posed were:

a) What is your attitude to statistics from your experience with teacher training in schools? (i.e what influence has the school had on their views of statistics?)
b) Do you observe experienced teachers teaching statistics?
c) How much statistics have you picked up from teaching in schools?
d) Where do you get support for statistics pedagogy?
e) Is any differentiation offered in relation to statistical knowledge needs in different application areas?
f) What has impressed students, if anything re: statistics training?
g) How do you intend to fill-in any gaps in your statistics knowledge during the next two years?

The following are the key comments relating to a) – g) in Topic 3 from students at all five universities. In appendix 8 we provide the rough (sometimes verbatim) notes made relating to the responses for topic 3.

The students reported that many of the teachers in the schools where they were doing their teacher training had little enthusiasm for statistics. A majority said they had not observed any statistics being taught in the schools where they did their teaching practice, and the perception expressed was that it is a rather boring subject – indeed it was regarded as 'a bit of a nuisance' within the subject mathematics. They felt that at school little meaningful was learned about what the subject is for and about, and most seemed to be at a loss to know where to get advice or support for statistics pedagogy.

Others reported that they thought statistics was taught as a process for exam preparation. Any statistics experience they got from teacher training within the school was an accident and not designed.

They felt that their in-school training would not give them a very positive attitude to teaching the subject in their careers, although against that they realised the importance of the subject in trying to get pupils to understand the world around them.

6.4 Topic 4 Good practice in teaching statistics

Questions posed were:

a) How would you define 'good practice' in teaching statistics?
b) Have you observed good practice in teaching statistics?
c) What was the good practice in teaching statistics that you observed?
d) Examples of good practice, how were they taught?

The following are the key comments relating to a) – d) in topic 4 from students at all five universities. In appendix 9 we provide the rough notes (sometimes verbatim) made relating to the responses for topic 4.

Most of the students at all five universities said they had not seen any examples of good practice in their school observations but almost all said that good practice should involve relevant and practical examples. Enabling students to collect their own data was important and it was also important to engage the students in practical statistics activities.

No one reported any coordination of statistics across their schools within or between those subjects that use statistics. A large number said that all cross-curricular statistics is hard to do, but is very important. They also said that appropriate use of technology is one of the keys to *doing* statistics and that they felt that it was appropriate to use software in controlled assessments but reported that they were not given guidance on the use of statistics in this respect.

When discussion on topics 1 and 2 had been completed the students were invited to summarise their views in writing on a hand out. The questions that were on the hand out relating to the four topics are in Appendix 10.

All the sessions ended with the students being asked to complete a questionnaire (see Appendix 11) which was collected as they left.

6.5 Summary of Main Issues

The following is a bullet point list of the main issues written down by the students.

- *Confusion over what statistics is for and about*
- *Cross-curricular teaching is hard*
- *Experience of teaching stats in schools is accident not design*
- *Support for pedagogy is sporadic*
- *Good practice involves practical examples, but most had not experienced it*
- *Some teachers in schools gave the impression to the PGCE trainees that stats is boring and a nuisance*
- *Statistics is part of maths*
- *Statistics should be taught separately from maths*
- *Great variation of knowledge of stats on entry to PGCE*
- *GCSE is where practical stats stops - GCSE and A level very different – the latter is too theoretical*
- *Stats is a set of procedures and formulae into which you substitute numbers*
- *Stats is about real life, but getting real examples is hard*
- *Students should be able to collect and experience their own data*
- *Statistics is not proper mathematics*
- *Large variation in the messages purveyed about the role and use of stats by the PGCE students' teachers in schools and their subsequent tutors at university before they get their undergraduate degrees*
- *Little coordination between statistics teaching within and between other subjects at school*

In the light of the focus group discussions, the written comments from the PGCE mathematics students and the survey they completed after the focus groups, we make the following five recommendations

Recommendation 3
We recommend that the Department for Education should promote the development of a database of resources containing examples of the use of the statistical problem solving approach across the curriculum and make this database available to school teachers. (RSSCSE/QCA 7).

Recommendation 4
We recommend that the Department for Education should promote the development of online CPD designed to demonstrate the use of the resources in Recommendation 3 to school teachers. The CPD should be developed in tandem with the teaching resources. (RSSCSE/QCA 8).

Recommendation 5
We recommend that the Department for Education should give priority to the development of online CPD resources that will enable school teachers to take ownership of their CPD needs by facilitating the transformation of their own case studies and examples into further resources in the style of those in Recommendation 3. (RSSCSE/QCA 8).

Recommendation 6
We recommend that a programme of CPD be developed for PGCE Mathematics Course Leaders and teachers responsible for mathematics training in the proposed teaching schools with particular regard to identifying good practice in the teaching of the problem solving approach (data handling cycle) in statistics. This will also be necessary for Course Leaders in many other subjects, for example, Science, Geography and Social Science as their trainees will be required to teach statistics within their disciplines.

Recommendation 7
We recommend that a programme of CPD be developed for teacher trainees' school mentors in mathematics with particular regard to identifying good practice in the teaching of the problem solving approach (data handling cycle). This will also be necessary for school mentors in other subjects such as Science, Geography and Social Science as their trainees will be required to teach statistics within their disciplines.

(III) Newly Qualified Teacher Survey, Data and Information

In this section we report the results of a survey of newly qualified teachers (NQTs).

7 Survey of NQTs

One important element of the study was to make contact with mathematics NQTs and to try to determine whether they were able to transfer what they had experienced on their PGCE into practice in their first employment as a newly qualified mathematics teacher. A questionnaire was devised which had as much overlap with the PGCE student questionnaire as was appropriate. The questionnaire was made available online using the open source software LimeSurvey and Appendix 12 shows screen snaps of the survey. Seventy PGCE mathematics course leaders were contacted personally by one of the authors by email and they were asked to send a message requesting their most recent cohort to respond to the questionnaire. The content of this email is reproduced as Appendix 13.

The difficulty with implementing this survey was the fact that we needed the course leader to be sufficiently interested in the project to email NQTs. Then, in turn, those NQTs needed to be motivated to complete the online questionnaire. We were unable to get direct access to the NQTs' emails owing to data protection issues.

We recognise the statistical imperfections of the NQT survey, especially the highly self-selected nature of the respondents. Nevertheless, we believe that valuable information has been obtained, especially as the responses are consistent with those obtained from the focus groups of the PGCE mathematics students.

7.1 NQT Responses

There were 27 respondents who, generally, completed all the online questions. Fourteen of the respondents had a degree qualification with mathematics as a substantial component and, for three of these, the mathematics was in combination with another subject. Perhaps surprisingly, nine of the respondents did not have a degree in any science, technology, engineering and mathematics (STEM) subject. Most (23) reported that just over a quarter of their first degree consisted of statistics. Only one teacher said they believed that statistics was not part of mathematics.

More than half of the newly qualified teachers stated they did not know about 'measures of location' on entry to the PGCE yet only about 11 did not know about 'measures of variation'. This seems unlikely (especially in the case of 'location') and might well be because of a lack of familiarity with the terminology used in the questionnaire.

In addition to the comment above, it is noticeable that the students expressed confidence in working with the data handling cycle, data collection, presentation and sampling and surveys, but much less so with other topics. Again we must express some caution about the use of the words 'measures of location' and 'measures of variation'. Note that while more than half confirmed that they knew about 'regression' and did not know about 'inference' on entry to the PGCE - the position is reversed when asked if they were confident in using the technique.

We asked the NQTs to indicate what statistics subject content they had acquired either as part of their taught PGCE course or as part of their teaching practice. Some of the teachers interpreted this question as asking what they studied before the PGCE and others what they were currently teaching. The full list of written responses is provided in Appendix 14.

As is to be expected, there was a marked difference between the proportion of their PGCE courses devoted to mathematics (70% reported more than a quarter) and the proportion devoted to statistics (they **all** reported at most a quarter). This supports the evidence provided by the PGCE students in their focus groups. Appendix 15 provides a convenient comparison between the groups of NQTs and PGCE mathematics students for directly comparable questions on the questionnaires.

The NQTs proved to be confident of their knowledge of statistics and handling data with 11 of the 27 saying it was very good or excellent and 22 saying they knew what the data handling cycle was. Only two of the NQTs said they would *always* use the cycle in their teaching of statistics and so, although the PGCE students in the focus groups were keen that practical examples and applications should be employed, the NQTs are not necessarily regarding the data handling cycle as a means to always deliver these.

Question 9 on the questionnaire explored the NQTs' teaching of a list of topics from the mathematics curriculum. For this question the statistical topics were deliberately 'sandwiched' between the mathematical topics in an attempt to avoid bias. The responses show a stark difference here between the confidence expressed about mathematical and statistical (data handling) topics.

For the remaining five statistical topics in question 9, excluding sampling and surveys, collecting data and presenting data, seven of the teachers expressed a lack of confidence in the topics and the number of teachers who said they were fully confident is less than half that for those expressing the same sentiment for the first three mathematical topics.

It is interesting that the confidence in the final two (mathematical topics) is as low as it is and this could well be due to the deliberate ordering of these questions topics.

(IV) PGCE Course Leader Data and Information

8. PGCE Mathematics Course Leader Survey

We devised a questionnaire to conduct a telephone interview with PGCE mathematics course leaders in England, Wales and Scotland. During the period May – June 2102 one of the authors conducted the interviews with mathematics PGCE course leaders from 17 universities: 14 in England, two in Wales and one in Scotland. We asked 14 questions and these can be found in Appendix 16.

The questions cover the qualifications, knowledge and pedagogic skills of the course leaders as well as the statistics knowledge and pedagogic content of the PGCE courses they manage. We asked them for their views on the role of statistics within mathematics teaching in schools and whether statistics should be taught separately from mathematics, within mathematics or through other subjects. The level of support provided for statistics knowledge and pedagogy, either by their courses or from within the schools where the trainee teachers were located, was also determined.

8.1 PGCE Mathematics Course Leader Responses

Qualifications

Almost all of the course leaders had a mathematical sciences-type degree; indeed the majority of them (10 out of 17) had Pure Mathematics degrees. The remainder had 'Mathematics with' another subject. There were nine with at least a Masters level qualification, and twelve with a PhD. Two did not have a post graduate qualification.

Despite studying mathematics in their first degrees, all but two of the PGCE mathematics course leaders studied less than 10% of statistics in them. Only one tutor studied up to 50% statistics and three of them studied no statistics. The lack of experience and knowledge in statistics could well be an influence on their attitudes to the role of the statistics in mathematics and other subject content at school.

Statistics Knowledge and Pedagogy

When those who had a first degree in pure mathematics were asked to make a judgement about their knowledge and pedagogy of statistics, 80% said this was good or very good for both of these. One person said their pedagogic knowledge was excellent and two said they had little statistics knowledge.

For subject content, none of the PGCE course leaders rated their statistics subject knowledge as excellent, however half rated theirs as very good. Surprisingly, three of the PGCE course leaders declared that they had little statistics subject content knowledge. Subject pedagogy knowledge received much more positive responses from the course leaders, with only two stating that they had little statistics pedagogical knowledge and two rated as being excellent.

Teaching Statistics

Seven of the PGCE mathematics course leaders thought that statistics should *not* be taught in a completely different way from mathematics. Of the negative responses, the reasoning behind them differed somewhat. A few examples are:

- mathematics needs to take statistics into account, as statistics takes the role of the application of mathematics;
- statistics is part of mathematics and should not be treated any differently;
- an enquiry based approach to statistics should be used, not an applied one.

Five of PGCE course leaders believed that statistics should be taught in a completely different way from mathematics. There appeared to be a common view amongst these responses that statistics is an investigative subject, which does not always provide a single clear answer to a problem.

Amongst the 'Yes and No' and 'Not sure' responses, there was a common theme of needing to achieve a balance between mathematics and statistics, with some respondents believing that statistics is, or should be, embedded within mathematics.

Many responses across the board discussed the idea of statistics needing to be taught with context and being much more applied than mathematics per se.

Support for teaching statistics

We found that support for teaching statistics varied greatly between the 17 universities. Many of the PGCE courses run one or two statistics sessions within the year, whereas others leave it up to self-teaching through attainment targets, pedagogy and observations of statistics lessons being delivered in the schools where they receive their training.

Throughout most institutions it appeared that there were tutors available should students need additional hours of support regarding their statistics subject knowledge.

However feedback from many of the PGCE mathematics students in the focus groups indicates they were unsure about getting support for statistics.

When asked how their courses monitored the students' exposure to statistics pedagogy in schools, a worrying number of PGCE course leaders were not aware how this was done, or admitted that the design of the PGCE was slightly flawed because no exposure was recorded.

A few PGCE mathematics course leaders believed that as 18 of the 36 weeks of the course are spent training in school, their students must be, by default, exposed to statistics pedagogy within that time. Although this may be true, it is difficult to assess the extent of exposure with no quantifiable measure. It is also difficult to judge whether any of the methods used to teach statistics to PGCE mathematics students are providing the appropriate experience required for them to then teach statistics themselves.

Allocation of time to teaching how to teach statistics

Ten of the 17 PGCE course leaders responded 'No' to the question concerning increasing the time allocation to teaching statistics. There was strong opinion that other topics would suffer if the between-topic time constraints were altered; there would just not be enough time on the PGCE courses to study statistics in further depth.

However, of the five who said 'Yes', there were concerns that statistics was not being taught well enough in schools. These course leaders concurred with the 10 who said 'No' and thought that it could not be carried out realistically owing to other competing time constraints within the course.

Division of time between mathematics and statistics

The time dedicated to statistics within the PGCE courses when compared with mathematics is between 5% and 50%. This large variation may be a result of the differing opinions on whether or not statistics is part of mathematics. The majority of universities appear to spend less than 25% of their time teaching statistics, with just over 10% spending up to 50% of their time teaching mathematics. The five PGCE course leaders who responded 'Don't know' tended to believe that mathematics and statistics were necessarily integrated and therefore a separation between the two could not be defined.

Teaching Statistics through other subjects and using real data

A large majority (14 in 17) of the PGCE course leaders believed that their students should experience teaching statistics through other subjects, as well as within

mathematics. This was a recommendation of the Smith (2004) report. Indeed, the American Statistical Association (ASA) report *Guidelines for Assessment and Instruction in Statistics Education (*GAISE, 2007) provides research evidence that statistics is more effectively taught and learned using context. The course leaders overwhelmingly believe that cross-curricular links could provide more meaningful ways to teach and learn statistics.

Many course leaders mentioned that although they would like this to happen there would not be enough time in the course to carry it through. This presents a dilemma. However, there are some cross-curricular links (for example between mathematics, science and geography) which could be exploited through collaborative planning. Few disagreed with this, suggesting that subjects should not merge into one another but rather statistics could complement the others. Note that enriching statistics teaching and learning through meaningful contexts, as expressed by the PGCE course leaders, resonates with one of the recommendations of the Porkess Report (2012), namely that there should be coordination between subjects through statistics.

All the PGCE course leaders stated that their courses encourage students to use real data when teaching statistics. This highlights a recurring theme from the responses from the questionnaire, namely that statistics needs to be taught in context, in this case, using real life data.

Unfortunately the PGCE students reported that there was little coordination between statistics and other subjects that use it in schools. Thus, at least for the students and course leaders we spoke to, the laudable aspiration to link between other subjects and their data is not realised in practice. These considerations lead us to the next recommendation.

Recommendation 8
We recommend that a comprehensive range of exemplar pedagogic materials be developed and made available to HE mathematics education, departments and all teaching practice schools to facilitate the teaching of all topics within the statistics and data handling content of the mathematics and statistics curriculum in schools. These should be designed to use real data, including that from other subject areas, and should embrace the problem solving approach.

The Data Handling Cycle

Over three quarters of the course leaders said that their students were always (8) often (1), or sometimes (4) encouraged to teach statistics through the data handling cycle. Just four course leaders seldom or never encouraged teaching statistics in this way. One course leader was unaware of the cycle.

This matches up with the practice we found with the PGCE students we spoke to, who generally did use the cycle to teach statistics, and it agrees with the responses obtained from the survey of the NQTs who also tended to use it in their teaching. (see section 7.1).

Woodage (2011) reviews the role of the data handling cycle in teaching and supports the continued emphasis of the cycle in teacher training. He also notes that it appears to be becoming increasingly marginalised in the secondary mathematics curriculum. This is, in our view, a step backwards and is unfortunate for a 'doing' subject that has the cycle at its very heart.

Statistics and Data Handling as part of Mathematics

Fourteen (over 80%) of the PGCE course leaders believed that statistics and data handling are part of mathematics. In the Scottish Education System, mathematics and numeracy is taught where statistics is part of numeracy. From the limited consultation available from this study, plus the policy towards numeracy, it does appear that the attitude towards statistics could be qualitatively rather different in Scotland. The report by Donalson (2011) and the response to it from the Scottish government (2011) in the form of accepting or partially accepting all 50 of the report's recommendations shows an unprecedented commitment to a collective effort to put excellence in teaching at the heart of Scottish education.

Some PGCE mathematics course leaders emphasised the point that they believed that 'statistics is an application of mathematics' and that it cannot be separated as it uses mathematics in its application; it was felt that it would lack content if it were to be classed as a subject in its own right. Only one PGCE mathematics course leader said that they are 'separate subjects' but agreed that statistics uses elements of mathematics for its application.

It is therefore unsurprising that there is no consistent quantifiable method for measuring exposure of the students to statistics and data handling as such a large number of people believe it to be one and the same as mathematics. From their point of view statistics is already catered for within the constraints of the current PGCE mathematics courses.

One respondent suggested that mathematics and statistics become separated later on in education, which is perhaps where the confusion arises, as up until GCSE and A-levels, mathematics and numeracy are not broken down into elements, such as statistics, pure mathematics, physics and mechanics.

We now make our final recommendation.

Recommendation 9
We recommend that all teachers involved in teaching statistics, including school mentors, should undertake a certified CPD course in teaching statistics similar in content to the two Teaching Statistics modules provided in the International Masters Programme at Plymouth University *Teaching Statistics Pre-university Level Mathematics and Statistics*.

(V) Discussion

In this part we draw some general conclusions from parts (II) – (IV)

9.1 Discussion and student quotes

The emerging picture of the attention paid to statistics pedagogy in British PGCE courses in mathematics is somewhat mixed from the point of view of wanting to improve the quality of teaching and learning at all levels. It is also clear that the attitude to *statistics as a subject* brought by students to university from their experience with studying it at school does not lay very good foundations for either learning or teaching it.

In fact our research supports the broad findings of the RSSCSE/QCA (2006) report and the Porkess (2012) report for the Royal Statistical Society and Institute of Actuaries, namely that the statistics provision in schools, from primary through to A levels, should be improved by giving prominence to the use of statistics as a collection of tools for solving problems using real data and by providing CPD and resources to support teachers in school.

Implicit in the Porkess (2012) report is the unhelpful attitude transmitted by some teachers of statistics in schools that the subject would be better replaced by more mathematics. This is reflected by the attitudes to statistics expressed in our focus group discussions by many graduates training to be mathematics teachers.

We list some typical quotes from PGCE Mathematics students. They are chosen to represent the many written and verbal comments we received from students throughout the investigation.

1. ***I'm clear on the curriculum but not how to teach it (statistics).***
2. ***(Statistics is) used in other subjects, but not given the justice because students don't understand the purpose, usually because the teacher doesn't.***
3. ***The statistics taught within the current curriculum does not reflect what is used in the real world of work. It is an area that needs, in my opinion, to be completely reviewed to reflect the modern use of data.***
4. ***I'm going to make it (teaching statistics) more exciting and practical (than I saw).***
5. ***The general consensus within the school is that statistics is a lesser, boring subject.***
6. ***If you don't understand mathematics you would not be able to do statistics.***
7. ***(Statistics) can be a very dry subject.***
8. ***(Statistics is) boring but useful.***

9. ***Data is what makes statistics enjoyable to students.***

10. ***A lot of teachers (in my school) … see statistics as 'non-mathematics'***

11. ***My class … frequently commented how it (statistics) is 'not real mathematics'***

12. ***Statistics is widely used, for eg in advertising or by politicians, and due to this it is very important. It should, therefore, be taught early on and it should be taught as part of Maths.***

13. ***It's a vital tool for critically understanding the world (including society) around us.***

14. ***I was told by my teacher that statistics is dull and boring, and by my university tutor that it is the vile pornography of Mathematics!***

15. ***Little experience gained of teaching statistics.***

With one or two exceptions, these comments do not, in general, reflect a very positive attitude to either the role of statistics within mathematics or as a useful tool in its own right. They do represent the wide range of opinions that the PGCE mathematics students and the NQTs communicated to us either in writing or verbally.

In carrying out the research we adopted a focus-group approach to talking to the PGCE mathematics students at five selected universities. The evidence of statistics knowledge and pedagogy possessed by the students between these universities was remarkably consistent in showing that there are many areas and topics where these could be improved. The general attitude to statistics was that it was a bit of a nuisance within mathematics, but was recognised as useful in places. Unfortunately, in England at least, this appears to be part of a vicious circle of opinion that starts in school and is continued into and through PGCE. However, in general, these views were not expressed by the PGCE course leaders we talked to. For many the patchy experience of improving statistics pedagogy in schools added to any negativity the students felt about teaching statistics in the first place.

In Scotland it appears that the positioning of statistics pedagogy and knowledge enhancement is improved by the fact that the curriculum embeds statistics within numeracy. The report by Donalson (2011) on Teacher Education in Scotland makes 50 recommendations. Although it is much more general than considering the teaching of statistics within PGCE mathematics-type courses, many of the recommendations, particularly about CPD, including masters-level courses, are much in line with the recommendations we make.

The following is a quote from Scottish Cabinet Secretary for Education and Lifelong Learning in the Scottish government's response to the Donalson report:

> *We cannot afford not to grasp the opportunities set out in Teaching Scotland's Future to provide the best context within which our teachers can learn and develop, and deploy their enhanced skills to achieve even higher standards of learning.*

We have presented evidence that supports the view that wherever statistics is taught and learned it should be done in context so that both the teachers and learners can better understand the world around us. One of the best places to start a new approach to pedagogy for statistics is within British post graduate teacher training courses.

(VI) Benchmarks for Statistical Education

Introduction

From the findings and recommendations in parts (I) – (V) we strongly believe there should be a radical overhaul of the approach to teaching and learning statistics in schools. This has implications for current teachers in schools and for PGCE mathematics training courses.

There is much research evidence that we should change the way statistics is taught. In the UK Stuart (1995) was one of the first to recognise a need to change the way we teach statistics. Garfield (1995) and Garfield and Ben-Zvi (2007) have provided research evidence-supported principles of teaching, learning and assessing statistics. Also, in the United States the American Statistical Association (ASA) produced the evidence-based report *Guidelines for Assessment and Instruction in Statistics Education* (GAISE, 2007) in which there are recommendations about how to better engage learners in statistics. In New Zealand in 2007 mathematics and statistics educators combined forces to produce their school curriculum *Mathematics and Statistics*, in which the content of, and approach to teaching both subjects has been changed to reflect research supported pedagogies.

In the UK, the ESRC-funded research project*, Mathematics learning, identity and educational practice: the transition into Higher Education*, undertaken by Professor Julian Williams, Dr Pauline Davis, Dr Laura Black and Dr Birgit Pepin of the University of Manchester and Associate Professor Geoffrey Wake from the University of Nottingham, focused on STEM subjects (see ESRC, 2012). The researchers found that students were not fully aware of the importance of the mathematical content in the courses they had joined at university, and how to apply mathematics in practice. This is particularly true for statistics because, as we have observed, it is often taught as an application of mathematics or as a selection procedure from a menu of techniques. There is an urgent need to understand other subjects to which statistics can be applied. The report also revealed that students were not always well prepared by the 'teach to the test' teaching style in some schools.

As the present report goes to press, Ofqual are engaged in a national consultation on A level reform. In this section, in setting out our views about the extent and form of statistics that should be taught at school, as well as PGCE mathematics courses, there are implications for the awarding bodies when considering reform in statistics and/or statistical content in A level Mathematics. The OfQual consultation document discusses the idea of benchmarks, internationally comparable post-16 courses of study and minimum expectations of learners. It also encourages that the development of the

material is done in consultation with appropriate learned bodies. The Royal Statistical Society, through its Professional Affairs Committee (PAC), Education Strategy Group (ESG) and its getstats campaign (www.getstats.org.uk) has long campaigned for good practice in teaching statistics. At university level the RSSCSE has recently been involved in bringing real industrial problems data into the HE curriculum (see http://www.rsscse-edu.org.uk/). These methods will soon be applied to data appropriate for teaching in schools.

In sections 10 – 14 we take the opportunity to update the material and recommendations that the RSSCSE first published on its web site in 2009 (see RSSCSE, 2009). We propose the extent, level and form of knowledge of statistics that every school leaver should have. We also propose how the material should be taught to motivate and enable every learner to become more statistically literate and aware. It focuses on the teaching of statistics in the UK education system up to the age of about 19 and is relevant to the current discussions on A level reform.

We first state our views on what comprises statistical literacy and awareness. This is important because they set the scene on the approach to statistical education that we believe should be practised in British schools from primary education through to a school leaving age of about 18.

10 Statistical literacy

Statistical literacy is the ability to appreciate the science and practice of understanding how things work and happen and how to make decisions where data are needed or produced: from deciding which mobile phone to buy to the design of new drug trials; from choosing between facial creams from different manufacturers to examining DNA evidence; from analysing surveys to determine the most popular MP3 player to optimising the mass production of burgers; from facial recognition in digital cameras to modelling the performance of fertilizer on crops. Data and the information they contain will play different roles and be implicit in reaching decisions or understanding of how the world works.

Statistical literacy brings a range of thinking and practical skills that include: knowledge; comprehension; application; analysis; synthesis; and evaluation. It enables a feel for data, including being able to support an argument with evidence, but also being aware of the variety of interpretations that are possible from those data. A statistically literate person will apply common sense to problems and appreciate that information that is

gleaned from data will have uncertainty attached to it and also will be able to assess risk. Statistical *analysis* allows us to determine the extent of any uncertainty or risk.

Becoming statistically literate does not happen overnight; rather, it takes time for the ideas and concepts to mature and experience with applications to develop. It requires the development of an appreciation or understanding that variability is all around us and impacts on everyone.

These attributes provide the background to how statistics should be taught.

11 Levels of understanding for statistical education

It is our contention that here are three levels of understanding that are appropriate for school leavers. These are what they should: (a) know about; (b) be able to identify and critically evaluate; (c) be able to do.

(a) and (b) are crucial in that they establish the broad role of statistics within society. They also help to define good practice in the approach to teaching and learning.

(a) What school leavers should know about

These include:

- simple applications of probability including relative and absolute risk;
- the statistical process of drawing inferences about populations from well-designed experiments or well-chosen samples; that these inferences can be quantified using probabilities and a clear idea of what these probabilities mean;
- the sort of information collected by government and other agencies and how this information is used;
- how statistics is used in industry and commerce, for example in quality improvement processes;
- some current areas in which statisticians are actively working and the sort of problems they are solving; examples can be found in *Significance* and *Chance* magazines as well as the more serious press and other journals;
- the use of statistical indicators to measure performance; their strengths and weaknesses;
- how and why businesses use large data sets;
- how statistics is used in different applied areas such as medicine and crime;

- basic technical terms that might be met in everyday reporting such as *standard deviation* and *confidence interval*.

Note that these are areas where it may not be feasible for the school leavers to do the statistics for themselves, but they should be able to discuss the issues on the basis of what they know.

(b) What school leavers should be able to identify and critically evaluate

These include basic concepts of how statistical arguments are sometimes used to inform or sometimes mislead, especially through advertising, the media and special interest groups. Examples include:

- newspaper and popular magazine accounts of an issue in which statistics was used;
- the use of statistics in other (school) academic subjects;
- officially produced tables of data;
- graphs of data;
- risk assessment.

School leavers would be expected to comment on such things as: the nature of the sampling or experimental design; nature of questions on a questionnaire; whether the written description matched with the numerical or graphical presentation; whether the important points are made; and whether there were any omissions, any misuses of statistics etc.

(c) What school leavers should be able to do

Activities should be focused on the major ideas of statistics, including using target populations and representative samples, using different measurement scales, using probability as a measure of uncertainty, using randomness and variability, reducing bias in sampling and measuring, using inference to make decisions. Real data should be drawn from a wide range of contexts.

The approach to teaching and learning in UK primary schools is not through compartmentalising different subjects. Rather, a holistic approach is taken that involves early learners in thinking about problems and solving them without special regard to the discipline or subject. In fact primary school learners carry out statistical activities within the *plan-collect-process-discuss* cycle as a natural process without really realising it. They compare numbers and consider their context, they make simple tables, they draw diagrams, they interpret all these things in the context of the real problem they are

looking at. It is that early philosophy and ethos that should be re-engaged in trying to make learners statistically literate using the knowledge and skills diagram as a template.

In some sense the methods of teaching and learning at primary school level should be a pre-cursor to the foundation level material proposed in the knowledge and skills diagram.

12 Rationale for the intermediate level material for school leavers

Historically the emphasis of nearly all school statistics courses has been on getting learners to *do* statistics. An intermediate level statistics course that all school leavers ought to have studied should also include material on what statistics (or statisticians) *can* and *can't* do. That is, there should be material on how statistics is used in society, the sort of questions that statisticians answer and how those answers can be interpreted. A well-educated school leaver should know about some of the success stories in statistics and the current areas in which statisticians are making a contribution. They should be aware of the many and various contexts in which statisticians have worked and do work – in many aspects of real life as well as in many different academic subjects. They should be helped to understand both the strengths and the limitations of the statistical way of approaching issues.

Statistics is now a very wide-ranging a subject. On the Royal Statistical Society's web site the following phrases can be found to describe different aspects of the subject.

i. Statistics changes numbers into information.
ii. Statistics is the art & science of deciding what the appropriate data to collect are, deciding how to collect them efficiently and then using them to give information, answer questions, draw inferences and make decisions.
iii. Statistics uses the language & ideas of probability to describe inferences and risk.
iv. Statistics uses samples to get insight into different populations.
v. Statistics is making decisions when there is uncertainty.

There are currently two intermediate level examined school-level courses in statistics available in the UK – from two awarding bodies. Both of the syllabus specifications include an aim that learners should acquire an understanding of the basic concepts of probability and statistics in such a way which encourages confidence satisfaction and enjoyment of the subject in everyday situations familiar to the school leaver and in other disciplines. They also have an aim that school leavers should develop an awareness of the importance and limitations of statistical information to society as a whole. These

seem appropriate as major aims for intermediate level statistical education for all school leavers. It is unfortunate that these two aims are largely under-represented in the *assessments* set for qualifications at this level.

Current school courses in statistics, at least in the UK, concentrate on the *process* implied by 4(iv). This is a major part of the way statisticians think and should not be lost. But the practical problems of getting good samples from target populations should be part of any basic statistical education course. The need to obtain good and accurate information (with its implications for experimental, survey and questionnaire design) is part of this. There is, however, a growing amount of statistical work that does not come easily under this structure.

There are also many areas where the data are there because they are collected routinely – examples include school returns to the UK Department for Education; data collected on hospital admissions and waiting times etc; data collected by large supermarkets when shoppers use their loyalty cards etc. They are typically large data sets with many variables. Some are used to get indicators of performance and construct league tables others are 'mined' to provide commercially useful information. A knowledge and discussion of how these are constructed and of the positive and negative effects, the strengths and weaknesses should be part of basic statistical education.

13 How statistics should be taught and learned

The material should be taught and learned at all levels through an appropriate mixture of demonstration, coupled with using a problem solving approach, similar to the method used by practising statisticians or people carrying out scientific inquiry. The following guidelines (from the American Statistical Association report *Guidelines for Assessment and Instruction in Statistics Education,* GAISE, 2007) provide a simple list that should keep a learner engaged when being taught statistics:

- emphasise statistical literacy and develop statistical thinking;
- use real data (and real world applications);
- stress conceptual understanding rather than mere knowledge of procedures;
- foster active learning in the learning environment;
- use technology for developing conceptual understanding and analysing data;
- use assessments to improve and evaluate learning.

We describe three levels of material for learning: foundation; intermediate; and advanced. The foundation level would be roughly equivalent to what is currently studied

in statistics by UK learners by the age of 14. Intermediate level material corresponds to what is studied by the age of 16 (currently UK GCSE Mathematics), while Advanced level corresponds to what learners study by about the age of 19 (optional content of *some* UK GCE 'A' level Mathematics, Statistics or other equivalent subjects).

Every school leaver should have studied at least to intermediate level.

14 Benchmark knowledge and skills

i. In Diagram 1 we present the knowledge and skills that all school leavers should have. They should be made statistically aware through a core that teaches a strategy for learning statistics through an iterative cycle of activities. These are represented by the five (yellow) rectangular boxes in the centre of the diagram. They are iterative because the *plan-collect-process-discuss* cycle should be revisited if the data originally collected suggest the plan should be modified after discussion.

ii. The next outer ring of boxes in Diagram 1 broadly divides topics into three exemplar areas of application: scientific/industrial; official/business data; and surveys. Foundation level material is represented by the outline of content in the first continuous rectangular band of statistical literacies. The second rectangular band represents Intermediate and the outer band Advanced.

iii. Diagram 1 emphasises the nature of the statistics that school leavers should be able to do at the various levels. At each level they should know about the techniques and sort of questions that might be asked at the next level and about the more complex contexts suitable for the next level.

iv. Moving from *Foundation* through *Intermediate* to *Advanced:*
   a) the contexts will become more complicated and more specialised;
   b) the techniques introduced at one level will become used in more complex contexts and tasks at the next level.

Every school leaver should have the knowledge and skills defined through using the core statistics problem solving paradigm together with the intermediate level material, briefly described within the second outer rectangular band of the diagram. These should be part of their common knowledge skills and attributes for entering work.

Diagram 1 Statistical Awareness for School leavers

Numbers-Data-Information-Collection-Presentation-Analysis-Discussion-Reporting-Decision Making

Advanced **Planning** More complex principles of design of experiments; more complex survey techniques; input for models with uncertainty ***Advanced***

Critically evaluate - Functional Literacy

Understand and discuss getting information from large and complex data sets; understand false positives & false negatives; quality improvement decisions for business and industry

Intermed **Planning** Sampling for a purpose; scales of measurement; devising suitable questions for statistical investigation; stratified sampling, paired comparison in designing experiments. Deciding what to measure. ***Intermed***

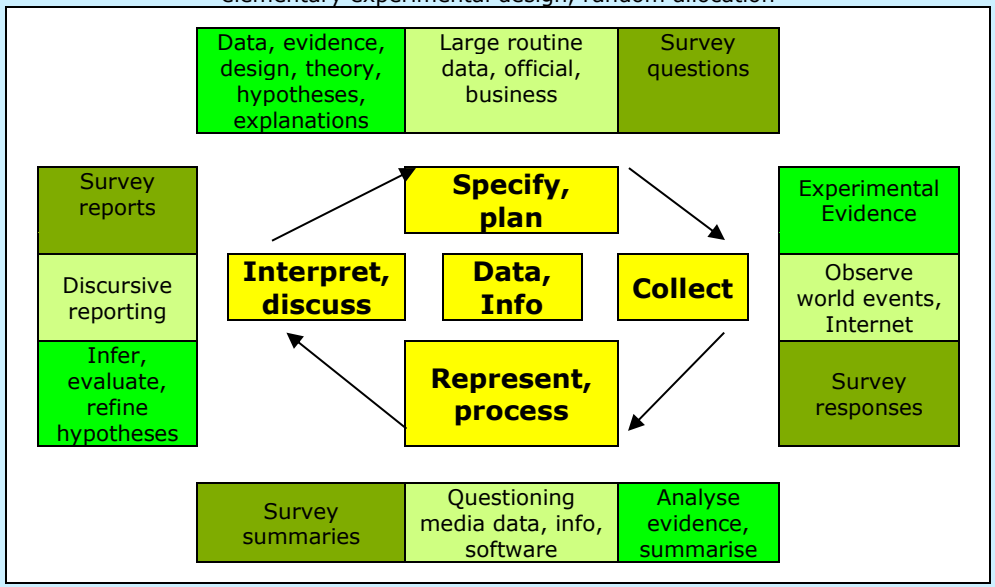
Critically evaluate - Functional Literacy

Evidence based decisions; findings in the context of problems and publicly available statistics; interpret-ing social data and several related variables; reading quality improvement graphs and charts

Foundation **Planning** Simple ideas of data variation; ideas behind sampling; random samples; elementary experimental design, random allocation ***Foundation***

Critically evaluate - Functional Literacy

Simple inference from charts, diagrams, graphs; Bivariate data; Reading tables; gleaning info from print and electronic media



Data production

Data loggers for the sciences; data and info from the Internet & media; use of web forms; data scrutiny; data for quality control

Foundation **Analysis** Functional ICT: software for charts, diagrams, graphs. ICT for elementary measures of location & variation for simple data sets. Showing correlation and regression. Uncertainty & elementary probability calculations, including risk ***Foundation***

Intermed **Analysis** Functional statistics: measures of location, variation for more complicated data sets. Probability models. Connections between correlation, causality and confounding. Fitting regression lines. Use of ICT to draw and analyse data, elementary simulation. Assessment of relative and absolute risk. ***Intermed***

Data production

Survey making and question-naire design using the Internet; getting useful data from other schools inside and outside the UK; getting data from scientific and observation studies

Data production

Functional data production from designed experiments, complex surveys. Use of ICT and simulation methods to produce data from probability distributions Online data from business and industrial processes

Advanced **Analysis** Advanced functional statistics: hypothesis testing, comparing measures of location, variation, probability, models with uncertainty. Presenting information from large data sets and in complex tables. Using probability distributions. Use of ICT for simulating and calculating probabilities. ***Advanced***

All school leavers should have knowledge and skills from doing the iterative cycle (yellow boxes) using material at intermediate (intermed) level

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Appendix 1

Numbers of accepted applicants for PGCE Mathematics by HEI 2007-2011

(adapted from Annual Statistical Reports of the GTTR at www.gttr.ac.uk)

Institution	2007	2008	2009	2010	2011
University of Aberdeen	24	9	18	16	12
Anglia Ruskin University	8	8	12	16	16
Bangor University	18	15	21	18	19
University of Bath	13	12	17	18	15
Bath Spa University	12	5	24	15	21
University of Bedfordshire	8	19	33	20	10
Birmingham City University	23	27	34	24	24
University of Birmingham	32	34	57	40	42
Bishop Grosseteste University College	10	12	12	14	4
Bradford College	4	3	6	4	9
University of Brighton	50	44	42	47	20
University of Bristol	29	30	26	29	31
University of the West of England, Bristol	22	19	29	14	31
Brunel University	18	22	30	29	36
University of Cambridge	15	14	18	21	20
Canterbury Christ Church University	23	23	37	29	30
Cardiff Metropolitan University	25	25	26	21	23
University of Chester	20	29	33	33	32
University of Chichester	17	12	14	6	17
University of Cumbria	*24	27	18	41	13
University of Dundee	5	7	3	9	9
University of Durham	21	22	25	21	22
University of East Anglia	17	23	24	24	22
University of East London	23	20	28	34	32
Edge Hill University	38	43	60	51	41
University of Edinburgh	30	24	32	15	15
University of Exeter	30	29	31	35	30
University of Glasgow	31	25	28	22	22
University of Gloucestershire	11	7	13	7	9
Goldsmiths, University of London	10	20	33	21	24
University of Greenwich	20	16	19	16	26
University of Hertfordshire	13	11	17	18	14
University of Huddersfield	6	5	14	13	8
University of Hull	24	9	25	13	12
Institute of Education, University of London	50	31	58	61	53
Keele University	-	7	2	13	9
King's College, University of London	24	34	30	27	31
Kingston University	19	19	26	22	19
University of Leeds	40	32	43	49	35

Appendix 1 (continued)

Institution	2007	2008	2009	2010	2011
Leeds Trinity University College	13	15	21	29	28
Liverpool Hope University	39	33	45	44	41
Liverpool John Moores University		10	33	10	21
London Metropolitan University	19	26	18	22	16
London South Bank University	13	15	22	16	15
University of Manchester	37	47	47	48	46
Manchester Metropolitan University	58	42	52	38	52
Middlesex University	22	30	27	26	24
Newcastle University	26	22	28	22	20
Newman University College	-	-	-	-	18
University of Nottingham	37	34	44	58	42
Nottingham Trent University	25	22	23	29	37
Oxford University	29	31	29	30	30
Oxford Brookes University	28	23	25	24	24
Plymouth University	9	11	18	12	13
University College Plymouth, MARJON	19	12	18	7	9
University of Portsmouth	16	13	23	17	13
University of Reading	17	13	25	20	24
Roehampton University	13	15	21	20	23
University of Sheffield	21	26	30	24	25
Sheffield Hallam University	30	38	58	31	48
University of Southampton	28	46	54	43	43
St Mary's University College	32	34	47	39	37
Staffordshire University	-	-	-	-	8
University of Strathclyde	79	46	54	44	37
University of Sunderland	18	14	13	20	13
University of Sussex	23	15	20	21	21
Swansea Metropolitan University	^45	27	37	43	42
University of Warwick	25	38	36	43	26
University of Wolverhampton	28	19	48	39	22
University of Worcester	13	19	22	21	21
University of York	24	23	32	25	31
TOTAL	**1538**	**1553**	**2019**	**1821**	**1756**
SCITT	107	46	59	60	55
	1645	1599	2078	1881	1811

*St Martin's Lancaster, in 2007 ^ Swansea Institute of HE in 2007

Appendix 2
Table A2.1
Numbers of accepted applicants on PGCE courses 2000-2011 by sex and subject

COURSES		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mathematics	Male	603	684	841	1020	1173	1107	943	872	846	1095	929	856
	Female	559	627	661	838	886	959	892	773	753	983	952	955
	Total	1162	1311	1502	1858	2059	2066	1835	1645	1599	2078	1881	1811
Biology	Male	281	292	301	327	277	326	269	255	285	293	338	227
	Female	625	621	635	611	626	629	628	626	581	580	607	505
	Total	906	913	936	938	903	955	897	881	866	873	945	732
Chemistry	Male	199	208	219	226	226	255	224	216	219	229	292	336
	Female	211	261	247	275	289	312	327	287	289	349	385	514
	Total	410	469	466	501	515	567	551	503	508	578	677	850
Combined Science	Male	256	301	307	382	400	438	415	438	442	503	355	210
	Female	466	442	406	469	514	607	583	591	626	616	438	221
	Total	722	743	713	851	914	1045	998	1029	1068	1119	793	431
IT	Male	206	273	402	537	586	604	504	502	476	568	530	348
	Female	214	244	292	337	360	377	340	270	255	310	298	231
	Total	420	517	694	874	946	981	844	772	731	878	828	579
Physics	Male	147	175	237	282	300	315	258	247	235	281	340	416
	Female	77	67	86	117	108	107	100	106	85	127	157	207
	Total	224	242	323	399	408	422	358	353	320	408	497	623
Psychology	Male	-	-	-	-	-	-	-	-	7	11	12	3
	Female	-	-	-	-	-	-	-	-	45	59	42	29
	Total		-	-	-	-	-	-	-	52	70	54	32

Table A2.1 (continued)

Numbers of accepted applicants on PGCE courses 2000-2011 by sex and subject

All Sciences	Male	1692	1933	2307	2774	2962	3045	2613	2530	2510	2980	2796	2396
	Female	2152	2262	2327	2647	2783	2991	2870	2653	2634	3024	2879	2662
	Total	3844	4195	4634	5421	5745	6036	5483	5183	5144	6004	5675	5058
Business Studies	Male	179	188	229	255	277	310	262	262	272	285	232	130
	Female	237	291	319	367	416	407	373	355	320	340	332	172
	Total	416	479	548	622	693	717	635	617	592	625	564	302
Citizenship	Male	-	-	3	67	90	76	82	74	76	71	68	62
	Female	-	-	5	102	120	145	129	146	138	152	151	97
	Total	-	-	8	169	210	221	211	220	214	223	219	159
Geography	Male	409	413	409	434	425	414	382	275	275	288	286	251
	Female	529	544	569	563	585	592	496	466	386	475	452	424
	Total	938	957	978	997	1010	1006	878	741	661	763	738	675
Social Studies	Male	37	79	89	35	30	36	18	20	30	33	27	21
	Female	112	155	172	104	132	130	101	83	123	139	129	58
	Total	149	234	261	139	162	166	119	103	153	172	156	79
Social Science	Male	625	680	730	791	822	836	744	631	653	677	613	464
	Female	878	990	1065	1136	1253	1274	1099	1050	967	1106	1064	751
	Total	1503	1670	1795	1927	2075	2110	1843	1681	1620	1783	1677	1215
All courses	Male	2317	2613	3037	3565	3784	3881	3357	3161	3163	3657	3409	2860
	Female	3030	3252	3392	3783	4036	4265	3969	3703	3601	4130	3943	3413
	Total	5347	5865	6429	7348	7820	8146	7326	6864	6764	7787	7352	6273

Appendix 3

In this appendix we provide the rough notes made relating to the responses from topic area 1(a).

Topic 1(a) Is it part of mathematics?

University 1

About a third of the students saw statistics as part of mathematics, with another third believed it was a subject in its own right. The remainder used terms like "it is just a set of procedures", "it is a branch of mathematics" or "it is wider than mathematics". Most could be interpreted as statistics being part of mathematics).The overall impression from the discussions was that most of the students thought of statistics as being part of mathematics.

University 2

Nearly all the students saw statistics as a part of mathematics and held this view quite strongly although one or two described it as linked to mathematics.

University 3

Just about all the students saw statistics as a part of mathematics. They mainly took the view that it was a subject which was used extensively in other subjects and did not really stand-alone (a subject in its own right but not much use unless applied to other subjects). As far as teaching goes they were less consistent in their view.

University 4

Is handling/analysis of (numerical) data (13) Too theoretical at present (5) Interpreting/drawing conclusions (4) Can be manipulated (4) Important that statistics is understood (3)

University 5

Yes, definitely part of mathematics. One of the areas of maths that is used in real life.
Use it more, without realising it. Bombarded with statistics in newspapers and on TV.
Need to have some understanding of statistics to tell when they are not lying but being selective about the stats they show you in Newspapers etc. Part of maths as you are analysing numbers and trying to find trends and patterns. Not always numbers, difference between qualitative and quantitative. Not just maths but does use logical reasoning. Categories of maths. Not exact, open to interpretation.

If you removed all the maths from statistics would there be any intellectual content?
Becomes more psychology then mathematics, interpreting the qualitative data. The psychology is why people are saying what they are saying and interpreting their words.

Interpretation an important part of statistics?

Yes, you need to be able to interpret it to understand it. So is that mathematics? Yes, reasoning, logic. Can't have stats without maths. Depends on your definition of maths.
Stats is maths. Maths is a big umbrella which stats comes under. What you do with the data is the maths.

Appendix 4

In this appendix we provide the rough notes made relating to the responses from topic area 1(b).

Topic 1(b) Does it need teaching separately to mathematics?

It is mathematics (1) Teach separately (2) Teach separately from A level onwards (2) Teach as a subsidiary to/in other subjects due to its wide applicability (1) For other subjects teach as eg A level in Statistics for ... (1)

University 1

When teaching statistics a large majority felt it should be taught with mathematics up to GCSE level. Then there was a fairly even split between A level being taught as a separate subject or within mathematics.

University 2

When it came to teaching there was an equally strong view that it should be taught as part of mathematics at GCSE level, but then views varied with some seeing statistics as needing to be taught separately at A level whilst some saw it as still being taught as part of a mathematics syllabus/module (this did not come out so clearly in their written comments).

University 3

About half felt statistics should be taught along with mathematics whereas the other half felt there was a break point after GCSE when statistics should be taught separately. The word "linked" came up a lot in the discussions and also appears in written comments.

University 4

It is mathematics (1) Teach separately (2) Teach separately from A level onwards (2) Teach as a subsidiary to/in other subjects due to its wide applicability (1) For other subjects teach as eg A level in Statistics for ... (1)

University 5

Taught in school. Need it in real life, we do this to understand graphs etc. wouldn't come under another subject. Although statistics appears in other subject areas, need maths understanding. Science also uses same skills, experimental data analysis as part of the process of doing an experiment. Pick up the skills in science. The need or desire to learn anything is necessity driven, if there is a situation in science that necessitates the need for data handling, then they will learn how to do the data handling.

One of the biggest challenges of mathematics is teaching the skills without necessarily having the context. PE data handling exercise. Put the data in context and used data, so there is a reason for the data. Children really enjoyed it; they could focus on what they wanted. Project based topic. Pie-charts, asked to design own question. They posed the question and went through the data handling cycle. Project works well as the pupils are given decision about what they want to do and the questions they want to answer. How they display and analyses the data to show, or not, what they wanted. Year 7 in one school did an entire half term on a statistics project on healthy living. Linked the project with food tech.

Appendix 5

In this appendix we provide the rough notes made relating to the responses from topic area 1(c).

Topic 1(c) How should statistics be taught?

University 1

When it comes to teaching statistics, their starting point was that it was a practical subject and should be taught as such. What they meant was that real-life and/or relevant examples and data should be used as a means of engaging students. Having said this, about a third did mention the need for a proper theoretical underpinning to the subject as part of a practical approach. In the discussions (but not on the feedback forms), they did say practical examples were not easy to find in some areas such as measures of location and spread (!!!). As a group they did feel it was good for students to collect their own data when possible.

University 2

When it comes to teaching statistics, they were very vocal about its practical nature. This meant that they saw using real-life and/or relevant examples and data as being key to engaging with their students. One or two mentioned the need to set a solid base of theory first but none felt it should be taught just as a theoretical subject. Many commented on the dearth of "real" examples in textbooks (but again this does not come across in written comments). Some went further and suggested students should collect their own data (at least some of the time) to give context.

University 3

When it comes to how statistics should be taught, the discussions were very strongly in favour of a practical approach where students ideally collect their own data, analyse it and interpret the results. However, in the written comments this came across much less clearly with the students tending to highlight only part of the above.

University 4

Number crunching exercise at present which is wrong (5) Should be taught with real-life examples (5) Use examples drawn from across different subjects (1) Should be taught across the full curriculum (1) Should link into other subjects/contexts (2) Should be investigation-led (4)

University 5

Had a simple scheme to follow, such as draw and interpret pie charts, scatter plots.
Looked at a few exam questions. Data handling cycle was mentioned just by one student with year 9 class. Used the data handling cycle to stop it coming to a dead end, present the data then what do you do with it? Data handling cycle stops this; it is something which is never really finished. There was a session on the data handling cycle within the course, although session wasn't strictly about statistics. Told if teaching statistics to use the data handling cycle. Students had seen something on teachers TV about the data handling cycle. Mentor in school advised a student to use the data handling cycle. Use the data handling cycle instinctively. Pupils need to understand why they are constructing graphs, pupils need to be able to analyse and draw conclusions from it so therefore it leads to their understanding. Assessment different to how it is taught.

Investigative work is done with years 7-9, year 10 and 11 are regimented into ‘can you draw this graph, can you draw that graph?’

Appendix 6

In this appendix we provide the rough notes made relating to the responses from topic area 1(d).

Topic 1(d) Experience of being taught statistics?

University 1

Their experiences of being taught statistics were fairly uniform at school. Almost everyone said they were taught statistics badly by uninterested teachers. Their university experience was rather more positive with a number saying it had changed their attitude to statistics but again a number felt their experience at university had been no better than school. As mentioned earlier, there were also comments about the mechanistic approach that seemed to be adopted to statistics with a culture of pick the right formula, put in the numbers and get the answer, with no interpretation at all.
A lot said in the discussions that they did not feel they had a good subject knowledge of statistics beyond GCSE (yet this clashes with their questionnaire responses to some extent).

University 2

Their own experiences of studying statistics were mixed. Many said they enjoyed statistics but did not articulate clearly why, in spite of being asked. Indeed, in the discussions their enthusiasm for statistics was less marked than in their written comments. Others said that whilst it was a useful subject it was a dry and uninspiring subject where all you needed to do was choose the correct formula and put the numbers in. One comment was that it lost its practical aspect when you moved from GCSE study to A level.

University 3

Their own experiences of studying statistics again split about half and half in the discussions. One view was that it was taught too theoretically/purely and they had not enjoyed it, yet the other view was that it was a very useful and relevant subject and they had enjoyed it. The latter group tended to be students who had experienced some practical element to how they had been taught statistics. The written comments do not give as strong an impression of liking statistics as came across in the discussions.

University 4

Potential to be interesting (1) (Also covered by comments about number crunching above)
What is the relevance of data within statistic teaching?
Key element

University 5

One student really enjoyed statistics, she had a good teacher that made it interesting. It was different from core maths, and it was fun! Another student was encouraged away from stats and was encouraged to take applied as student's maths was stronger. This student had not done statistics since their GCSE. No connections between GCSE stats and A Level. The A level didn't build upon GCSE. Did psychology degree and understood the need for stats but not within the A level course.

A level is about probability tests and distributions.

Some did the coursework element and they enjoyed that aspect. There was no context for learning the tests in A level. It was better learned in biology rather than in stats on its own. A level was just the process part of the cycle. Could depend on the teacher, not just there is the theory go and practice. Year7-9 could possibly finds stats more interesting and would want to carry on with it in years 10 and 11. There were students who did no stats in their degrees. Felt statistics was a lot of number plugging. Felt more comfortable teaching subjects such as algebra then statistics. Students have taught little statistics whilst on the course.

What is the relevance of data within statistics teaching?

Need the context to hook the students in, maybe not so much at A level or high ability levels. Doing abstract maths to a mixed ability set is asking a lot of them. Data they collected and own. Get involved. Trust the data. What is the point of this? Not take things on trust. Don't need the teacher to say there is an application for the data. Data they can relate to. Needs a problem to solve or a question they are trying to answer. If an unexpected result comes up from their own data they are more likely to want to know why and look at it further, highlights the different techniques and graphs and why each one is used. Real data doesn't behave nicely.

Appendix 7

In this appendix we provide the rough notes on topic 2 from PGCE students at five universities.

Topic 2. Experience within PGCE

University 1

Their knowledge on entry was mixed. There were only a few mature entrants who had work experience and all said their knowledge was poor. They either had little experience of being taught statistics or could not remember it (like others before). About 50% of the group had some experience of statistics at A level. A couple had done statistics degrees. When responding to their level of knowledge, over 50% of those that did respond said poor/quite poor. Only three felt their knowledge was good on entry to the PGCE.

When we discussed the national curriculum there was prolonged silence from some. Eventually some ventured views about the content but most (in spite of pushing) talked in generalities like "my knowledge is adequate" without saying what adequate was. This was reflected in their written comments where a third said their knowledge was adequate, a third said good or very good and the remainder said variously poor, unclear or average.
Given this is aPGCE course that does not claim to teach subject material, it is not surprising most said they had learned very little or no statistics on the PGCE. There were, however, a group of 10 who did feel they had learned something about probability from a session within the PGCE.

In discussions they were unclear about support for pedagogy. However, once they had thought about the usual sources were written in their comments. NCETM came out top (about 50%) but almost as many mentioned online resources generally and teachers on placement. Only a few mentioned mentors/tutors or textbooks.

Finally, when asked about different approaches to teaching statistics in different subject areas, there was a general view that the teaching of statistics should be the province of those areas (except one person who had been taught statistics in Biology and felt it needed someone who knew statistics to teach it). Their written comments, where made, suggest a strong feeling for teaching the statistics within the subject area/context.

University 2

Their knowledge on entry varied quite a lot. There were five or six mature entrants who had work experience but either had little experience of being taught statistics or could not remember it. Most of this group claimed quite a bit of statistics experience from work but when pressed my impression was this was mainly "looking at numbers" with little analytical work. About 50% had some experience of statistics at A level. Only one or two seemed to have any significant experience of statistics at University level. Three said they had little or no statistics knowledge on entry to the PGCE.

When we discussed the national curriculum most talked (and wrote) about data handling modules and some about descriptive statistics. One or two described their knowledge as good and one or two as limited. Others did not venture an opinion but in the discussions nearly all claimed they were confident (or very confident) about their statistics knowledge.

Given the nature of the PGCE in mathematics at this university it is not surprising most said they had not learned much statistics on the course. In one or two ventured areas

where they had developed their knowledge, these being graphs (in teaching) and analysing school data/performance measures (for schools).

They struggled with support for pedagogy but eventually raised a number of sources. More or less equally represented were internet sources, mentors and colleagues, with textbooks and "in school" also mentioned. More than one or two said they did not know.
When asked about different approaches for statistics in different subject areas there was a general view that the teaching of statistics should be tailored or left to those areas. This does not come out at all in their written comments.

University 3

Their knowledge on entry varied but most felt they had a good knowledge, this coming mainly from degree level study. There were some mature entrants who had work experience that involved use of statistics and they were very positive, both about their knowledge and about the importance of statistics. Two students said their knowledge was a distant memory or non-existent.

The national curriculum knowledge is perhaps an unfair question at this stage of their training but about half, in the written comments, claimed to know what was covered. In the discussions they were not able to say what was covered beyond data handling, probability and histograms.

PGCE coverage of statistics is not a relevant question to these students.
With support for pedagogy they were very vociferous. All of the following were mentioned both in discussions and in written comments. Internet sources, mentors, tutors, other students and textbooks.

When asked about different approaches for statistics in different subject areas there was little discussion What little was said leant toward teaching within the context of other subjects. Only three responded in their written comments and these did not really address the issue (one did say within specialist subject).

University 4

a) What is their knowledge of statistics on entry?

   A level study (12)
   Degree modules (11)
   GCSE Data Handling (5)
   Work experience (2)
b) What is their level of knowledge of statistics in the national curriculum?
   Data handling in NC (2)
c) How much statistics have they picked up in their PGCE?
   Citizenship sessions (4)
   CensusAtSchool (3)
   Few sessions (1)
   Largely ignored (4)
d) Where do they get support for statistics pedagogy?
   No responses
e) Is any differentiation offered in relation to statistical knowledge needs in different application areas?
   No responses

University 5

- Not really taught pedagogy on the course.

- Taught who to teach generally, but not specific topics.
- About 4 sessions were delivered about statistics.
- Focused on misconceptions then actual teaching.
- Sessions were better when teachers spoke about actual experiences.
- Got advice from the teachers on placement when asked or look in a textbook rather than look back at university notes.
- Had to ask teacher what the students needed to know and how to teach it on certain topics.
- If the university did teach how to teach the subject, the PGCE students would find it hard to find their own way of teaching the subject. This university encourages independent learning.
- Should be encouraged in university as possibly need five different ways to teach a subject to a single class and finding five ways to do this on your own is difficult.
- Give a broad range of ways of teaching which would be gained after 5 years of teaching, need "skills in our armoury".
- Students do share their experiences. There is little specific time for this set side.
- There is a discussion board (blackboard), but not many use it.
- Felt there should be more focus on training in teaching and practising teaching. Not being thrown in at the school doing everything from the ground up in one go.
- Some (school) students prefer stats to algebra. This could depend on which topic it follows.
- Results for the data handling unit from one student were higher than that of algebra. (Year 8 class).
- Nice and visual, graphs etc. end up with something to see, students like the colouring. Achieve something at the end.
- Some used *CensusAtSchool*. Collected own data and used secondary data from *CensusAtSchool.*

Appendix 8

In this appendix we provide the rough notes on topic 3 from PGCE students at five universities.

Topic 3 Experience whilst on practice in school

University 1

Most had only had 6-8 working days in schools so felt unable to answer questions in this area with any authority. In discussions about 60% said they had seen statistics taught whilst on placement. This was not borne out by their written responses where about 60% said they had seen no statistics being taught. Where they had seen statistics lessons they did not seem to have had a positive experience in general. Whilst some said the lessons were OK, others said the lessons were boring, teachers unenthusiastic or disinterested, although these opinions were moderated by their saying it was the start of the subject.

Only four felt they had learned anything meaningful about statistics when at school, three saying probability and one saying mean, median and mode.
For support with pedagogy, of those that responded, the same set of responses as earlier were given. Proportionately, more cited textbooks, teachers and mentors/tutors, with online resources about the same. Mainly multiple replies.

In the discussions there was a general recognition that there would be differing needs and statistics should be taught from within the subject (this did not come across at all in written comments). (Exactly the same as at University 2).

There was very little in the way of responses (in discussion or written) about what had impressed them about statistics training. Overall view was that it was too early. However, there was also a view that there was very little and that it was boring. Two students did feel that they had gained lots of "fun" ideas" for teaching statistics.

When it came to being asked about filling knowledge gaps, there seemed to be some concern that they might have gaps! However, they did then admit they might need help and cited textbooks, experienced teachers and online resources in equal measure. One mentioned peers. Written comments mirrored this but, as mentioned above, many did not provide comments in this area.

University 2

In the discussions about 50% seemed to suggest the school had little or no influence on their view of statistics and this was similarly reflected in written comments. One or two mentioned the emphasis on targets and performance criteria within their schools. Very few observed teachers teaching statistics (We got the impression most PGCE mathematics students went into school and taught without first observing lessons). Of those (7) that did observe statistics lessons, these were all data handling topics except for one A level lesson.

A sizeable number said they had picked up no new statistics from their school (with many saying they knew it already so nothing extra picked up). Fewer felt they had developed their knowledge of data handling with one adding survey design.

For support with pedagogy, most seemed at a loss as to where to seek help. There were multiple answers from a few of the students suggesting they would approach colleagues in school (most common), use the internet or its resources, reflect on University studies/experience, use own research and PGCE (least common, only one response).

Only one student mentioned different needs of other areas where statistics formed part of the subject (psychology). In the discussions there was a general recognition that there would be differing needs and statistics should be taught from within the subject (this did not come across at all in written comments).

It was difficult to get any responses about what had impressed them about statistics training as this did not feature formally in their course. Many said "nothing" but one or two mentioned practical elements including *CensusAtSchool*.

When it came to filling in knowledge gaps I think their start point in discussions was that they would have no or few needs in this area. However, they did mention one or two areas and this was expanded upon in their written responses. Again multiple responses were given with colleagues, internet and self-teaching figuring most commonly. Others mentioned using books, exam board resources and one is taking a statistics course!!

University 3

No school practice yet so only area we could really cover was support for pedagogy. In discussions and in written comments there were multiple responses. These mirror earlier comments but, in addition, observation of other teachers and talking to other teachers were mentioned.

University 4

a) What is their attitude to statistics from their experience with teacher training in school?
   Taught as a 'process'/examination preparation (2)
   Need to relate to real-life examples, no convenient textbook (5)
b) Do they observe experienced teachers teaching statistics?
   Yes (2), No (3)
c) How much statistics have they picked up from teaching in schools?
   Very little (5)
   Expected to teach it with little/no advice (3)
d) Where do they get support for statistics pedagogy?
   Opportunity to teach S1 (1)
e) Is any differentiation offered in relation to statistical knowledge needs in different application areas? No responses
f) What has impressed students, if anything re: statistics training? No responses
g) How do they intend to fill any gaps in their statistical knowledge during the next two years? No responses

University 5

- Peer review depends on what point the teacher was in the scheme of work.
- Need to learn how to teach the basics well at an early age for each topic to make the teaching of the same topic easier later on. Not ever covered on the course but one student felt it was fundamental stuff that you need to be able to teach. The first introductory lesson on a topic will affect the pupils' attitude towards that topic later on.
- Didn't pick classes on the topic they were teaching, went for example to see a teacher who was good at classroom management.
- Some did observe statistic lessons, but by accident not by design. One student did decide to go and observe a lesson on probability.

Appendix 9

In this appendix we provide the rough notes on topic 4 from PGCE students at five universities.

Topic 4 Good practice in teaching statistics

University 1

Given their general experiences of being taught statistics it is hardly surprising there is not a lot to report here. They did feel that good practice required the use of relevant and practical examples/data. See below for a couple of examples. They emphasised the need for engagement but were not clear how to get it. Most said they had not seen any examples of good practice. What they were positive about was the need for teachers to be enthusiastic about the subject.

Some specific examples of good practice identified were:

- Probability exercise where teacher put labels with probabilities round room (almost certain, evens, highly unlikely etc), then quoted events and asked students to go to descriptor they thought described probability of event.
- Year 7s throwing wellies and measuring the distance thrown. Then, as a group, summarising the results and forming a cumulative frequency curve in playground, the students being the curve. (Not entirely sure how this was done).
- Histograms of shoe sizes in class.

More general comments were:

- Teachers using students to find data, then analyse it.
- Teaching concepts in non-technical ways eg find 'middle' number rather than starting by defining median.

University 2

Rather disappointing lack of response both in the discussions and the written comments. They were clear good practice involved use of relevant and practical examples/data. See below for a couple of examples. They talked a lot about getting engagement but not how to get it. Most said they had not seen any examples of good practice (not surprising given earlier responses about observation but not entirely explained away eg own experiences of being taught?).

Only three gave examples of what was good practice. These were

- the practical NRich tasks run throughout the year
- getting students involved in lessons and
- interactive lessons in probability and data collection (asked student to give more details in written comments but this did not happen).

Two specific examples were:

- Year 8 topic covered whole cycle from designing a questionnaire to collecting data to analysing the data and producing a report.
- Collecting data about themselves / generating own data and *CensusAtSchool* was mentioned.

University 3

- In the discussions we were told a few stories of examples of good practice they had experienced. These were a little vague and in spite of asking the students to expand on these in their written comments, they didn't. One example was measuring all the

heights in a class and analysing the results. Another, more vague example, involved use of different resources, group work and investigation. It was a probability exercise but the student could not remember any more about it.

- They felt good practice involved practical and relevant examples/applications. Collecting your own data was important and it had to be something that engaged students. Honest and common sense were mentioned.

University 4

a) How would they define 'good practice' in teaching statistics?
   Teaching for understanding of concepts (1)
   Active/interactive lessons (1)
   Letting students discuss ideas/ think for themselves (2)
   Project work/context/drawing conclusions (4)
   Establishing understanding of uses and limitations of statistics (1)
b) Have they observed good practice in teaching statistics?
   Need teachers committed to the subject (1)
   Explaining relevance of statistical concepts in real-life (1)
   Bad practice of teacher 'made' to teach statistics when they did not want to (1)
c) and d) merged together
   What was the good practice in teaching statistics that they observed. Examples?
   Not number crunching, use real data (10) (This should probably be in a) above)
   Practical work (4) (This should probably be in a) above)
   Throwing tennis balls into box to illustrate Binomial Distribution
   Standards Unit example of simulating probabilities
   Teacher had collected whole year data re: heights etc for students to compare (familiar?)
   Not sure what this involves but a teacher's chair goes missing and the students use deduction to work out who did it (from amongst teachers and students)!!!
   None seen (2)

University 5

- Make it functional, creating a hook for the students.
- Use the data handling cycle. Purpose for doing it.
- Make statistics functional for the pupils there and then, not when they're in business when they're 30.
- Interesting lesson with high ability class about how stats is twisted and need to read between the lines. How you interpret, example used in the class was the Asda advert, pie charts in newspapers.
- Limitations of charts, making sure students understand why and how data can be misrepresented.
- Have the students received any guidance on the range of application for stats? No, there is the maths4grads website with some application, but for all of maths not just stats.
- Some university websites for maths their departments have applications of where stats are used in industry and there are some good links, good of the higher GSCE pupils.
- No communication of data across subjects.
- One student in one school found that the maths and ICT departments were running parallel data handling projects but no-one knew. There was no co-ordination. Pupils had the same lesson twice in a row.
- One student found in a smaller school, teachers spoke to one another.
- Subjects are taught from scratch in different subject areas. No wonder the pupils get bored doing the same lessons over again.

- ICT a special case, one student found, in a school they were in, ICT was not taught as ICT but integrated into the other lessons and felt this was a much better way of teaching ICT as it would get rid of the problem that nobody knows what was taught in ICT.
- Found that other cross-curricular stuff was hard to do.
- Pupils had made no connections between line graphs and gradients in science and line graphs and gradients in maths. Confusion between subjects, line graphs in science, bar charts and the gaps between the bars when it is not continuous data. Causes confusion for the pupils as they are being taught two different things for the same information, pupils asking what's the point of the difference.
- Box and whisker plots are better in Autograph, but pupils are familiar with Excel.
- Problem with ICT is the resources, are there enough ICT rooms? Also what have they learnt in ICT lessons.
- Disjointed for the pupils if they learn how to produce graphs in Excel in a maths lesson and then again in an ICT lesson, adds confusion and takes away from the point of the lesson.
- Really good to use ICT as you can use large datasets with ICT, good for project work and open ended work, gave the pupils more freedom and control.
- ICT is a key tool.
- Balance, pupils need to be able to construct the graphs in an exam.
- Are the GSCE's pitched right as teachers we need to teach pupils for the future jobs etc, and they might have to work with Excel. This is the overlap with ICT. One student commented that they understood it better when they went through the process by hand first even if it took them a long time.
- Software (Autograph was the example) is used in controlled assessment which is coursework with the teacher watching. In the written exam software is not used.

Appendix 10

These are the questions given to the students following the group discussion.

Topic 1. Your perceptions of statistics

Let us know your views on what statistics is and what statistics is for. Please also indicate how you think these should influence the way that statistics is taught.

You might wish to consider the following in your response

a) How do you perceive statistics? (Maths by another name/subject in own right?)
b) Does it need teaching separately to maths? (Why?)
c) How should it be taught (is it theoretical/practical/other)
d) What is your attitude to statistics from your own studies at school and university?
e) What is the relevance of data within statistics teaching?

Topic 2. Your experience within the PGCE

Let us know your knowledge and experience of statistics, how it is taught and the role it plays in the national curriculum. Let us know what contexts, if any, you see statistics being taught in.

You might wish to consider the following in your response

a) What is your knowledge of statistics on entry to the PGCE?
b) What is your level of knowledge of statistics in the national curriculum?
c) How much statistics have you picked up during your PGCE course?
d) Where do you get support for statistics pedagogy?
e) Is any differentiation offered in relation to statistical knowledge needs in different application areas?

These were printed on either side of an A4 sheet to allow plenty of space for the students' responses. When students had completed their comments the facilitator continued the session by addressing items 3 and 4 at the end of which the students responded to the following which were on a separate sheet of A4.

Topic 3. Your experience while on practice in school

Let us know the ways in which your teaching practice helped you in your approach to teaching statistics.

You might wish to consider the following in your response

a) What is your attitude to statistics from your experience with teacher training in schools? (i.e what influence has the school had on your views of statistics?
b) Do you observe experienced teachers teaching statistics?
c) How much statistics have you picked up from teaching in schools?
d) Where do you get support for statistics pedagogy?
e) Is any differentiation offered in relation to statistical knowledge needs in different application areas?
f) What has impressed you, if anything re: statistics training?
g) How do you intend to fill-in any gaps in your statistics knowledge during the next two years?

Topic 4. Good practice in teaching statistics

Let us know what good practice is in teaching statistics is and provide any examples of good practice you have observed on your course or while in school.

You might wish to consider the following in your response a) How would you define 'good practice' in teaching statistics? b) Have you observed good practice in teaching statistics? c) What was the good practice in teaching statistics that you observed? d) For any examples of good practice, how were they taught?

Appendix 11

ROYAL STATISTICAL SOCIETY
Centre for Statistical Education

WITH PLYMOUTH UNIVERSITY

RSSCSE
and
Teaching Statistics Trust

PGCE Mathematics Student Questionnaire

This is a confidential survey designed to be filled in by PGCE students

Q1 What was the title of your first degree course?

Q2 Approximately what percentage of the content of your first degree course consisted of statistics?

None	up to 5%	6% to 10%	11% to 25%	up to 50%	up to 75%	more than 75%
❑	❑	❑	❑	❑	❑	❑

Q3 For each topic in the list below please indicate whether you knew about it on entry to the PGCE course and whether you feel confident in working with the technique?

Topic	Studied before PGCE	Confident about using
Handling data cycle	❑	❑
Sampling and surveys	❑	❑
Data collection	❑	❑
Data presentation	❑	❑
Measures of location	❑	❑
Measures of variation (univariate and bivariate)	❑	❑
Regression and time series	❑	❑
Analysis of variance	❑	❑
Inference from data	❑	❑

Q4 Bearing in mind your subject knowledge profile, please indicate what statistics subject content you have acquired either as part of your taught PGCE course or as part of your teaching practice.

Q5 **Approximately what proportion of your PGCE course has been devoted to (a) mathematics and (b) statistics subject content?**

(a) Mathematics

None	up to 5%	6% to 10%	11% to 25%	up to 50%	up to 75%	more than 75%
❑	❑	❑	❑	❑	❑	❑

(b) Statistics

None	up to 5%	6% to 10%	11% to 25%	up to 50%	up to 75%	more than 75%
❑	❑	❑	❑	❑	❑	❑

Q6 **How would you describe your knowledge of statistics and data handling?**

	Excellent	*Very good*	*Good*	*Some*	*Little*
It is	❑	❑	❑	❑	❑

Q7 **Do you know what the handling data cycle is?**

Yes.....❑
No .....❑

If you answered No please go directly to question 9

Q8 **How frequently would you use the handling data cycle in your teaching of statistics?**

	Always	*Often*	*Sometimes*	*Seldom*	*Never*
I would use it in my statistics teaching	❑	❑	❑	❑	❑

Q9 **Do you believe statistics and data handling is part of mathematics?**

Yes .....❑
No.....❑
No View.....❑

Many thanks for your help with this survey and our research, your help is very much appreciated.

Appendix 12
Newly Qualified Teacher online questionnaire

Newly Qualified Mathematics Teacher Questionnaire

Newly Qualified Mathematics Teacher Questionnaire

*** 01:**
Q1 What was the title of your first degree course?

Please write your answer here:

*** 02:**
Q2 Approximately what percentage of the content of your first degree course consisted of statistics?

Please choose the appropriate response for each item:

None	Up to 5%	6% to 10%	11% to 25%	Up to 50%	Up to 75%	more than 75%
☐	☐	☐	☐	☐	☐	☐

03a:
Q3a For each topic in the list below please indicate whether you knew about it on entry to the PGCE course?

Please choose the appropriate response for each item:

	Studied before PGCE
Handling data cycle	☐
Sampling and surveys	☐
Data collection	☐
Data presentation	☐
Measures of location	☐
Measures of variation	☐
Regression	☐
Time series	☐
Analysis of variance	☐
Inference from data	☐

03b:
Q3b For each topic in the list below please indicate whether you feel confident in working with the technique?

Please choose the appropriate response for each item:

	Confident about using	Not confident about using
Handling data cycle	☐	☐
Samplling and surveys	☐	☐
Data collection	☐	☐
Data presentation	☐	☐
Measures of location	☐	☐
Measures of variation	☐	☐
Regression	☐	☐
Time series	☐	☐
Analysis of variance	☐	☐
Inference from data	☐	☐

*** 04:**

Q4 Bearing in mind your subject knowledge profile, please indicate what statistics subject content you have acquired either as part of your taught PGCE course or as part of your teaching practice.

Please write your answer here:

*** 05:**

Q5 Approximately what proportion of your PGCE course was (a) devoted to mathematics and (b) to statistics subject content?

Please choose the appropriate response for each item:

	None	Up to 5%	6% to 10%	11% to 25%	Up to 50%	Up to 75%	more than 75%
a) Mathematics	☐	☐	☐	☐	☐	☐	☐
b) Statistics	☐	☐	☐	☐	☐	☐	☐

*** 06:**

Q6 How would you describe your knowledge of statistics and data handling?

Please choose the appropriate response for each item:

Excellent	Very good	Good	Some	Little
☐	☐	☐	☐	☐

07:

Q7 Do you know what the handling data cycle is? If you do not know please go directly to Q9.

Please choose *only one* of the following:

☐ Yes

☐ No

08:

Q8 How frequently would you use the handling data cycle in your teaching of statistics?

Please choose the appropriate response for each item:

Always	Often	Sometimes	Seldom	Never
☐	☐	☐	☐	☐

*** 09:**

Q9 How confident are you, or would you be, at teaching each of the following?

Please choose the appropriate response for each item:

	Fully confident	Confident	Somewhat confident	A little unsure	Totally unsure
Number patterns	☐	☐	☐	☐	☐
Area of a two dimensional shape	☐	☐	☐	☐	☐
Linear equations	☐	☐	☐	☐	☐
Sampling and surveys	☐	☐	☐	☐	☐
Data collection	☐	☐	☐	☐	☐
Data presentation	☐	☐	☐	☐	☐

Measures of location	☐	☐	☐	☐	☐
Measures of variation	☐	☐	☐	☐	☐
Regression	☐	☐	☐	☐	☐
Time series	☐	☐	☐	☐	☐
Inference from data	☐	☐	☐	☐	☐
Transposition of formulae	☐	☐	☐	☐	☐
Circle theorems	☐	☐	☐	☐	☐

*** 10:**

Q10 Do you believe statistics and data handling is part of mathematics?

Please choose *all* that apply:

☐ Yes

☐ No

☐ No View

11:

Many thanks for your help with this survey and our research, your help is very much appreciated. Please click 'Submit' to record your results.

Appendix 13

Email request sent to PGCE course leaders

Dear

Statistics Pedagogy and Knowledge of Newly Qualified Teachers

The Teaching Statistics Trust has commissioned the Royal Statistical Society Centre for Statistical Education(RSSCSE) to investigate the extent and form of statistics pedagogy and knowledge in BRITISH teacher training courses. It is expected this research project will last until October 2011.

The aims are to:

1. identify and catalogue mathematics teacher training courses and highlight those that pay attention to statistics knowledge or pedagogy;
2. classify the entry profiles of students to such courses, particularly their statistics backgrounds;
3. identify how the statistics content is delivered and the nature of the attention paid to statistical thinking and reasoning (as opposed to mathematical thinking and reasoning) for British PGCE secondary courses in mathematics and other relevant subjects;
4. identify and synthesise elements of good practice in statistics knowledge and pedagogy delivery within BRITISHPGCE courses and BEd courses and disseminate findings.

As part of the project we would like to survey newly qualified teachers who graduated from their courses last summer. In order to do this we need to invite those with NQT status to complete our online questionnaire.

I am therefore asking whether you would be willing to help us and forward the url at the bottom of the letter to your students who qualified in the last year or so?

Naturally, when the report is complete towards the end of the year we will send you a copy for your own use.

Many thanks.

Yours sincerely

Neville Davies

Professor Neville Davies

Appendix 14

In part A of this appendix we list the raw results from the online survey of NQTs and in part B we give the verbatim responses to question 4

Part A

Q1 What was the title of your first degree course?

Mathematics (or similar) 12, Combination with Mathematics 3, Electrical and Electronic Engineering 0, Computer Science 1, 2 other Engineering degrees, 4 Social Science type degrees and a 5 others.

Q2 Approximately what percentage of the content of your first degree course consisted of statistics?

0	up to 5%	6% to 10%	11% to 25%	26% to 50%	51% to 75%	more than 75%
4	3	9	7	2	2	0

and 1 no response, 23 out of the 27 have 25% or less, the modal group is 6 - 10%.

Q3 For each topic in the list below please indicate whether you knew about it on entry to the PGCE course?

Topic	Before PGCE		Confident about using	
	Yes	No	Yes	No
Data Handling cycle	18	9	22	2
Sampling/surveys	24	3	24	3
Data collection	23	4	25	2
Data presentation	23	4	26	1
Measures of location	12	15	12	12
Measures of variation	16	11	17	10
Regression	16	11	12	14
Time Series	14	13	15	10
ANOVA	16	11	16	10
Inference	13	14	18	8

More than half of the newly qualified teachers did not know about 'measures of location' on entry to the PGCE yet only about 4 in 10 did not know about 'measures of variation'. This seems unlikely (especially in the case of 'location') and might well be because of a lack of familiarity with the terminology used in the questionnaire.

In addition to the comment above, it is noticeable that the students express confidence in working with the data handling cycle, data collection, presentation and sampling and surveys, but much less so with other topics. Again we must express some caution about the 'measures of location' and 'measures of variation'. Note that while more than half confirmed that they knew about 'regression' and did not know about 'Inference' on entry

to the PGCE the position is reversed when asked if they were confident in using the technique.

Q4 Bearing in mind your subject knowledge profile, please indicate what statistics subject content you have acquired either as part of your taught PGCE course or as part of your teaching practice.

None 5
Not much 2
Data Handling (GCSE) 35
Probability 5, variance 2, Time series, regression and CLT 1 each

Some of the teachers interpreted this question as asking what they studied before the PGCE and others what they were currently teaching. The full list of written responses are provided in part B of this appendix.

Q5 Approximately what proportion of your PGCE course was (a) devoted to mathematics and (b) to statistics subject content?

% devoted to Mathematics

0	up to 5%	6% to 10%	11% to 25%	26% to 50%	51% to 75%	more than 75%
0	0	2	6	7	6	6

% devoted to Statistics

0	up to 5%	6% to 10%	11% to 25%	26% to 50%	51% to 75%	more than 75%
1	10	8	8	0	0	0

There appears to be a clear difference between the responses here with the NQTs PGCE courses providing predominantly Mathematics coverage which is consistent with the results from the focus groups of PGCE students.

Q6 How would you describe your knowledge of statistics and data handling?

Excellent	Very Good	Good	Some	Little
4	7	11	5	

This suggests the NQTs are reasonably confident (22 out of 27 saying 'Good' or better) in their knowledge of statistics.

Q7 Do you know what the handling data cycle is?

Yes 21, No 4

Q8 How frequently would you use the handling data cycle in your teaching of statistics?

Always 2 Often 6 Sometimes 10 Seldom 1 Never 0

Although the PGCE students in the focus groups were keen that practical examples and applications should be employed, the NQTs are not necessarily seeing the DH cycle as a means to deliver this.

Q9 How confident are you, or would you be, at teaching each of the following?
Please choose the appropriate response for each item:

	Fully confident	Confident	Somewhat confident	A little unsure	Totally unsure
Number patterns	21	4	2	0	0
Area of a two dimensional shape	26	1	0	0	0
Linear equations	26	1	0	0	0
Sampling and surveys	18	4	4	1	0
Data collection	19	6	2	0	0
Data presentation	19	6	2	0	0
Measures of location	10	4	3	7	3
Measures of variation	8	9	3	3	4
Regression	6	5	4	6	6
Time series	9	4	6	3	5
Inference from data	8	10	2	4	3
Transposition of formulae	16	6	3	2	0
Circle theorems	14	6	6	0	1

For this question the statistical topics were deliberately 'sandwiched' between the mathematical topics in an attempt to avoid bias. The responses show a stark difference here between the confidence expressed about mathematical and statistical (data handling) topics.

For the remaining five statistical topics in this question, excluding sampling and surveys, collecting data and presenting data, least 7 out of the 27 teachers expressed a lack of confidence in the topics and the number of teachers who said they were fully confident is less than half that for those expressing the same sentiment for the first three mathematical topics.

It is interesting that the confidence in the final two (mathematical topics) is as low as it is and this could well be due to the deliberate ordering of these questions topics.

Q10 do you believe statistics and data handling is part of mathematics?

Yes 26, No 1
Only one teacher said they believed that statistics is not part of mathematics.

Part B

Q4 Bearing in mind your subject knowledge profile, please indicate what statistics subject content you have acquired either as part of your taught PGCE course or as part of your teaching practice.

None from PGCE course.

Doing calculations by hand. On my psychology course it was all on computer.

On the PGCE I did no statistics and my only knowledge is from what I did in my statistics GCSE and the statistics modules that I did as part of my A-level in maths. On teaching practice I never had to teach statistics and even now I only have to teach it to foundation GCSE students.

I am teaching S1 this year, and have had to learn a large proportion of the syllabus as I go along.

All foundation level (GCSE) Data Handling.

More so on the teaching side, the PGCE course did not really cover any.

Time Series.

Nothing in terms of content but lots in terms of teaching it.

When I was at university, I took 5 statistics options out of a possible 9.

None.

No new statistics content has been dealt with since the start of the PGCEs.

No new knowledge.

Certain aspects of probability theory.

Probability, time series, regression, and variance.

N/A.

Acquired through teaching practice.

Probability - deeper understanding of it as a measure of certainty.

Currently teaching GCSE statistics as an NQT. During PGCE taught lower level GCSE statistics and a couple of topics for A level S1 course.

Little knowledge acquired.

I have gained a deeper understanding of the central limit theorem.

Unit 1 AQA GCSE - statistics and data handling Some AS Level Statistics through lesson observations.

Only currently using GCSE level knowledge so not finding this difficult at this stage.

Frequency densities, working with histograms, calculate the standard deviation and variance of discrete/grouped data.

I have taught year 11 students the GCSE AQA Statistics topics this year. It is the first real experience of using statistics. I studied S1 as part of my own A-Level.

A small amount of probability which essentially comprised an organised discussion involving a dozen or so people about what misconceptions may arise when teaching probability.

Appendix 15

Questionnaire responses and comparisons between NQT responses and PGCE mathematics students' responses.

NQTs (A) and PGCE (B)

Q1 What was the title of your first degree?

	Percentage	
	A (27)	B (128)
Mathematics	44	41
Mathematics combined	11	14
Engineering	7	14
Computer Science	7	3
Social Sciences	15	9
Other	15	19

Q2 Approx. what percentage of the content of your first degree course consisted of statistics?

Percentages

	None	<5%	6-10%	11-25%	26-50%	50-75%	>75%
A	15	11	33	26	7	7	0
B	10	27	22	28	9	2	2

Q4 How much statistics have you acquired on the PGCE (A, from written responses)?

Percentages

None 51% Not much 2% Basic 16% Lots 26%

(5% non-response)

Q3 For each topic listed below please indicate whether
a) you knew about it on entry to the PGCE course
b) you feel confident in working with the technique

	A (27)		B(105)	
Topic	Knew before	Confident	Knew before	Confident
Data handling cycle	67%	81%	79%	70%
Sampling/surveys	89%	89%	93%	87%
Data collection	85%	93%	94%	89%
Data presentation	85%	96%	93%	90%
Measures of location	44%	44%	69%	49%
Measures of variation	59%	63%	57%	33%
Regression and Time Series	41%	30%	62%	30%
ANOVA	59%	59%	76%	36%
Inference	52%	67%	64%	38%

Q5 Approx. what percentage of the content of your PGCE course devoted to

a) Mathematics
Percentages

	None	<5%	6-10%	11-25%	26-50%	50-75%	>75%
A	0	0	7	22	25	22	22
B	4	3	6	11	20	20	32

b) Statistics
Percentages

	None	<5%	6-10%	11-25%	26-50%	50-75%	>75%
A	4	37	30	30	0	0	0
B	10	50	22	10	4	0	0

Q6 How describe knowledge of stats and DH?

Percentages

	Excellent	Very Good	Good	Some	Little
A	15	26	41	19	0
B	3	17	53	23	3

Q7 Do you know what the handling data cycle is?

Percentages

A	Yes	78%	No	15%
B	Yes	59%	No	41%

Q8 If yes to DHC How frequently would you use the data handling cycle in your teaching of statistics?

Percentage

	Always	Often	Sometimes	Seldom	Never
A	10	29	48	5	0
B	7	45	34	7	7

Q8 is stats part of maths?

Percentage

	Yes	No	No view
A	96	4	0
B	78	5	17

RSSCSE
and
Teaching Statistics Trust

PGCE Maths Course Leader Questionnaire

This is a confidential telephone survey designed to be completed by PGCE course leaders.

Q1 What was the title of your first degree course?

Q2 What postgraduate qualifications do you have?

Q3 Approximately what percentage of the content of your first degree course consisted of statistics?

None	up to 5%	6% to 10%	11% to 25%	up to 50%	up to 75%	more than 75%
☐	☐	☐	☐	☐	☐	☐

Q4 Does statistics need to be taught in a completely different way from mathematics?

Yes / No / Not sure

Please give reasons for your answer

Q5 Where do your students get support for how to teach statistics?

Q6 How does your course monitor the students' exposure to statistics pedagogy in schools?

Q7 Do you think more time should be allocated to the way in which statistics is taught in the course?

Q8 Approximately what proportion of your PGCE course is devoted to (a) mathematics and (b) statistics subject content?

(a) Mathematics

None	up to 5%	6% to 10%	11% to 25%	up to 50%	up to 75%	more than 75%
☐	☐	☐	☐	☐	☐	☐

(b) Statistics

None	up to 5%	6% to 10%	11% to 25%	up to 50%	up to 75%	more than 75%
☐	☐	☐	☐	☐	☐	☐

Q9 Do you think more time should be allocated to statistics pedagogy on your PGCE course?

Yes / No / Not sure

Q10 Do you think your students should experience teaching statistics through other subjects?

Yes / No / Not sure

Q11 How would you describe your own knowledge of statistics and data handling and its pedagogy?

(a) Statistics subject content

	Excellent	*Very Good*	*Good*	*Some*	*Little*
It is	☐	☐	☐	☐	☐

(b) Statistics pedagogy

	Excellent	*Very Good*	*Good*	*Some*	*Little*
It is	☐	☐	☐	☐	☐

Q12 Does your course encourage students to use real data when teaching statistics?

Yes / No / Not sure

Q13 Are students taught to use the handling data cycle in their teaching of statistics?

	Always	*Often*	*Sometimes*	*Seldom*	*Never*
They are taught it	☐	☐	☐	☐	☐

Q14 Do you believe statistics and data handling is part of mathematics?

Yes / No / Not sure

Many thanks for your help with this survey and our research, your help is very much appreciated.