Educating Future Statistics Teachers: Experiences and Challenges in Helping Mature Students to Retrain

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1. Introduction

In 2002 the United Kingdom's Secretary of State for Education, Charles Clarke, set up an independent Inquiry into Post-14 Mathematics Education under the chairmanship of Professor Adrian Smith FRS (Smith, 2004). This was in response to the perceived need for a closer examination of the mathematics education provision in England. It was widely recognised that mathematics, as well as a major intellectual discipline in its own right, underpinned much of science, engineering and, increasingly, social and medical sciences. In addition, there was a long held concern about the supply of appropriately qualified mathematics teachers in secondary schools and colleges.

The terms of reference for the so-called Smith Report were: *To make recommendations on changes to the curriculum, qualifications and pedagogy for those aged 14 and over in schools , colleges and higher education institutions to enable those students to acquire the mathematical knowledge and skills necessary to meet the requirements of employers and of further and higher education.*

The report is far-reaching and was generally well-received by the Government, academics, educators and industry. Of particular interest here are the concerns and recommendations relating to the Supply of Teachers of Mathematics (Chapter 2): "The shortage of specialist mathematics teachers teaching mathematics is the most serious problem we face in ensuring the future supply of sufficient young people with appropriate mathematical skills." At the time of the report it was estimated that there was a shortfall of 3,400 specialist mathematics teachers in maintained secondary schools in England and that 30% of those currently teaching mathematics did not have a post Advanced (A) level (i.e. post school) qualification in mathematics. In order to overcome this, over 40% of the annual UK output of mathematics graduates would need to be recruited to teaching, which was clearly unrealistic. One scheme, aimed at boosting the supply of mathematics teachers, was an enhancement course, which would enable those without appropriate existing mathematics qualifications to acquire these as a first step to training as a mathematics teacher.

After consultation with the mathematics community, in 2003 the Teacher Training Agency, then the body responsible for the training of teachers in England, set out the specification for the Mathematics Enhancement Course (MEC) (TTA, 2003). In 2004 the MEC was piloted in two regions, one based in Liverpool in the north of England and one in the south-east; initially, the two pilot schemes were allocated 20 places each.

By 2007, there were 13 providers throughout England, each of which is a consortium of 2-4 universities or other higher education (HE) institutions that ran Initial Teacher Training (ITT) courses in the region. The MEC is usually taught by a mix of staff from university mathematics and mathematics education departments. Although originally conceived as having 20 participants per provider, currently, this ranges between 12 and 30.

2. The Mathematics Enhancement Course

The MEC was designed for graduate career changers who have an A-level (or equivalent) in mathematics and some occupational experience of using mathematics. The 26 weeks of taught content, running from January to July, should enable them to develop their mathematical skills and knowledge before attending an ITT starting in the following September. The MEC is concerned primarily with developing the ability in these graduates to teach mathematics to pupils aged 11-16, although some participants will be interested in and able to teach mathematics above this level. The course is free and, in addition, students are

paid a bursary of £225 per week to attend, typically for four days a week. In addition, participants are expected to spend some time in local schools. So far there have been more applicants than places.

As is common, statistics is taught in secondary schools in England within the mathematics syllabus, although of course used in many other subject areas. The MEC specification states that the course should be structured to provide opportunities for the use and application of mathematics, including statistics.

Amongst the many aims there are some which are of particular relevance to statistics. In each of the following the terms "mathematics" or "mathematical" could easily be replaced with "statistics" or "statistical" respectively.

In mathematical learning, the MEC will enable participants to:

- Develop the skills and gain the confidence to recognise areas in their own subject knowledge that they need to develop…;
- Begin to develop a profound understanding of fundamental mathematics, emphasising deep and broad understanding of concepts, as against surface, procedural knowledge;
- Use mathematical reasoning …;
- Consider how mental and visual images can aid mathematical thinking and understanding;
- Harness ICT to enhance the learning and teaching of mathematics and to provide motivation;
- Recognise and analyse their mathematical conceptions and misconceptions.

In professional learning the MEC will enable participants to:

- Integrate subject knowledge and pedagogy…;
- Consider the demands and challenges placed on pupils aged 11-18 learning mathematics…;
- Develop an understanding of differences between mathematical and everyday language…

(TTA,2003)

The MEC specification does not give detailed syllabuses, recognising that the 13 providers have their own professional and mathematical expertise. However, it does suggest that the course should cover Algebra, Geometry, Trigonometry, Calculus, Mechanics, Statistics and Discrete Mathematics, with a suggestion that there should be at least an introduction to mechanics and statistics for all participants.

The MEC specification gives exemplar questions and concept maps for each area to guide the content. The concept map for Probability and Statistics is given below in Figure 1.

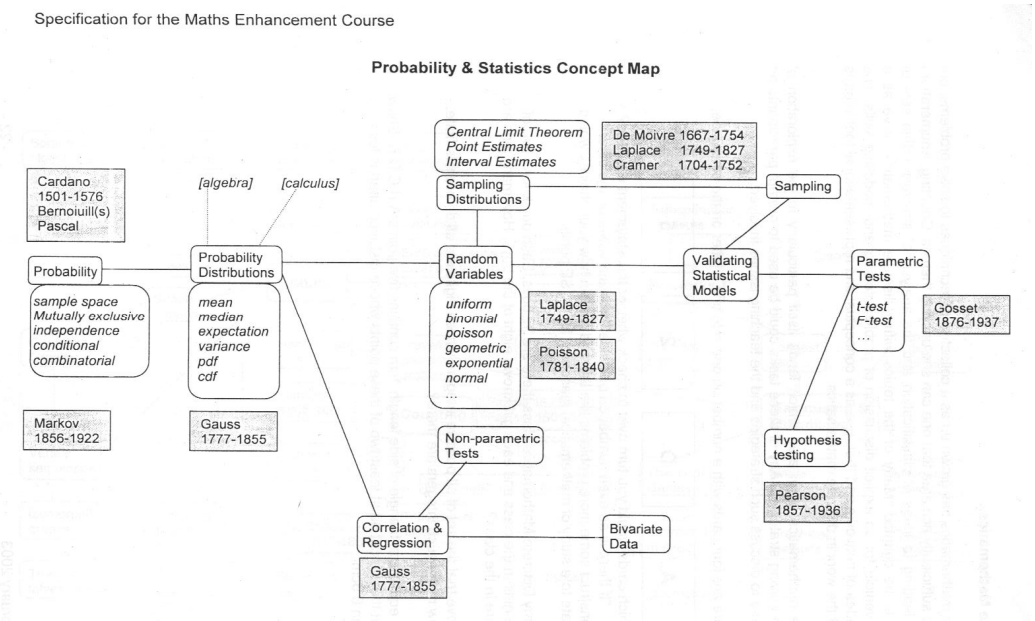

Figure 1 Specified Probability and Statistics Concept Map

One exemplar question is:

A survey measures the heights of all pupils in two classes, 4A and 4B. Five children are then moved from class 4A to class 4B. As a result the average height for both classes increases and the standard deviation for both classes decreases. How is this possible?

This question reflects the move towards a focus on statistical reasoning and thinking, rather than mechanistic problem solving.

3. The Kingston Experience – a case study

The original consortium consisted of 3 universities and one HE college, located in the outer South-West London area. All the consortium members have ITT provision and most of the successful MEC students would complete their training at one of these, although they could choose from several other ITT providers in the region.

Our MEC began in January 2006 with 27 students, 20 of whom were female. The age profile was quite young with 12 being under 25, a further 14 between 25 and 35 and 1 over 40 at this time. Reflecting the local area, two thirds of our students were from ethnic minorities. The entry requirements for the MEC are an A-level in mathematics and a degree that had some mathematical/statistical content. Fifteen of the students had a pass in A-level Mathematics, although none at the highest grade; two more had taken the A-level but failed and a further 2 had passes an AS level, which is equivalent to about half an A level in content and complexity. Ten of the students had not been exposed to A level mathematics at all. At least eighteen of the students had degrees (Economics, Business, Psychology, Forensic Science) that must have included some statistics. The four Computing and one Chemical Engineering students would have studied some mathematics and perhaps some statistics in their degrees, but it is unlikely that the remainder (1 English Literature and 3 Law graduates) had been exposed to any mathematics or statistics for a number of years. Thus, many of our first cohort did not match the specified entry criteria, but were recruited as they were deemed to have other qualities suitable for school teaching.

In 2007, 30 graduates were recruited to the MEC, the majority female. On average the participants are slightly older, although 10 are under 25. The main difference is that, for the 2007 intake, the entry qualifications are much higher, with 20 having achieved A level passes, 4 at the top grade.

In light of the MEC specification, the experience of the pilot scheme, and taking into account the expertise of its members, the consortium developed a programme of study so that the Probability and Statistics module was taught in the second term, after students had been exposed to 13 weeks of mathematics, including some algebra, trigonometry, geometry and mathematical reasoning. The modules run concurrently, one on each of the four attendance days. In addition, students undertake individual activities, such as an extended mathematical study and school based units.

As seen above there is a great variety in the background and experience of the MEC students in mathematics, and perhaps even more in statistics. Nevertheless they will all be required to teach mathematics to children aged 11-16. The national curriculum in mathematics for this age range, has 4 attainment targets - using and applying mathematics; number and algebra; shape, space and measures, and data handling. There is also a programme of study, indicating how the material is to be taught; assessment, set at four key stages, is based on these programmes of study. For the MEC participants, key stages 3 (aged 11-14) and 4 (aged 15- 16) are relevant. At key stage 3 the data handling target is described by the cycle shown in Figure 2 (DES, current).

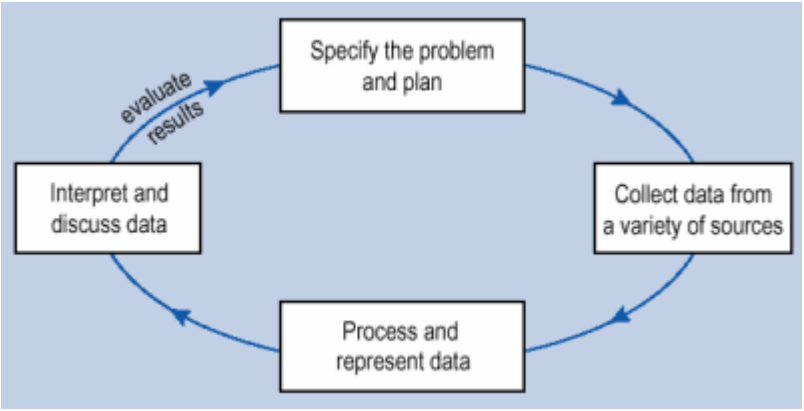

Figure 2 The Data Handling Cycle

A typical key stage 3 test, that the MEC students were asked to complete as part of their initial preparation, contained 18 questions to be completed in 1 hour. Of these, 4 were in probability and statistics - three concerned interpretation of graphical data – a scatter graph, stacked bar charts, box plots and cumulative frequency graphs and a probability question:

> I have two fair 4-sided dice
>
> One dice (sic) is numbered **2, 4, 6,** and **8**
> The other is numbered **2, 3, 4,** and **5**
>
> I throw both dice and add the scores.
> What is the probability that the total is **even**?
> You **must** show working to explain your answer.

The vast majority of English children study for the General Certificate in Secondary Education (GCSE) in Mathematics at age 16; this can be taken at three levels but all contain some basic statistical concepts. Again, the MEC participants tried one of these papers as preparation for their course. This 2 hour GCSE paper contained 21 questions, 2 of which were on probability including completing a tree diagram, one on interpreting information displayed by a histogram and one on sampling.

These are the sort of areas of statistics that MEC students will need to be familiar with before they start teaching, as they will all be expected to teach to this level. Many will go on to teach A level Mathematics and possibly Further Mathematics. These are run by three examination boards – OCR (Oxford, Cambridge and RSA), AQA (Assessment and Qualifications Alliance), Edexcel. Within these A levels there are possibilities to take statistics papers, known as S1, S2 (for Mathematics) and S3 and S4 (for Further Mathematics), where the numbers indicate a progression in content and difficulty. In addition statistics can be taken as a GCSE or A level on its own. Very few school children take the former and much of the content of the latter is included in S1-S4. Table 1 below shows the content of our MEC Probability and Statistics module and where these topics appear in GCSE (indicated by Yes) and A-level Mathematics syllabuses.

		A level Boards		
Topic	**GCSE**	**OCR**	**AQA**	**Edexcel**
Types of data- discrete, continuous, categorical etc. Summarising data with tables, bar and pie charts and histograms	Yes	S1	S1	S1
Measures of average – mean, mode and median Measures of variation – standard deviation, variance and IQR. Box plots	Yes			S1
Probability mutually exclusive and independent events. Conditional probability Tree diagrams	Yes	S1		S1
Idea of a random variable and statistical distributions Introduction to discrete distributions – binomial, Poisson		S1/S2	S1/S2	S1/S2
Continuous distributions- the Normal. Normal approximation to binomial and Poisson		S2	S1	S1
Idea of Central Limit Theorem Elementary ideas of Inference Confidence intervals and hypothesis test about the population mean		S2	S1/S2	S3
Bivariate data and the relationship between them Scatter plots, Correlation	Yes	S1	S4	S1/S3
Idea of a statistical model e.g. Simple Linear regression		S1	S1	
Contingency tables and χ^2 tests of association			S2	

Table 1 MEC content mapped across GCSE and A-level syllabuses

We have attempted to develop both the content and the pedagogy of this module with an eye toward what prospective statistics teachers will be asked to do in their own secondary classrooms. Statistics presents its own challenges for teaching and learning compared with those of mathematics, especially with the

growing recognition of and research around statistical thinking. Rather than focusing on statistical skills, procedures, and computations, there has been a growing call to encourage students to reason and think statistically (Ben-Zvi and Garfield, 2004). Thus there is an increasing emphasis on data collection, exploration of data, and the interpretation of results, which are heavily dependent on context.

Given the ethos of the MEC to model pedagogical approaches that are recommended good practice for teachers and recent research in statistics education, our emphasis was on teaching with real data, using suitable computer packages where appropriate. We were fortunate to have a room set up so that each individual had access to computing facility when required, but which could also be put away when not. This allowed for illustration of various concepts as well as allowing students to familiarise themselves with various packages and resources on the WEB. Typically schools in England will not have particular statistical packages, although Fathom and Autograph are used. Excel, although a spreadsheet, is usually available as part of the Microsoft suite and whilst somewhat limited can be used in the classroom.

The MEC aims to consider links between subject knowledge and pedagogy, so that, across the course, assessment tasks should be varied and help participants recognise their strengths and weaknesses. Suggested modes of assessment that are particularly appropriate to statistics are computer based assignments, investigations, modelling assignments, presentations and group work.

In our first year we set two assessment tasks in statistics – the first consisted of a mix of traditional A-level type questions to test basic knowledge and skills and others investigating real data through descriptive statistics and graphical methods; it also contained some questions on probability. As noted above the variety of backgrounds and experiences, especially in statistics, means that students find different aspects of the course difficult. One way to enrich their understanding is collaborative learning, so that they can recognise the enhancement in their learning which occurs as a result of self reflection and relating their understanding to that of others. Thus, for the second assessment, students were asked to work in groups of 3-4, looking at some real data, which had been taken from the STARS project (STARS website, current). For this they had to decide on appropriate presentation and analysis of the data, guided by some background materials relevant questions. The students were assessed as a group on a final written report and oral presentation of their work.

The 4 assessment criteria, as defined in our MEC, were acquisition of knowledge of the subject; ability to apply skills and techniques; ability to make connections and identify applications and ability to communicate. These were judged at one of 4 levels – exceptional, good, pass and fail. Thus, for example, under "ability to make connections and identify applications," an exceptional performer would "make insightful connections", whilst a pass student would make an "appropriate choice of method." Our two assessments gave the MEC students opportunities to achieve these criteria.

Our MEC was evaluated formally by the participants themselves, by an external examiner and an external evaluator. Generally, the students found the Probability and Statistics module the most difficult, although all passed it. Informal discussions with colleagues at other MECs indicate that this reaction is quite common. Perhaps it is to be expected as statistical reasoning and thinking is rather different to that in mathematics, and our students are just getting used to the latter. Whilst statistical reasoning and thinking are not always clearly defined, Wild and Pfannkuch's model provides some clarity and gives a way of examining what these terms mean. Their five components of statistical thinking are recognition of a need for data; ability to 'transnumerate' the data; recognition of variation; being able to reason from models and being able to integrate statistical and contextual knowledge (Wild and Pfannkuch, 1999). Statistical problem solving and decision making depends upon understanding, explaining and quantifying the variability in data and these are difficult concepts. In relation to this the MEC students felt that they would like an introduction to some statistical ideas in the first term. Although handouts were praised as a good "starting point", students suggested that they would like to have a good A level reference text too. Each of these suggestions will be included for the 2007 intake.

4. Concluding thoughts

The MEC has been developed as one way to address the shortage of mathematics teachers in secondary schools in England. Within two years the number of courses has grown rapidly from two in the pilot scheme to 13 in 2007. Currently demand for the MEC outstrips supply of places on such a course, which we hope is good news for the future supply of mathematics teachers in English schools. Here we have described the first year in one such course with a particular emphasis on the probability and statistics content. To quote Peter Holmes (Holmes, 2003) "The price of good statistics teaching is eternal vigilance. If we can encourage teachers,… to incorporate the best of what has been developing… then there is some hope. The

major need is to maintain a broad vision of the nature of our subject and its applicability". Being a part of the MEC has been a stimulating and worthwhile experience; it has presented challenges in considering appropriate approaches to teaching statistics to "mature" students, who do not have a strong mathematics background, but will shortly be teaching statistics to school children. The experiences may well have applications beyond the UK.

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RESUME

The Smith Report, "Making Mathematics Count", 2004, highlighted the shortage of qualified mathematics teachers in secondary schools in the UK. One recent government initiative in response to this is the Mathematics Enhancement Course (MEC), designed for graduates in "other" disciplines that have some mathematical/statistical content, such as psychology or business, who want to re-train as mathematics teachers. The course, currently run at 13 regional centres around the UK, gives the participants 26 weeks to develop their breadth and depth of mathematical, including statistical, knowledge, prior to progressing to a teacher-training course.

As statistics is, generally, sited within the mathematics curriculum in UK schools, one of the 8 modules on the MEC course is "Probability and Statistics". As well as developing students' skills and understanding of statistical concepts, a main aim of the MEC is to integrate subject knowledge and pedagogy, so that the teaching on the course models good practice. Hence participants are continually working on two levels – learning more about statistics and having a variety of teaching and learning experiences that might help them to become effective teachers themselves. In this paper two main aspects will be discussed – development of an appropriate syllabus and approaches to teaching and assessment methods suitable in such a course. The varied profiles of knowledge and achievement that participants have in mathematics, let alone statistics, on entry and a consideration of what new teachers "should" know greatly influence these aspects of the module.

This is a challenging but very stimulating course to teach and, so far, from students' responses, to learn. The approaches to teaching statistics to "mature" students, who do not have a strong mathematics background, but will shortly be teaching statistics to school children, may well have applications beyond the UK.