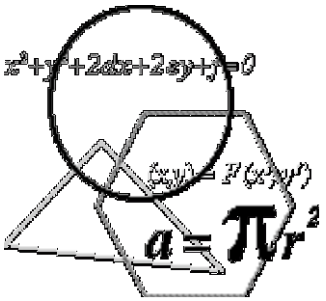
Harper Adams University College

Aspire Development Fellowship 2005/6

Students' Learning of Mathematics and Statistics

Final Report October 2007



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APD Academic and Professional Development Module for first year students

RDA Research Design and Analysis Module for second and third year natural science students

Report Summary

This Harper Adams *Aspire* CETL Development Fellowship Award consisted of pedagogic research into students' learning of mathematics and statistics, with development of statistics resources and numeracy workshops. Nationally and at Harper Adams University College there have been concerns that students find mathematical subject areas more difficult than in the past, and that this caused difficulties with student progression and retention at university, and was a concern for society in general.

The data collection method was based on student surveys of the whole first year cohort and all second year degree students in 2005 and 2006. Questionnaires asked students about their attitudes towards, and experiences of, learning mathematics and statistics. A smaller number of student interviews were also conducted. Student responses to the questionnaires were analysed together with student achievement details.

A large amount of analysis has been undertaken and only a selection of the results is contained in this report. Overall it was found that higher mathematics qualifications pre-university were associated with better confidence and achievement in mathematics and statistics at university, as expected. First year students taking a general statistics module as a compulsory part of their course had the lowest confidence in their ability. Generally second year students were more confident than first year students and students felt more confident at the end of a module. Engineers learning mathematics had a noticeably different outlook (from non-engineers learning statistics), often appreciating the necessity of the mathematics for their course; similarly second year natural scientists appreciated that statistics would be necessary for their final year project. This necessity appeared to overcome a dislike or lack of confidence in the subject. Students appreciated that doing exercises and practising mathematics would help them improve, and the use of computer packages was rated highly for learning statistics.

The statistics resources produced were six booklets, each relating to a statistical hypothesis test. These were made available to students from March 2007, both in paper and electronic formats. The resources have proved useful for mathematics support and as a general student resource with high student demand, and have received positive feedback. Four types of workshops were developed and delivered, from which feedback was obtained in 2006/7, which was positive.

The outcomes of this *Aspire* CETL Development Fellowship have had a positive impact on the fellowship holder in terms of the professional development undertaken in doing the pedagogic research as part of a higher degree, and have also had a positive impact on a large number of Harper Adams students, from first year undergraduates to taught post-graduate students, in providing an opportunity to make their views known and also providing workshops and resources to enable better learning of mathematics and statistics.

This pedagogic research also forms part of a higher degree by research, and fuller reporting of the findings will be contained in the thesis.

1. Introduction

The *Aspire* Development Fellowship relating to **Students' Learning of Mathematics and Statistics** comprised three distinct areas, described below.

- **Research into students' learning of mathematics and statistics**, consistent with the *Aspire* Development Fellowship aim and HEFCE CETL aim of encouraging research into teaching and learning.

- **Statistics resource development** and evaluation, for integration within a separate Research Methods Resources project.

- Development, delivery and evaluation of **workshops** to support numerically weak first year students.

The overall aims of the fellowship were to better understand student experiences and to provide additional resources for students learning mathematics and statistics.

2. Central Question, Issue or Problem

The 2005 *Aspire* Development Fellowship Award proposal was in response to the central issue of difficulties encountered by students learning mathematics and statistics, which is widely known in higher education as the 'Mathematics Problem' (Hawkes and Savage, 2000).

It is recognised that nationally many students find mathematics and statistics difficult at school and university. The government Inquiry into Post-14 Mathematics Education Making Mathematics Count identified three key issues of major concern with school mathematics, one of which was *'the failure of the current curriculum, assessment and qualifications framework to meet the needs of many learners and to satisfy the requirements and expectations of employers and higher education institutions.'* (Smith, 2004). Difficulties in school were evidenced by very high failure rates in AS and A2 level mathematics which necessitated reduced content (by one sixth) from September 2004 (Porkess, 2003), a two tier Mathematics GCSE was introduced from September 2006 to overcome problems with the three tier GCSE, coursework was discontinued, and further GCSE changes relating to 'functional mathematics' were being considered and trialled (OCR, 2007). Ken Boston, QCA Chief Executive, describes the teaching, curriculum and assessment of mathematics as '*one of the most challenging areas in contemporary education.'* (Boston, 2006).

Concern over university students' skills and progression in subjects with mathematical content has been documented since the mid 1990's (e.g. Hawkes and Savage, 2000, and Kent and Noss, 2003) and many universities now provide mathematics support (Lawson et al, 2001) over and above the normal curriculum delivery in response to student needs and difficulties. At Harper Adams, a study was conducted into student progression across the college, which concluded *'there was a strong (95 to 98%) probability that the lack of GCSE Mathematics Grades 'A' to 'C', was a significant factor in the withdrawal of students from the 1995 HND and Degree entry to the college.'* (Cowap,1998).

The consequences of difficulties with mathematics at school and university have wider repercussions. The 2002 Roberts Report (in Smith, 2004*)* called 'SET for Success: the supply of people with science, engineering and mathematics skills' emphasised these skills as central to the UK government's strategy for innovation and productivity, and provided evidence of skills shortages which it concluded threatened this strategy and the future strength of the UK economy. The 2006 CBI Employment Trends Survey found that 44% of employers were unhappy with school leavers' numeracy skills (CBI, 2007). Ken Boston, QCA Chief Executive, described the range of young people's abilities in mathematics to be '*extraordinarily broad within the context of the fundamental importance of mathematics to the economy.'* (Boston, 2006). Thus it can be seen that there is evidence of widespread difficulties with potentially serious consequences.

At Harper Adams much had already been achieved since 2001 to improve student learning and to overcome difficulties with mathematics and statistics: including redesign of modules, provision of mathematics support, provision of student handouts and use of computer packages. The Research, Design and Analysis module, and Engineering Mathematics modules with mathematics support, both received 2003 Harper Adams Teaching Fellowship Awards, thus demonstrating that good work had been done in these mathematical/statistical areas. However, despite these improvements, there remained fundamental issues with some poor student skills and attitudes (which were perceived to be formed pre-university), an unwillingness of some students to learn mathematics and statistics which could result in a downward spiral of poor motivation, effort and achievement, and some evidence that poor student achievement was associated with high numerical module content.

The work in this *Aspire* fellowship award was relevant to hundreds of students across the college, relating to or affecting the following student groups:

- first and second year engineering students studying mathematics,
- first year students, all of whom study Academic and Professional Development (APD) statistics, and some study other modules with numeric content,
- all second year degree students, all of whom study one of three variations of Research Methods modules containing statistics, and
- final year and MSc students undertaking statistical analysis.

3. Summary of Work Undertaken and Outputs

3.1 Research into Students' Learning of Mathematics and Statistics

3.1.1 Research Methodology

Student questionnaires were administered in May 2005 (246 questionnaires) and May 2006 (277 questionnaires) to first, second and third year students who had taken mathematics and statistics modules. Open and closed questions gathered information on entry qualifications, student confidence, attitudes, and experiences at and before university. The students completing the questionnaires could be categorised into three types: Engineering students (MEng, BEng, BSc and FdSc/HND), Natural Science students studying agriculture and animal related courses, and Social Science students studying business, surveying, countryside and leisure related courses. Different versions of the questionnaires were administered according to which student type, course and year of study. Seven versions of the questionnaires (six plus a pilot) were used in 2005, and six versions in 2006. Core questions were common to all versions, but topic/course/year

specific questions varied mainly depending on the module just studied by those students. The responses were analysed with student module marks using Microsoft Excel, Genstat and SPSS. A smaller number of student interviews were conducted (eight), primarily with final year students.

3.1.2 Research Findings

Responses from the 2005 and 2006 student mathematics learning questionnaires have been analysed and reported in two longer reports produced in April 2006 and April 2007, further details of which may be obtained from Sarah Parsons. A selection and summary of findings are given below.

Overall Findings

- Students had a range of Maths qualifications, and range of confidence levels and attitudes towards mathematics and statistics. Generally, better maths entry qualifications were associated with more positive attitudes and confidence towards the subjects (mathematics and statistics), and higher achievement in these and related subject areas at university. Students' mathematics qualifications (both Mathematics GCSE and Mathematics A level) were shown to have a significant effect on marks for mathematics and statistics assessments.

- Similar responses were obtained from the corresponding 2005 and 2006 questionnaire results, which contributes to confirming the reliability and validity of both sets of results.

- More significant relations were found between student marks and their questionnaire responses (regarding mathematics and statistics) for assessments which were mathematics or statistics examinations. Fewer relationships, and sometimes no relationships, were found for student assessments which were written reports.

- There was a noticeable difference between engineers' attitudes towards learning engineering mathematics and non-engineers attitudes towards learning statistics. Engineers were more motivated, confident and generally positive about learning mathematics, primarily because they understood that mathematics was necessary for their chosen course and careers.

  The differences in the attitudes of the different student groups can be seen in Table 1, the percentages of students who responded 'Yes' to the question

  'Given a choice would you have chosen to study this module?'

  where the wording of the question for combination modules (Academic and Professional Development module and Research Methods modules) specified *'the statistics in this module*?.'

Table 1. Percentage of 2004/5 Students who Would Choose to Study Mathematics or Statistics Modules

Module	%
1st Year Engineers' Mathematics - MEng and BEng students	**83%**
1st Year Engineers' Mathematics - BSc students	**100%**
1st Year Engineers' Mathematics - HND students	**50%**
2nd Year Engineers' Mathematics	**82%**
1st Year Academic and Professional Development Statistics	**31%**
2nd/3rd Year Natural Scientists' Research Design and Analysis	**44%**
2nd/3rd Year Social Scientists' Research Methods	**35%**

- It can be seen in Table 1 above that the majority of first, second or third year students who study statistics (including Research Design and Analysis (RDA) and Research Methods (RM) modules) only did so because it was a compulsory element of their course, and not by choice.

- Students' level of confidence in their mathematics and statistics ability was often established a long time ago, mostly at school. Generally second and third year students were more confident in mathematics and statistics than first year students. Students generally reported improved (or same) confidence at the end of modules (all modules surveyed). This demonstrates that the lack of confidence experienced by many students is in general a phenomenon originating from school, rather than originating from experiences at this college.

- Whilst second and third years students learning statistics were more confident than first years from their comments and ratings, their confidences were still generally low (means below 3 out of 5), which was lower than the excellent exam results obtained, and lower than student ratings for the value of doing mathematics and statistics calculations by hand calculator and computer packages (Excel, Genstat, SPSS) which were all given mean ratings above 3 (out of 5).

- Neither dyslexia nor gender had a significant effect on student module marks for any module surveyed, but age sometimes did. Mature students were often conscientious and achieved well, however there were relatively few mature students (approx. 4%) and their marks were variable.

  Example responses given by dyslexic APD students in 2005 to 'How had their Dyslexia/Dyscalculia affected their learning of mathematics/statistics?' are given below, which can be seen to reflect a range of effects from very little to '*every possible effect'*, although no positive effects were reported.

  - *'Takes longer to absorb info'*
  - *'Takes longer to do calculations'*
  - *'Makes it more difficult to understand'*
  - *'I don't feel it really affects me'*
  - *'Every possible effect'*

Whilst dyslexia was not found to have a significant effect on marks (e.g. in 2005 the mean APD assignment mark for dyslexic respondents was 51%, and was also 51% for non-dyslexic respondents). Dyslexic students considered that they took longer to learn and do the work required. However, the positive outcome is that the results demonstrate that they managed to achieve similar marks to their non-dyslexic peers.

- Mathematics support received positive comments and ratings (first year engineers' rating 4.7 overall and APD students' rating 4.1 overall in 2005), which was consistent with positive comments received through the college annual course monitoring feedback. The Mathematics support, 'Extra Maths', was the first year engineering students' most frequent response (26%) to what had helped their learning. Mathematics support has been shown to be taken up more by students with lower mathematics qualifications (than those who do not use the support); see further details below. As the students with lower qualifications generally achieve lower marks, analysis has been carried out to investigate whether supported students' marks were improved. In many cases it can be seen that, within GCSE grades for APD students or within award levels for engineers (BEng, BSc or HND), the supported students' mean marks are slightly higher than for unsupported students. These differences, however, were not found to be significant when tested statistically (possibly due to the wide variation in student marks, small samples sizes and some factors were not independent). The current data does not reflect the amount of support that students received, whether a one-off or regularly every week. Overall the mathematics support had a positive effect, feedback was positive, and the effect on achievement can be shown as a 'value added measure' rather than a direct comparison of supported/unsupported students.

- The use of computer packages (Excel, Genstat or SPSS) was the most frequent response by students learning statistics for features that had helped their learning.

Findings Relating Specifically to Students Studying Statistics (excludes engineering students)

Natural and Social Science students were surveyed in their first year regarding their experiences learning statistics as part of the Academic and Professional Development module (APD). Natural Science students taking the Research Design and Analysis (RDA) module and Social Science students taking the Research Methods module (in either their second or third year depending on the timing of their year out on work placement) were also surveyed regarding their experiences learning statistics. A summary of the key findings is given below.

Note: First and Second year Engineering students were surveyed in their mathematics lectures and although some of their responses relate to statistics, most of their responses relate to learning engineering mathematics, hence these students are considered separately and not included in the summary findings below.

Findings Specific to First Year Students Learning Statistics

- 2004/5 First Year Academic and Professional Development (APD) Statistics students were grouped by GCSE Mathematics Grade, and higher mathematics GCSE grades were associated with higher confidence and achievement.

- First Year APD students responded with the minimum percentage of those who would have chosen to study the statistics from all the modules surveyed. This was consistent with a high number of students who reported lacking confidence; 35% rated their confidence as only 1 or 2 (out of 5), and 50% rated their liking of statistics as only 1or 2 (out of 5). However only 14% rated themselves as less confident (only 1 or 2 out of 5) as a result of this module, and the most common responses to 'How long they had held this level of confidence?' were of the nature ' forever' or 'long time'. These findings are consistent with a lack of confidence and dislike of learning mathematics and statistics at school which continues at university. 86% of students were the same or more confident in statistics as a result of the module, of whom 41.0% were more confident and 44.4% rated their confidence unchanged (only 14.5% rate their confidence as worsened), so overall the module can be viewed to have a more positive than negative effect on students' confidence in their ability in statistics.

  An example of a particularly pessimistic student's response is given below.

  'Bad experiences with maths previously have made me have little confidence in my maths ability now. So don't try very hard as believe will get it wrong anyway.' First year Business Student, 2005 Questionnaire response.

- Mathematics Support was reported on by 21 of the 118 2005 APD students surveyed, representing an 18% take-up of the help offered. Overall 55 students, 16% of the total 341 students on the module, received support for APD statistics in 2004/5 which was for a mixture of individual and/or group support, but not all of these completed questionnaires. It has been found that the students who used the mathematics support had generally lower GCSE mathematics grades, but performed at least as well as those who did not use the support, despite lower GCSE grades being very highly significantly related to lower APD marks.

  The number of APD students by mathematics GCSE grade is shown on Figure 1. below, and it can be seen that supported students had a higher proportion of Grade C and D, than those who did not take up support, and none of the supported students had A* grades.

  Figure 1. Number of 2004/5 Surveyed APD Students by Mathematics GCSE Grade and whether Students received Mathematics Support

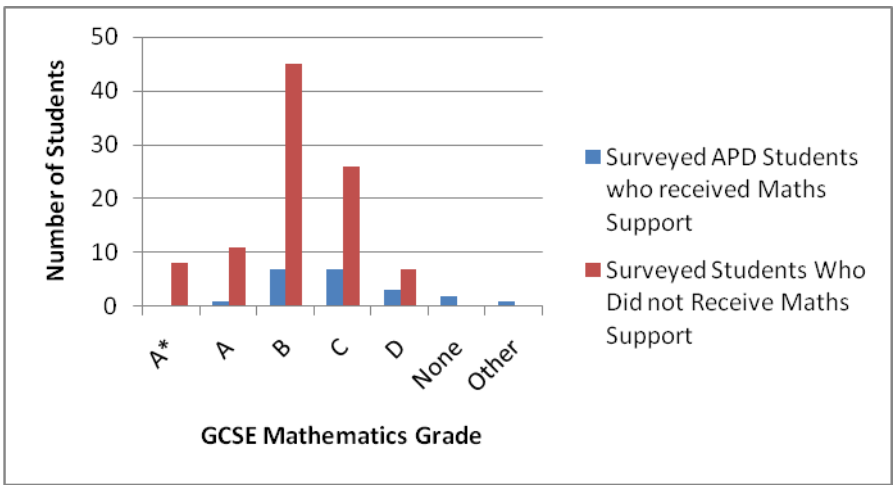


Table 2 below details the number of 2005 APD Statistics students and the mean mark achieved by mathematics GCSE Grade, shown separately for students' who received mathematics support and those who didn't. A numeric value was assigned to each Grade (A*=1,A=2, B=3, C=4 and D=5), and whilst it was recognised that the grades do not really constitute a ratio scale, it was considered reasonable that this would be approximately correct and a 't-test' was performed comparing the 'numeric values' of the grades for supported and unsupported students. It was found that there was a significant difference between the numeric values of the grades of supported and unsupported students (P=0.04). Supported students had on average significantly poorer Maths GCSE grades (mean 3.6, closer to Grade C) than unsupported students (mean 3.1, closer to Grade B).

Table 2. 2005 APD Statistics Student Numbers and Marks by Mathematics GCSE Grade shown separately for Supported and Not Supported Students

	Maths Supported Students			Not Maths Supported Students			All Surveyed ADP 2005 Students
Maths GCSE Grade	**No. Students**	**% of Students**	**Mean APD % Mark**	**No. Students**	**% of Students**	**Mean APD % Mark**	**Mean APD % Mark**
A*	0	0.0	-	8	8.2	61	61.4
A	1	4.8	65	11	11.3	61	61.6
B	7	33.3	57	45	46.4	54	54.0
C	7	33.3	48	26	26.8	44	45.1
D	3	14.3	39	7	7.2	41	40.5
None	2	9.5	45	0	0.0	-	45.0
Other	1	4.8	60	0	0.0	-	60.0
	21	100.0	-	97	100.0	-	-

Note: For eight students marks were not available.

It can be seen that for grades A, B and C the mark achieved by supported students is slightly higher than for not supported students (except for Grade D for which there was only a small number of students), however the difference between the supported students' marks and the unsupported students' marks was not found to be significant, either by paired t-test or ANOVA tests. This lack of significant difference is possibly due to the wide variation in student marks, the small numbers of students for some GCSE grades and the fact that the assessment was a report so the marks are not only representing ability in statistics, but also ability in report writing which is quite possibly clouding these results. See the comment regarding the 2004/5 Research Methods research report marks.

- 2004/5 First Year APD students' responses to what had been helpful was overwhelmingly the use of Excel (44% of responses), followed by doing examples (13% of responses), most of it (9%), none of it (8%), good teaching (4%), handouts (3%) of 80 responses. For features listed as unhelpful the most common response (33% of responses) was 'Nothing/None of the module'.

Findings Specific to Second and Third Year Students Learning Statistics

- An analysis of responses of intermediate level students studying Research Design and Analysis in 2005 to the open question 'What was their attitude towards studying mathematics and statistics' found that 20 students of 52, 38%, (alternatively 20 out of 43 responses, 47%) responded with positive attitudes. 10 of the 20 positive attitudes related very clearly to the understanding that the knowledge of statistical analysis techniques was required for their Honours research projects (referred to as IP, Investigative Project, below).

  Example student comments included:

  'I know it's useful for my IP so I am keen to learn' BSc AgLFM student

  'Do it because need to for my IP' BSc Agriculture student

- A summary of responses of intermediate level students studying Research Design and Analysis in 2005 to the open questions 'What had helped their learning?' and 'What had hindered their learning?' are shown in Table 3 below.

Table 3. 2004/5 RDA Students' Features Which Helped Their Learning

What Helped Students' Learning	**No. responses**
Doing exercises	**13 (or 17*)**
Practise tests at start of lecture	**6**
Lecturer	**5**
Genstat / Use of Computers	**4***
Lecture Notes	**3**
Various other (none more than 2)	**10**
Total	**41**
What Hindered Students' Learning	
Being taught on a Friday afternoon	**3**
The speed and intensity of information	**2**
Being confused	**2**
Lecturer talking when trying to think	**2**
Various others (none more than 1)	**10**
Total	**19**

As can be seen the most frequently reported feature which helped learning was 'Doing exercises'. As these exercises were done using Genstat, it would be reasonable to combine these responses with the 4 responses which related to Genstat or use of computers (see * above).

- Advanced Research Methods Students responded similarly to the responses of RDA students shown in Table 3 above, whose most frequently cited helpful feature was use of SPSS computer package (9 out of 24 responses, 38%).

- Natural Science and Social Science students generally had low confidence in their ability in statistics, and disliked statistics. This was not consistent with good (often excellent) achievement in the second year statistics examinations. Overall second/third year students thought their confidence had improved and viewed statistics as fairly important. Table 4 below details student achievement and mean response ratings to questions regarding confidence, liking of subjects, motivation and the rating of different methods of calculations. Social Science Research Methods students' results have been analysed by GCSE mathematics grade. Figures 2, 3 and 4 portray the variation in these results by students' GCSE Mathematics grades.

- Table 4 presents a summary of 2005/6 questionnaire responses, rather than 2004/5 questionnaires for the following reasons. In 2004/5 the second year social science students' Research Methods module end of year assessment was a research report. The analysis of students' responses with the students' marks found almost no significant relations between questionnaire responses and the students' marks for the research report. Thus showing that confidence and attitudes to learning statistics are not related to achievement in general report writing. However in 2005/6 the end of year assessment was changed to an exam comprising four questions each worth 25%, in which two of the four questions were statistics calculations. Analysing the scores for the statistics questions produced many significant relationships with the surveyed data, hence the 2005/6 data is presented in this summary.

- Table 4 also presents an overall summary of natural science second and third year responses. The mean assessment mark shown relates to a statistics exam using Genstat statistics package. Many significant relations were found between the 2004/5 and 2005/6 questionnaires responses and the students exam marks. Thus again demonstrating that students prior maths qualifications, confidence and motivation are related to achievement in a statistics exam.

- It can be seen in Table 4 and Figure 2 that the students' 'Confidences in Mathematics' and 'Confidences in Statistics' decreased with the lower GCSE mathematics grades. However, students' 'Confidence in Life' showed almost the reverse trend, Grade D students' 'Confidence in Life' mean was 4.3, which was the highest mean confidence calculated. Thus those who rated themselves as the most confident people in general (on average) were also those who were least confident in mathematics and statistics. This further highlights the lack of confidence in their ability in mathematics and statistics ability that these students have reported. We can also see that confidence in ability to do statistics was generally lower than confidence in ability to do mathematics. Similarly, students' 'Liking of mathematics' and 'Liking of statistics' also decrease with the lower GCSE mathematics grades, with statistics liked less than mathematics. Students' motivation however does not follow the same trend with GCSE maths; Grade C students being the most motivated, which is positive as this was the largest group of these students. In general all these mean results are low for students' confidence, liking and motivation in these subjects. Exceptions were responses from mathematics GCSE Grade A/A* students, and 'Confidence in Life' ratings. Similar mean responses were found in 2004/5 when this same cohort of students was surveyed in their first year APD statistics lectures.

- Figure 3 presents second year social science research methods students' actual examination marks. The exam comprised four questions each worth 25%, two questions were statistics questions (from a choice of three which were a selection of t-test, z-test and Chi-squared tests questions), and the other two questions

were written answers based on a research case study studied in advance. The mean percentage achieved by students for the two statistics calculation questions and the students' total exam mark, by students' mathematics GCSE grade, are shown in Table 4 and in Figure 3.

The mean marks achieved by the 45 students were very good (for those who completed questionnaires and for whom marks were available). The overall average was 68.4% for the statistics questions and 56% for the whole exam. It is interesting to note that the mean mark for the statistics questions was above 50% for all the Maths GCSE grades. The trend of marks for the different grades was the same trend for both the statistics questions and for the exam overall. Mathematics GCSE Grade A/A* students achieved the highest marks, followed by Grade B, then D, then C. The Grade D students (of whom there were only 4) may have worked harder to achieve their higher mean mark than the students with Grade C GCSE mathematics.

It is also interesting to note that the mean marks for the statistics questions were higher than the mean total exam marks, for all the Mathematics GCSE grades. Thus, whilst these students were lacking confidence in their ability to do statistics, this contrasts with their actual good performance in this exam. Not only has the sample of surveyed students achieved good results but the whole cohort mean results were similar: mean Social Science students' 2006 exam mark = 52.0%, mean Natural science students' 2006 exam mark 62.6%.

- Second and third year students rated highly all methods of doing/calculating statistics: by hand, calculator, Excel and Genstat or SPSS. See Table 4 and Figure 4 for mean ratings. Mean ratings were all above 3 for each method of calculation, which contrasts with mean confidences which were almost all below 3. Less well qualified students rated use of computer statistics packages (Excel, SPSS and Genstat) most highly, and more than calculations by hand, as did the majority of students.

  Maths GCSE grade A/A* students, however had a different opinion of the use of computer packages and, were in the minority, on average preferring hand calculations and calculators to using computers. An extreme example of this is demonstrated by a Maths GCSE Grade A students who used the 'Any Other Comments' question to state 'Genstat = worst program ever written'.

- Second and third year students gave varied responses regarding how their confidence and attitudes had changed towards studying statistics, many more were positive than negative. Further work could potentially be done to investigate how these positive changes in attitude could be achieved earlier, but it may be an issue of student maturity, the cumulative effect of two years of teaching and drawing close to the time when they will work on their honours research projects.

Table 4. 2005/6 Second Year Research Methods Students' Response Summary

Responses were given to Likert Scales 1-5 (1=low, 5=high)

Maths GCSE Grade	No. Students	Statistics %	Exam Total %	Confidence in Maths	Confidence in Stats	Confidence in Life	Like Maths	Like Stats	Motivation	Time Spent (hr per week)	Mean Topic Confidence	Rate Hand Calculation	Rate Use of Calculators	Rate Use of Excel	Rate Use of SPSS / Genstat (denoted by*)	Importance of Stats
A*/A	9	84.4	66.3	3.8	3.2	3.8	3.5	2.8	2.7	0.9	3.5	4.2	4.3	3.3	3.3	3.3
B	14	74.3	62.1	2.8	2.4	3.6	2.6	2.3	2.9	0.9	3.1	4.1	4.2	3.4	3.3	3.2
C	18	57.0	47.1	2.5	2.2	3.8	2.4	2.4	3.1	1.5	3.2	3.8	4.3	4.2	4.0	3.0
D	4	60.3	49.8	1.5	1.5	4.3	2.0	2.0	2.5	1.3	3.1	3.8	4.5	4.8	5.0	3.8
Mean Soc	**45**	**68.4**	**56.0**	**2.8**	**2.4**	**3.8**	**2.6**	**2.4**	**2.9**	**1.1**	**3.2**	4.0	4.3	3.8	3.7	**3.2**
Mean Nat	**102**	**63.3**	**-**	**3.3**	**2.7**	**3.8**	**3.0**	**2.5**	**2.7**	**0.8**	**3.4**	**3.6**	**3.9**	**3.7**	**3.7***	**3.4**

Figure 2. 2005/6 Social Science Research Methods Students' Confidence, Attitudes and Motivation in Learning Statistics by GCSE Mathematics Grade

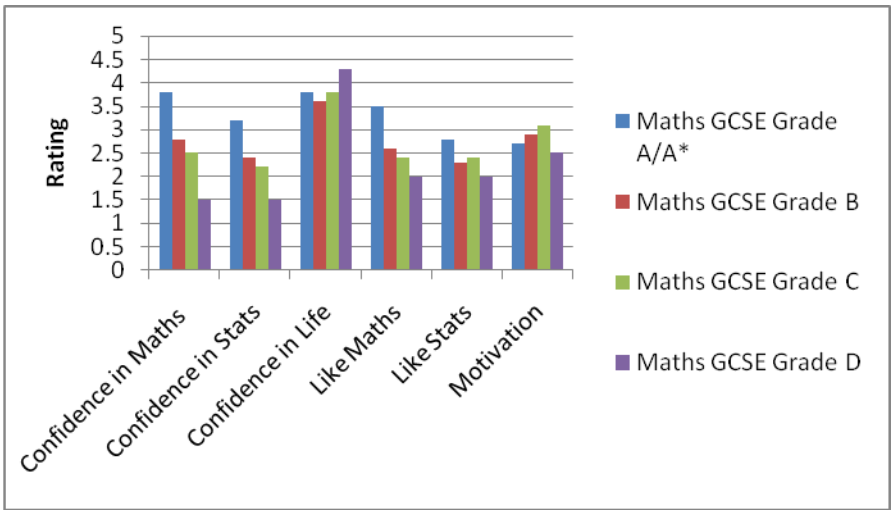


Figure 3. 2005/6 Social Science Students' Research Methods Exam Statistics Questions Mark and Total Exam Percentage Mark by GCSE Mathematics Grade

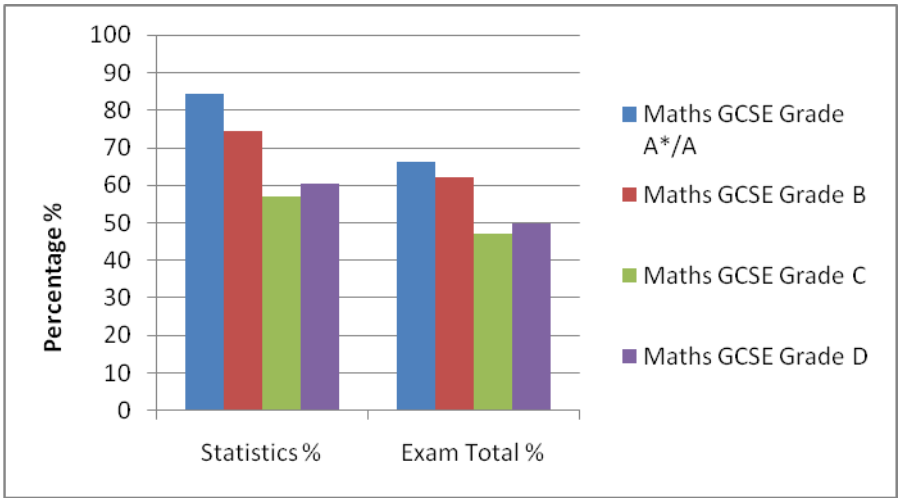
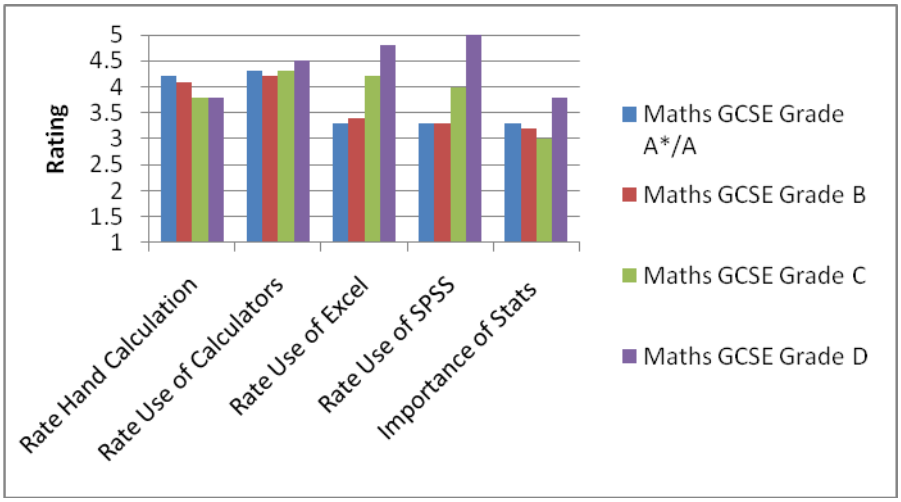


Figure 4. 2005/6 Social Science Research Methods Students' Ratings for Different Methods of Calculation by GCSE Mathematics Grade



Findings Relating Specifically to Engineering Students

- Significant relationships have been found between students' marks in mathematics examinations and each of the following:
  - A level Maths - whether students had studied A level Mathematics.
  - Award Levels: MEng and BEng, BSc and HND/FdSc
  - Confidence in Mathematics
  - Motivation (self-rating 1-5)
  - Confidence in Life (negative correlation)
  - Liking of mathematics

The mean marks for the first year engineering student award levels were: MEng and BEng 85%, BSc 66% and HND/FdSc 56%. It can clearly be seen that the MEng and BEng students have achieved the best, even though their examinations and syllabus were more difficult. Students are recruited onto the different award levels based on their mathematics qualifications, so these mean marks are consistent with the overall finding that students with better qualifications in mathematics perform better in mathematics at university.

- Engineering students at Harper Adams generally had good to medium confidence in their mathematical ability at the end of their first and second years of study. A portion of both first and second year engineers reported their confidence to have improved at the university college.

- The majority of the engineers surveyed (over 80%) would choose to study their first and second year mathematics modules. See Table 1.

- A common motivating attitude of the engineers was '*Maths is necessary*', *'has to be done'* which appeared to compensate for lack of confidence or dislike of the subject.

- Features cited by students as having been helpful, and improved their confidence and ability included: mathematics support (26%), challenging work (17%), good teaching (13%), doing examples (9%), and handouts (9%) which contained: theory, worked examples, exercises and answers. The most frequent response for features which hindered students' learning was 'None' (47% of responses).

- Mathematics Support was rated highly by engineering students, overall first and second year mean rating 4.8 (out of 5). 2005 first year mean mathematics support ratings were: Helpfulness 4.7, Clarity 4.6, Relevance 4.8, Timing 4.5. As stated above the support was the most frequent response for 'helpful features' of the module (26% of responses).

  Mathematics support was used most by BSc students during the year. Analysis of the marks of BSc engineering students, comparing the marks of supported students against those who did not take up the support, found that the supported students achieved slightly higher marks (mean 68.0%) compared to those who did not take up the support (mean 63.6%). However, this difference was not found to be significant (possibly due to a wide range of marks and small sample sizes).

3.2 Statistics Resources

3.2.1 Leaflet Content and Intended Users

The following leaflets were produced and made available in March 2007, with pilot versions in use throughout 2006/7. ANOVA is an acronym for 'Analysis of Variance', a statistical hypothesis test.

- ANOVA Glossary
- ANOVA - Single Factor ANOVA Example
- ANOVA - Factorial ANOVA Example
- ANOVA - Dose Response ANOVA Example
- T-test Notes

- Chi Squared Test Notes

The leaflets were aimed at students across the college from first year to MSc students. The leaflets were designed to be complete but concise, for use as a revision aid for previously learnt material or as a means to learn a new statistical test with recommended reading listed for more detail.

The ANOVA glossary leaflet explained the particular terminology associated with ANOVA tests. Many terms have multiple equivalent names which need to be known in order to relate lecture notes to text books and computer terminology (for example residual variation is also called the within groups variation).

The example notes for the three types of ANOVA tests: Single Factor, Factorial and Dose Response contained: descriptive text, a data example, Genstat computer output with interpretation, presentation of results and recommended reading. Excel and SPSS output were also included in the Single Factor ANOVA leaflet. It was, however, considered that only Genstat was appropriate for the other two more complex types of ANOVA. The ANOVA leaflets were reviewed by a colleague, and as a result a few small changes were made before the final versions were completed.

The t-test notes and Chi squared notes contained descriptive text, a data example, hand calculations using a formula, examples of computer output (Excel, Genstat and SPSS) with interpretation and recommended reading. Longer descriptive text and hypothesis test steps were also included in these leaflets. The version of the t-test formula used in the leaflet was consistent with first year APD statistics notes.

3.2.2 Leaflet Distribution

The leaflets were made available to students in March 2007 by placing in racks in the *Aspire* Centre outside office AC10 for Mathematics Support and on the college network. Paper copies were made on yellow paper. Announcements of their availability were made to students by e-mail both before and after Easter and by lecturers to natural science students during Research Methods lectures after Easter. The timing of the release of the notes was in time to aid students with revision for exams. The documents were also made available to a Research Methods Resource under development within Harper Adams' Virtual Learning Environment.

The resources have been used in mathematics support one-to-one appointments and in small group support. The t-test leaflet has been used for first year APD statistics support, all leaflets have been used with second year research methods students, and all leaflets have been used with a smaller number of final year FdSc, BSc, MEng and MSc students. It has been particularly useful to give leaflets to students at the time of booking a mathematics support appointment, such that students had the opportunity to read the leaflet before their appointment, enabling better use of the appointment time as students were then better informed.

Precise numbers for use of these leaflets are not known, however, approximately 125 copies of the t-test notes have been distributed and approximately 50 copies of each of the other leaflets. The use of documents on the college network by students cannot be quantified, although, this proved to be an effective and straight forward means to provide immediate access to these leaflets for all students.

Whilst recommended texts and other statistics books are available from the library, the number of copies available, even for the best stocked books, are insufficient for large numbers of students during times of peak demand. These leaflets provide a supplement to lectures notes to help to meet a demand for further reading. Additionally, the leaflets were designed to be consistent with Harper Adams lecture notes and statistics packages currently used, which was not always the case for text books.

3.2.3 Statistics Resources Feedback

The resources have been well received and much used in mathematics support, for individual appointments from first year APD support to MSc support and in the APD drop-in support sessions (t-test only).

Positive comments were received after distribution of ANOVA leaflets in Research Methods lectures for natural science students, with some students asking for the leaflets to be made available earlier in the module. In future the leaflets will be included in the reading list on the natural scientists' module Scheme of Work.

A 1-page feedback form for the leaflets was made available in the racks outside AC10 and on the H: drive, however, only a small number of completed forms were received, mainly, it is thought, due to timing difficulties for returning the forms at a later date. Students were generally given the leaflet to take away for further reading so they could not complete the feedback until after reading the leaflet at which point most students were not seen again. In support drop-ins and workshops there was pressure of time, for example APD support, and it was not possible to ask for feedback on the leaflets. However, the completed feedback forms received were from a broad range of students, across the full range of leaflets and provided some useful comments.

Example written feedback comments received included:

> *'Steps were easy to follow'* Year 1 student regarding the t-test notes.
>
> *'Good examples – showing manual and computerised results so that students can understand what the figures mean in relation to each other'* APD lecturer comment regarding t-test notes.
>
> *'Very detailed, more so than any notes I've had in the past. They also explain what the tests are used for which I've never understood before'*
> BSc Veterinary Nursing and Practice Management Final Year Dissertation student comments regarding Chi Squared and Single Factor ANOVA notes.
>
> '*ANOVA Glossary useful. Good clear examples to demonstrate purpose of tests. Printed on Yellow paper so easy to find in my file! Citations and references useful – more lecture material should adopt this method. i.e. minimum requirement of 12 d.f. in residual column is referenced to books available in HAUC library.'* MSc Agricultural Engineering student comments regarding ANOVA leaflets.

The overall average rating received for the leaflets was 4.5 (out of 5).

The Chi-squared notes were amended after Easter to include a Genstat output example, and the t-test notes are intended to be revised to add more annotations to

computer printout examples as yellow shading did not show up on the yellow paper used for copies.

3.2.4 Statistics Resources Development Potential

Further production of statistics handouts for students would be beneficial, e.g. for Correlation and Regression, Normal distribution and Standard Deviation, and less commonly used tests, for example Fisher's Exact test in place of Chi Squared for data with low frequencies and other non-parametric tests.

3.3 Workshops

Workshop materials were developed for the following first year modules with numerical content and delivered during the academic years shown below. The aim of these workshops was to supplement lectures with additional teaching and resources on particular mathematical topics within other subjects, to enhance the skills of numerically weak students.

- Valuation Calculations for REALM students (2005/6 & 2006/7)
- Elasticity Calculations for Economics (2005/6 & 2006/7)
- Drug Dose Calculations and Solution Calculations for veterinary nursing students (2005/6)
- Statistics Support workshops for students on first year animal and veterinary nursing courses (2006/7).

The materials developed were additional handouts, written to supplement and be consistent with module content, which was considered important.

Feedback was gathered from the workshops held in 2006/7. Positive feedback was obtained with good average overall ratings for the sessions: Valuations 4.4, Elasticity 4.6 and APD Support 4.7 (out of 5).

Student responses to 'What did you find useful in this session?' included:

'General clear structure for help with % and valuations'

'All the session. I find maths very hard'

'Step by step ways to do various statistics'

'The summary sheets given were very useful'

'Getting different, slightly simpler notes was useful'

'Was explained so that we could understand'.

The impact on student achievement from the workshops could not be quantified due to lack of 'without intervention' students for comparison. Feedback to and from course managers indicated that the sessions were beneficial and had a positive impact on student achievement. Some students have indicated verbally to the support tutor they would not have been able to write their report without the extra tuition. Increased student confidence was noted by teaching staff for students using drug calculations following the workshop.

Lessons which could be learnt from the first year statistics support workshops were that students could be made more aware of the support and should be encouraged to take up support earlier in the module (particularly APD). Student feedback requested more opportunities for the students themselves to do examples during workshops which would require more time available, which also necessitates student attendance at earlier opportunities. From the tutor perspective it is beneficial to be prepared for workshops should extra demand arise at critical times (for example approaching submission deadlines), which has happened in the past.

4. Impact on Personal Development

The research has been conducted under supervision and registration with Loughborough University's Mathematics Education Centre as part of a higher degree by research. The questionnaire data has provided opportunities for use of Excel, Genstat and SPSS statistical packages on larger real datasets. Writing the leaflets and support materials for the workshops involved background reading, particularly of statistics books recommended for Harper students, which was beneficial. All of the professional development undertaken for this work has been useful and has in turn informed support given to students, including those undertaking honours projects and dissertations.

5. Lessons for the Future

The key findings from the research for lecturers to implement in their teaching of mathematics, numeracy and statistics skills to students are:

- To stress the usefulness, relevance and importance of the mathematics and statistics throughout the module(s)
- To maximise opportunities for the students themselves to do the mathematics/statistics by all and various means
- To include use of computer packages to do the mathematics/statistics (e.g. Excel, Genstat, SPSS), as students approach this with a different attitude and most students enjoy the use of computers
- To provide student handouts
- To provide a selection of worked examples
- Allow sufficient time and correct pace for students to think during lectures
- To include real life examples and applications of the maths/statistics
- As students' mathematics qualifications have a significant effect on performance, it would be beneficial for lecturers to identify weaker students to target for support during lectures and to encourage to take advantage of the extra Mathematics support available
- To encourage students to seek help at earlier opportunities in the modules.

The additional student workshops have shown that targeted and appropriately timed additional support of mathematical topics can be beneficial to students. It is considered important that workshops and resources are consistent with module content and expectations on students, and that workshops are arranged with or by the course manager or the related module tutors.

The positive student and staff responses to the new statistics resources, especially their usefulness in mathematics support, demonstrate the benefit of such resources, the range of which could be further extended (see Statistics Resources Development Potential section).

6. Conclusion

Students have a wide range of qualifications, confidences and attitudes towards learning mathematics and especially statistics. Students' experiences pre-university have the greatest effect on their experiences at university, both their entry qualification in mathematics, which were shown to have the greatest significant effect on university performance, and their confidence formed at school which is carried over into university. Confidence and attitudes were also found to have some significant relations with achievement before and at university. Higher achievement at university was generally associated with higher entry qualifications in mathematics and higher confidence in their mathematical ability.

Engineers' attitudes towards learning mathematics and motivation were overall better than for non-engineers' learning of statistics, and some evidence was found that this is in part due to the understanding that mathematics is necessary for engineering. Second year natural science students also reported a high level of understanding that the module was necessary for their honours project and these students also demonstrated a greater willingness to learn than those student groups who did not see the usefulness or relevance of statistics.

Students on all modules surveyed appreciated the benefits of doing exercises, using all methods. Use of computers (Excel, Genstat and SPSS) was appreciated by the majority of students learning statistics, especially by less mathematically qualified students, and were the most common response to features which were helpful for learning statistics, This is consistent with similar findings in schools that use of ICT has a motivating effect on pupils learning mathematics.

Efforts that have been made at Harper Adams to provide mathematics support, the redesign of mathematics and statistics modules, provision of handouts and good teaching, all received predominantly positive feedback, as did the new resources and workshops produced for this Development Fellowship. However, there were still some negative attitudes, lack of confidence and motivation reported by a considerable number of students, particularly by those learning statistics. Whilst it is considered that the root cause was often pre-university experiences, further efforts could usefully be invested to extend resources and the support provided, and for university lecturers to seek to boost student confidence in mathematics and statistics as part of their teaching.

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