MSOR connections

Articles, case studies and opinion pieces relating to innovative learning, teaching, assessment and support in Mathematics, Statistics and Operational Research in HE.

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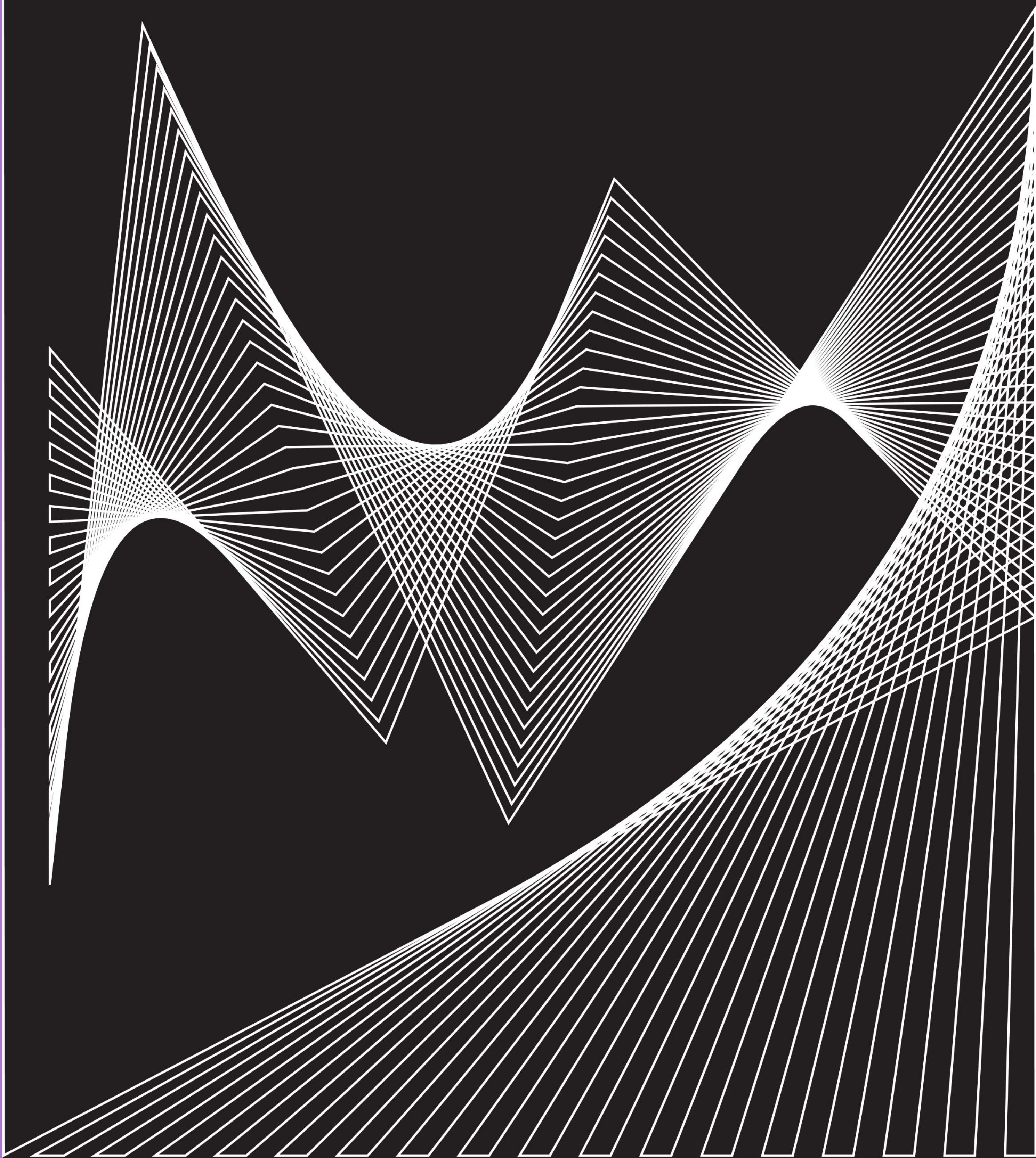

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EDITORIAL

Editorial

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It is a year on from the ‘re-launch’ of MSOR Connections and I am delighted to report that there is clearly still a strong appetite across the community to share ideas and experiences of mathematics learning, teaching and support. As the sigma-network begins a new phase of development, following on from the end of the funding period secured by **sigma**, it is anticipated that MSOR Connections will have an increasingly important role to play in disseminating practice across the sector. Therefore, on behalf of the editors, I would like to take this opportunity to keep encouraging all readers for their contributions as we all look to learn from one another and develop our practice.

The breadth of contributions submitted to Connections is again reflected in this latest issue. We begin with an article from Darlington and Bowyer who report on student perceptions of A-level Mathematics and Further Mathematics. This is followed by two case studies from Khan and Cornock who consider alternative approaches to motivate first year undergraduate students in the study of statistics and skills development respectively.

The next two articles involve undergraduate projects. Hunt and Bradshaw discuss how a ‘research paper’ approach has been developed in place of more traditional project assessment methods; while Sienko et al. report on how an undergraduate project has directly enhanced exam scheduling procedures at their institution.

We then have three papers which demonstrate the advances being made in Mathematics Support across Ireland. Pfeiffer et al. present a review of the 10th annual workshop of the Irish Mathematics Learning Support Network, which focussed on the importance of tutor support and personal development in the provision of mathematics support. Donlon and Ni-Fhloinn report on how mathematics support is being extended to secondary school students by Dublin City University. Then McIvor et al. highlight the process of establishing the first Mathematics Support Centre in any Further and Higher Education College in Northern Ireland.

The final articles in this issue review some of the electronic tools that are now available to complement mathematics learning and support. Cross discusses the potential benefits of using a Microsoft Surface Pro tablet when providing mathematics support; while Farmer provides a detailed review of popular survey tools that are currently available to students to collect the various forms of data often required as part of their studies.

Finally, I would like to congratulate Tony Croft and Duncan Lawson in being awarded the prestigious Gold Medal from the Institute of Mathematics and its Applications (IMA). Tony and Duncan’s hard work and commitment in establishing **sigma** has led to a thriving community of mathematics support practitioners and this award is well deserved recognition of the sustained and outstanding contribution both have made to mathematics education across Higher Education.

RESEARCH ARTICLE

Students' views of, and motivations for, studying A-level further mathematics

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Abstract

In response to recently-announced reforms to A-level Mathematics and Further Mathematics, a large-scale study was undertaken regarding current undergraduates' views of those qualifications. Students of Science, Technology, Engineering, Medicine and Mathematics (STEMM) and Social Science degrees who had Further Mathematics were surveyed regarding their experiences of the subject and motivations for studying it. Results were positive, across students of a range of degree disciplines, highlighting the benefits of its study as preparation for mathematically-demanding degrees. Whilst access to studying Further Mathematics is poor in some schools, we suggest that more is done by universities to promote its study as a means of better-preparing students for their future degree courses.

Keywords: Mathematics, A-level, Further Mathematics, transitions, motivation.

1. A-level Further Mathematics

Advanced 'A' levels are qualifications taken by students in England, Wales and Northern Ireland in their final year of secondary schooling, age 18. Students typically study three or four subjects, and most universities require certain pass grades at A-level in order for applicants to be offered a place to study for an undergraduate degree. Students are awarded an Advanced Subsidiary 'AS' level after the first year of study, after which they may cease studying that subject. It is common for students to take one AS-level in addition to their A-levels.

A-level Mathematics was the most popular A-level in 2015, comprising 10.9% of all A-levels taken. A-levels in Further Mathematics, Statistics and Use of Mathematics are also available, though are not as popular. Nonetheless, Further Mathematics has become one of the fastest-growing A-level subjects and, in 2015, had 14,993 candidates (Joint Council for Qualifications, 2015).

A-level Mathematics and Further Mathematics are modular, comprising six individually-assessed, equally-weighted units. A-level Mathematics consists of four Core Pure Mathematics units, and two applied units from three strands: Statistics, Mechanics and Decision Mathematics. Students may specialise in one area or take units from different strands.

There are two compulsory Further Pure Mathematics units in A-level Further Mathematics. The remaining four units may be chosen from any of the other applied units, or from a further three Further Pure Mathematics units. AS Further Mathematics consists of two Further Pure Mathematics units and one optional unit, which may be pure or applied.

However, A-levels Mathematics and Further Mathematics are undergoing reform. From 2017, A-level Mathematics will have no optional components, and will consist of Pure Mathematics, Statistics and Mechanics content. This will benefit universities as students will receive equal preparation in both areas of Applied Mathematics. Further Mathematics will have a compulsory

Pure Mathematics component, with the remaining content determined by the awarding bodies. It is likely that this will include a mixture of Applied and Pure Mathematics.

2. The Mathematics Problem

Over recent years there have been numerous calls to increase the mathematical ability of new undergraduates and those entering the workforce. A seminal report, Tackling the Mathematics Problem (London Mathematical Society, 1995), claimed that it is increasingly common for students to appear underprepared for Mathematics degrees despite achieving good grades at A-level. Furthermore, once students advance to undergraduate study, many fail to succeed in this new environment. Low pass rates in mathematical subjects are common in the first year of study (London Mathematical Society, 1995), and the Mathematical Sciences had the highest drop-out rate (29.9%) of all disciplines in 2013 (Higher Education Statistics Agency, 2014). It is noted that [1] this is the most current data available. The Advisory Committee on Mathematics Education has also written a large range of reports on this topic, relating to both mathematical preparedness for higher education and the workplace (ACME, 2011a, 2011b).

In response to these concerns, a number of initiatives have been introduced to encourage wider participation in post-compulsory Mathematics. Some universities now require Mathematics' applicants to take admissions tests or other examinations (e.g. Sixth Term Extension Papers or Advanced Extension Awards). Others perform diagnostic testing on new students in order to ascertain their mathematical competency. It is also increasingly common for some universities to require that students have taken A-level Further Mathematics for admission to Mathematics and Engineering degrees.

However, not all schools are able to teach Further Mathematics due to teacher expertise and timetabling issues, which means that some students are unable to study it. Consequently, the Further Mathematics Support Programme (FMSP) was introduced in 2004 in order to increase student access to Further Mathematics. It provides support for students, schools and teachers through professional development, online support, and enrichment days (Further Mathematics Support Programme, 2015).

3. Method

3.1 The Study

In order to ascertain the mathematical needs of students going on to study STEMM (Science, Technology, Engineering, Mathematics and Medicine) and Social Science subjects at university, a large-scale project was undertaken (see Darlington and Bowyer (2016)). Part of the study investigated students' views regarding how well Further Mathematics prepared them for university study and their motivations for and experiences of studying it.

This article reports on data collected from an online questionnaire distributed to students who had studied at least one year of an undergraduate course in STEMM or Social Sciences. Universities were contacted to ask whether they could send information regarding the study to their students, and the questionnaire received responses from over 4,000 participants. These data relate only to the 2,243 participants who had taken AS or A-level Further Mathematics.

3.2 Sample

The data described here are from participants who studied at 66 British universities. Most participants studied Mathematics (41.4%) or Science (50.3%), with a further 8.3% studying a Social Science (see Table 1).

Table 1. Participants' undergraduate subjects

Degree Area (including. joint honours)	Number of participants	Proportion of participants (%)
Architecture	15	0.7
Bioscience	54	2.4
Business Studies, Accounting and Finance	35	1.6
Chemistry	135	6.0
Combined Sciences	258	11.5
Computer Science	59	2.6
Economics	90	4.0
Engineering	216	9.6
Geography	29	1.3
Geological Sciences	4	0.2
Linguistics	9	0.4
Mathematics	928	41.4
Medicine	85	3.8
Other Social Sciences	2	0.1
Physics	302	13.5
Psychology	21	0.9
Statistics	1	0.0
Total	2,243	100.0

Most participants were in their second year (52.7%), with a further 31.8% in their third year, 14.9% in their fourth year, and 0.6% in their fifth year or above. Most participants were male (62.3%), 36.8% were female, 0.3% identified as other and 0.6% preferred not to say.

Most participants had taken A-level Further Mathematics, with the remaining 21.2% having taken only the AS-level.

4. Students' Motivations for Studying Further Mathematics

Participants were asked to rate how influential certain factors were in their decision to study Further Mathematics.

The Likert scale question, requiring participants to describe a factor as having 'influenced me a lot', 'influenced me a little' or 'didn't influence me', was adapted from a questionnaire used by the Qualifications & Curriculum Authority (2006). The QCA reported on participation in A-level Mathematics from the perspectives of A-level students; however, the questions were applicable to this study.

Not all participants answered all questions, so the number of responses is indicated in Table 2.

Table 2. Factors motivating students to take Further Mathematics

Factor	Number of responses	% Participants		
		Influenced me a lot	Influenced me a little	Didn't influence me
I enjoyed school Maths.	2,179	81.9	14.0	4.1
I was thinking of doing a Maths or Maths-related degree at university.	2,181	72.0	18.7	9.3
I was better at Maths than at other subjects.	2,177	70.1	23.1	6.9
I coped well with GCSE Maths.	2,169	67.0	23.0	10.0
I thought it would be a useful qualification to have.	2,172	64.3	28.4	7.3
It fitted well with my other subject choices.	2,167	60.0	26.0	14.0
I needed Maths for my future career.	2,168	47.0	31.6	21.4
I wanted to challenge myself.	2,180	43.8	32.2	24.0
I knew it was a requirement for the degree I wanted to do.	2,172	40.9	24.3	34.9
The teaching staff were good.	2,169	37.0	32.6	30.4
The topics covered looked interesting.	2,151	24.0	35.1	40.9
My teachers encouraged me to study it.	2,166	22.9	37.2	40.0
My school Maths department's results were good.	2,162	12.4	22.1	65.5
My parents encouraged me to study it.	2,161	9.3	23.2	67.5
I wanted to do the same subject as my friends.	2,161	2.9	8.3	88.8

The items from this question fit broadly into four areas:

4.1. Enjoyment of Mathematics

Enjoyment of school Mathematics had the greatest influence on participants' decisions. This was more so the case for Mathematics students (85.0% were influenced a lot) than Science and Social Science students (both 80.0%).

However, participants predominantly reported that they were not influenced by the topics of Further Mathematics looking interesting. Nevertheless, significantly more $(\chi^2(4) = 18.843, p = 0.001)$ Mathematics undergraduates reported that they were influenced a lot by this factor (28.3%) than Science (20.4%) or Social Science undergraduates (23.3%).

4.2. Preparation for future career/study

Whilst the majority of participants reported that they were influenced a lot by the belief that Further Mathematics would be a useful qualification to have, most Medicine students (53.8%) reported that they were only influenced a little. This could be because many universities state that they do not consider Further Mathematics as a separate A-level subject for admission to Medicine (Further Mathematics Support Network, 2011).

Unsurprisingly, responses regarding the influence of thinking of studying a Mathematics or related degree differed by participants' degree subject areas. Considering studying for a Mathematics or Mathematics-related degree only featured in the three most influential factors for Engineering, Mathematics and Physics students. Unsurprisingly, significantly more Mathematics undergraduates said that this influenced them a lot (82.6%) compared to Science (66.1%) or Social Science (54.0%) undergraduates ($\chi^2(2) = 99.951, p = 0.000$). Furthermore, women were less likely to have been influenced by this factor than men ($\chi^2(2) = 23.357, p = 0.000$).

There were also subject variations regarding the expectation that Mathematics would be required for students' future careers. Most Engineering (76.3%) and Physics (57.6%) students were influenced a lot by this. However, most Geography (58.6%), Medicine (52.5%) and Psychology (64.7%) students said that they were not influenced by it. It was most common for Bioscience (52.9%), Chemistry (51.2%) and Computer Science (45.8%) participants to only be influenced a little. Additionally, men were more likely than women to report that they were influenced a lot by this factor ($\chi^2(2) = 22.138, p = 0.000$).

4.3. Prior success in Mathematics

Prior success in Mathematics appeared to be a strongly influential factor. This was both in terms of coping well at GCSE, and being better at Mathematics than other subjects. Mathematics students were significantly more likely than other participants to be influenced by the latter ($\chi^2(2) = 28.920, p = 0.000$; see Figure 1).

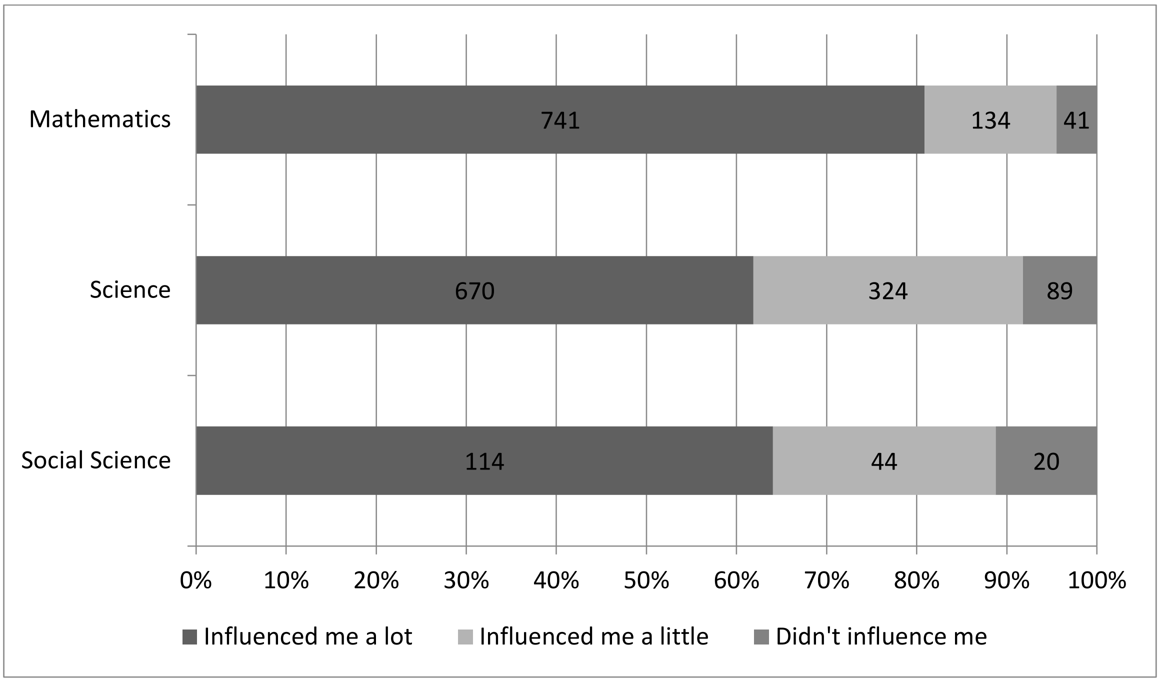

Figure 1. 'I was better at Maths than at other subjects'

4.4. Others' views

Overall, participants reported that they were not influenced by parents, teachers or friends. However, women were more likely to have been influenced by these factors than men.

5. Students' Experiences of Studying Further Mathematics

Using a Likert scale, participants were asked to indicate their relative agreement with a number of statements regarding their experiences of studying Further Mathematics. Overall, their responses were positive (see Table 3).

Table 3. Participants' experiences of Further Mathematics

	Number of responses	% Participants				
		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I'm glad I did Further Maths.	2,187	69.5	25.7	3.2	1.1	0.5
I enjoyed Further Maths.	2,196	49.9	38.4	7.5	3.2	1.0
Further Maths was more demanding than Maths.	2,188	48.6	39.3	7.7	3.8	0.6
In my first year at university, we were taught material that I had learned in Further Maths.	2,175	42.2	36.6	5.9	8.6	6.8
Most people on my university course studied Further Maths.	2,071	36.9	22.1	12.3	18.1	10.5
Studying Maths and Further Maths was sufficient preparation for my degree.	2,186	32.7	40.9	10.9	11.1	4.3
I found Further Maths challenging.	2,192	26.6	47.9	13.8	8.8	2.9
Further Maths was my most difficult A-level.	2,172	25.3	17.6	13.1	30.9	13.1
The material covered in Further Maths was of a different kind to Maths.	2,184	21.3	46.0	18.6	12.5	1.6

When combining the 'strongly agree' and 'agree' responses, and the 'strongly disagree' and 'disagree' responses, a number of differences emerged between participants:

5.1. *Further Mathematics as preparation for students' degrees*

Overall, the data suggest that Further Mathematics is good preparation for degrees in Mathematics, Science and Social Science. 73.6% of participants reported that they agreed or strongly agreed with the statement, 'Studying Maths and Further Maths was sufficient preparation for [the mathematical demands of] my degree'. Figure 2 shows that this differed significantly between subject areas ($\chi^2(4) = 62.466, p = 0.000$).

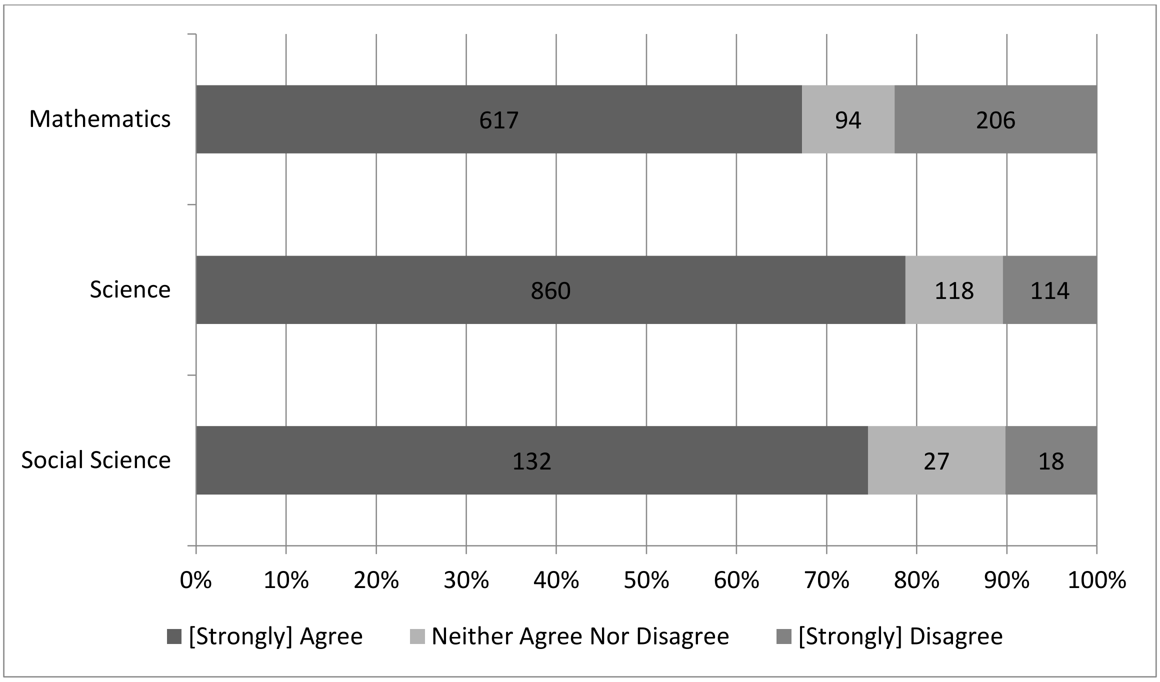

Figure 2. ‘Studying Mathematics and Further Mathematics was sufficient preparation for my degree’

Furthermore, whilst most participants reported that they had studied material in their first year of university that they had learned in Further Mathematics, this was significantly more ($\chi^2(4) = 126.756, p = 0.000$) so the case for Mathematics and Science students than Social Science students (see Figure 3).

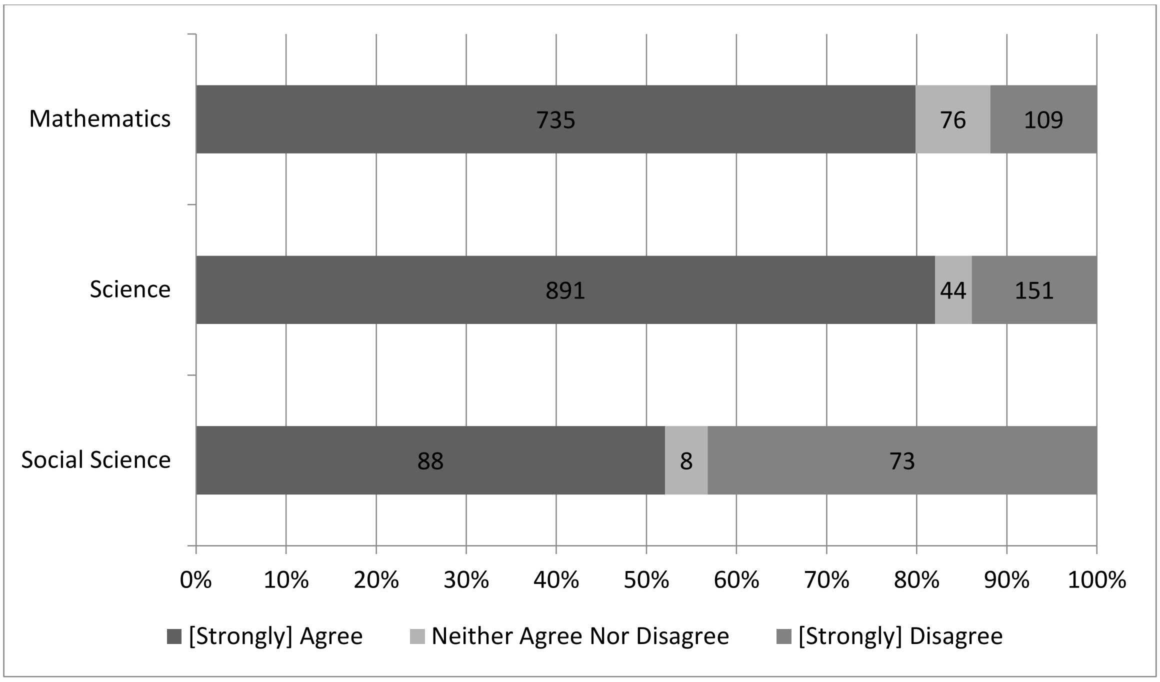

Figure 3. ‘In my first year at university, we were taught material that I had learnt in Further Mathematics’

5.2. Enjoyment of Further Mathematics

Responses indicate that students enjoyed and appreciated Further Mathematics. Overall, 88.3% of participants agreed or strongly agreed that they had enjoyed Further Mathematics, and 95.2% were glad that they had taken it. However, a significantly greater proportion of Mathematics students reported that they had enjoyed Further Mathematics than Social Science students (see Figure 4).

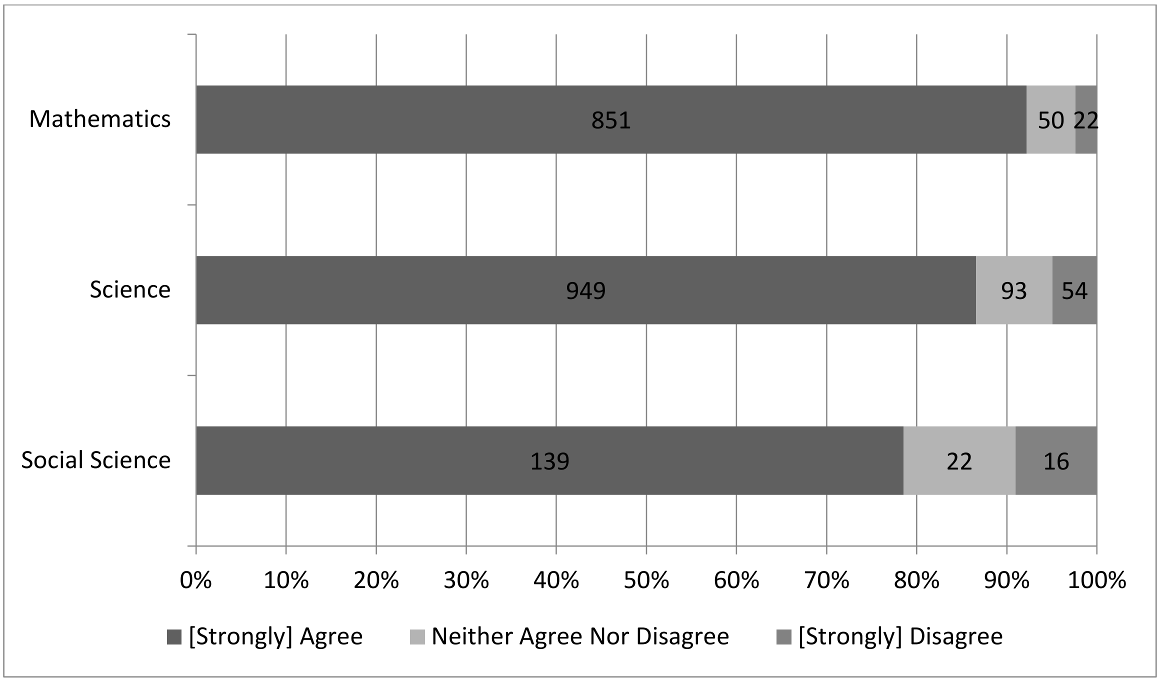

Figure 4. 'I enjoyed Further Mathematics'

5.3. Perceived difficulty of Further Mathematics

Whilst nearly three-quarters of participants either agreed or strongly agreed that they found Further Mathematics challenging, only 42.9% reported that it was their most difficult A-level. Opinion was polarised, with similar proportions disagreeing and strongly agreeing with the latter.

Social Science participants were more likely ($\chi^2(4) = 70.426, p = 0.000$) to strongly agree or agree that they found Further Mathematics challenging (87.0%) than Science (79.0%) or Mathematics (66.9%) participants. Furthermore, Social Science students were more likely ($\chi^2(4) = 30.661, p = 0.000$) to describe Further Mathematics as their most difficult A-level (51.0%) than Science (47.3%) and Mathematics (36.2%) participants.

Finally, the vast majority of participants agreed that Further Mathematics was more demanding than A-level Mathematics. Significantly more participants ($\chi^2(2) = 67.680, p = 0.000$) reported this if they had taken the full A-level (90.8%) than just the AS-level (76.4%).

6. Limitations

A large-scale study such as this has a number of limitations owing to the nature of data collection and sampling. As participants were self-selecting, there is sample bias. This occurred on two levels – not only can we not be sure how many universities passed on details to their students and how (e.g. in a newsletter or a stand-alone email), but those who took part did so by choice. These students may have been those who were particularly satisfied or dissatisfied by their mathematical preparation, potentially skewing the results.

Participants were current students in their second year or above. The further a participant was into their degree, the longer it had been since they had taken their A-levels. This means that their memory of motivations or experiences of the subjects may not have been as clear as for those only in their second year of study. Participants were also given 'unsure' as an option, to reflect this possibility. Very few chose that option, so their responses have been omitted for the purposes of this article.

The views of students who had not taken Further Mathematics are not analysed here in detail. The questions regarding students' motivations and experiences of Further Mathematics were only posed to those students who had taken the qualification. However, those who had not taken Further Mathematics were nonetheless asked to describe whether they believed that taking AS or A-level Mathematics had been good, bad or neither good nor bad preparation for the mathematical demands of their degree. The majority of respondents for all subject areas reported that they believed A-level Mathematics had been good preparation. This data will be reported in full in due course.

7. Discussion and conclusions

The data described in this article are generally positive. Undergraduates of STEMM and Social Science subjects who took AS or A-level Further Mathematics prior to going to university generally enjoyed studying it and believed that it was beneficial preparation for the mathematical demands for their degree.

Some differences existed between students of different subject areas. The mathematical demands of Mathematics degrees are obviously much stronger than in Science and Social Science; hence, the mathematical competency required of students is likely to be higher, leaving more scope for dissatisfaction with Further Mathematics. However, the vast majority of Mathematics participants were satisfied with the mathematical preparation that Further Mathematics offers (see also Darlington (2015)).

Students' motivations for studying Further Mathematics reflected the varying mathematical demands of undergraduate courses. Only prospective Engineering and Mathematics applicants to certain universities are required to have taken Further Mathematics. Consequently, these universities may tailor their teaching and course content to their students' mathematical backgrounds. This means that students who have taken more Mathematics than is required are likely to be at an advantage in the first year of their degree, though others may find it boring to study material which is already familiar to them.

Furthermore, prior success in Mathematics was a strong motivating factor for many participants, and is reflected in Further Mathematics candidates' high grades. In 2015, 56.3% of those who took A-level Further Mathematics achieved at least an A grade (Joint Council for Qualifications, 2015). These highly mathematically-competent undergraduates nonetheless found Further Mathematics challenging, though relatively small proportions described it as their most difficult A-level. This indicates that Further Mathematics offers an appropriate level of challenge, even for those students who are mathematically talented.

8. Recommendations

Whilst Further Mathematics is rarely required for university admission, its merits are certainly clear. Undergraduates studying subjects with a mathematical component were positive about their experiences of Further Mathematics and described it as valuable preparation for their course. Consequently, it may be beneficial for admissions tutors of more mathematically-demanding subjects (e.g. Engineering, Physics, Mathematics) to promote Further Mathematics, even though concerns regarding widening access means they might not implement a formal requirement.

Teachers, career advisers and schools could also play a more active role in promoting the study of Further Mathematics and making use of resources such as the FMSP. These data suggest that students perceive Further Mathematics to have been useful preparation, even for subjects which are not traditionally viewed as requiring strong mathematical backgrounds. Additionally, A-level Mathematics is not usually required for the majority of the degree subjects in this study. Nevertheless, the positive responses of students regarding the utility of Further Mathematics indicate that A-level Mathematics could be useful for prospective applicants of such courses. Recommendations for its study have the potential to be beneficial for both students and lecturers alike.

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CASE STUDY

Lottery Strategy: An activity for new undergraduate students to introduce and reinforce introductory statistical concepts

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Abstract

Most university mathematics courses involve the students studying a statistics module in their first year. However, depending on which modules they took at A-level, they arrive at university with varying degrees of interest and ability in statistics. This article presents a classroom activity that introduces and reinforces introductory probability concepts to help prepare and engage the students for the statistics that they will encounter on their course. In the activity, the students consider and contrast two different strategies for selecting numbers for a lottery, in order to conclude which is best under which circumstances. It comprises a mixture of experimentation using a lottery machine, analysis using probability theory, and simulation using computers.

Keywords: Practical Activity, Lottery, Probability, Statistics, Simulation.

1. Background

At Coventry University (CU), as with many other universities, the students on the various mathematical related degrees all need to take a statistics module in their first year. However, when studying mathematics A-level, some may have taken mechanics and / or decision maths modules and hence encountered very little statistics. According to Cole (2015), of those students in the UK who sat the Edexcel exam board mathematics A-level in 2013, 79% had chosen the Statistics 1 module, with only 19% also choosing Statistics 2; thus 21% didn't study any statistics. Indeed some may be particularly averse to the subject. Hence, at CU an activity was introduced in induction week to help prepare and engage the students for the statistics that lay ahead. It needed to be fun and interactive for those who lacked interest in the subject and also for those who had met some of the topics before. The aim was to introduce and reinforce concepts such as combinatorics, mutual exclusivity, probability distributions, expected values, variances, tree diagrams, and conditional probability, and also create opportunities for further discussion on decision trees and utility functions which they would meet in another module.

2. Activity

1.1. Introduction

At the beginning, it is always a good idea to obtain an indication of the prior statistical experience of the students, as this can vary from year to year. This will, to a certain extent, help to determine the prospective pace of the session and detail of the content. A simple show of hands for those who have done the Statistics 1 or Statistics 2 A-level modules will suffice.

The activity starts with asking the students if they or any other family members play the lottery, if they have any particular strategies for picking the numbers, and whether they have won anything. This can lead to a brief discussion on different people's strategies and their respective merits. For example choosing combinations such as 1, 2, 3, 4, 5, 6, or numbers in the central column of the ticket are likely to result in lower payouts as they are much more popular (Cox, Daniell and Nicole, 1998).

Using PowerPoint or some other display method, the following format for a simple ’15 ball lottery’ is then introduced:

- 3 balls are drawn from 15;
- It costs £1 a play to pick 3 numbers;
- If 2 balls match you win £5, if 3 match you win £180.

1.2. Experimentation Using a Lottery Machine

The class should be split nominally into groups of four. Clearly it is highly unlikely that the number of students is an exact multiple of four, in which case some ‘imaginary friends’ are added to the groups. It should be ensured that there are an even number of groups. The usual class size at CU for this activity has been around thirty-five students, so this means that there are usually around ten groups.

Each group (of four) are then told that they have four plays of the lottery i.e. they need to make four selections of three numbers. Half of the groups are told to follow Strategy 1 (S1) and the other half to follow Strategy 2 (S2) as follows:

- S1- Pick 12 different numbers e.g. (1,2 ,15), (3,6,10), (4,7,14), (9,12,13);
- S2- Pick 4 numbers and repeat them e.g. (2,4,7) (2,4,10) (2,7, 10), (4,7,10).

They discuss within their groups and record their selections. Mini whiteboards work well for this. It is important to circulate during this to ensure that the correct directions have been followed, as invariably there will be some students who need clarification.

They are then asked which of the two strategies they think will be the most profitable. The most common reply has been that they are equally profitable. I have then responded by predicting that S1 will win the most money in total.

The lottery draw then takes place. At CU we purchased a bingo machine for around £20 (they are available from many toy outlets), but a simple bag will do.

Figure 1. Lottery Machine and Visualiser

A visualiser was used to transmit the action to screens around the classroom; this is recommended in a large room for maximum involvement. Additionally a lively bingo style commentary can enhance engagement.

When the balls have been drawn, the total winnings for all the groups using S1 are compared with the total winnings for all the groups using S2. Usually S1 will come out on top, and the students will be keen to know how I successfully predicted the outcome. Note that S1 doesn't always fare better than S2 here- I have run this activity six times and S1 has 'won' on five of them. If the prediction isn't correct and S2 wins, then they will still be keen to know why it was predicted that S1 would win.

1.3. Analysis Using Probability Theory

The various calculations for the outcomes and their respective probabilities are then shown as follows:

Strategy 1:

$$\mathrm{P(Match\ 3\ Balls)} = \frac{1}{\binom{15}{3}} \times 4 = \frac{4}{455} \qquad \text{Win £180.}$$

$\binom{15}{3}$ is the number of possible combinations for drawing the 3 balls. It is multiplied by 4 because the four plays are mutually exclusive. This gives an opportunity to introduce to or remind the students of the concepts of combinatorics and mutual exclusivity. Similarly,

$$\mathrm{P(Match\ 2\ Balls)} = \frac{\binom{3}{2}\times\binom{12}{1}}{\binom{15}{3}} \times 4 = \frac{144}{455} \qquad \text{Win £5.}$$

$\binom{3}{2}$ is the number of ways that two of the selected numbers in a play could match the 3 drawn balls, and $\binom{12}{1}$ is the number of ways that the remaining selected number in a play could match the 12 balls not drawn.

Strategy 2:

$$\mathrm{P(Match\ 3\ Balls)} = \frac{\binom{4}{3}}{\binom{15}{3}} = \frac{4}{455} \qquad \text{Win £180 + £5 x 3 =£195.}$$

$\binom{4}{3}$ is the number of ways that the 3 drawn balls could match the four individual numbers chosen over the four plays.

The higher win amount has often been a surprise for many students. Because the numbers are repeated, if one of the plays matches 3 balls, then the other three plays in the group will all match 2 balls.

$$\mathrm{P(Match\ 2\ Balls)} = \frac{\binom{4}{2}\times\binom{11}{1}}{\binom{15}{3}} = \frac{66}{455} \qquad \text{Win £10.}$$

Again, if one of the plays matches 2 balls, another play will match 2 balls.

The figures are then collated, introducing the idea of probability distributions. These are shown in Table 1 and Table 2 below.

Table 1. Strategy 1 Theoretical Outcomes with Probabilities

Group Winnings (£)	**0**	**5**	**180**
p	$\frac{307}{455}$	$\frac{144}{455}$	$\frac{4}{455}$

Table 2. Strategy 2 Theoretical Outcomes with Probabilities

Group Winnings (£)	**0**	**10**	**195**
p	$\frac{385}{455}$	$\frac{66}{455}$	$\frac{4}{455}$

The students are then asked to recall the formula for expected value, $E(X) = \Sigma xp$, and consequently calculate the expected values for the two distributions as follows;

$$\mathrm{E(S1\ Winnings)} = 5 \times \frac{144}{455} + 180 \times \frac{4}{455} = £3.16.$$

$$\mathrm{E(S2\ Winnings)} = 10 \times \frac{66}{455} + 195 \times \frac{4}{455} = £3.16.$$

Thus both strategies expect to win the same on average, backing up what many students thought earlier. However, the key is that the two distributions have different variances. Recalling the formula for Variance, $Var(X) = \Sigma x^2 p - [E(X)]^2]$,

$$\mathrm{Var(S1\ Winnings)} = 5^2 \times \frac{144}{455} + 180^2 \times \frac{4}{455} - 3.16^2 = 283.$$

$$\mathrm{Var}(S2\ \mathrm{Winnings}) = 10^2 \times \frac{66}{455} + 195^2 \times \frac{4}{455} - 3.16^2 = 339.$$

This tells us that the amount won using S2 is more variable than with S1.

The values from Table 1 and Table 2 can be represented on a tree diagram, as shown in Figure 2.

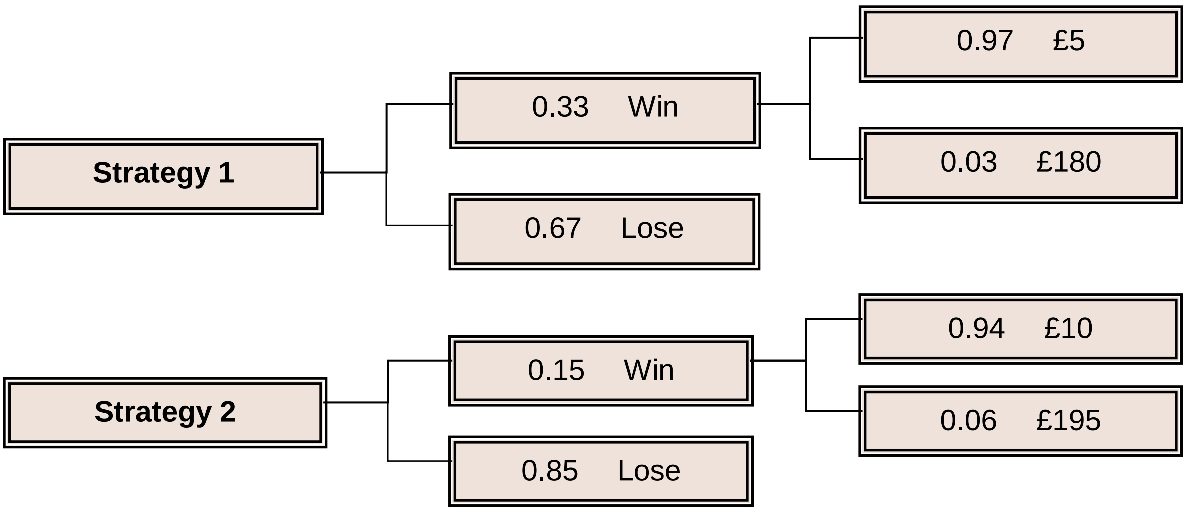

Figure 2. Outcomes and Associated Probabilities for Each Strategy

All of the students will have met probability trees at GCSE Maths. At CU this was a good opportunity to introduce the concept of a decision tree, which the students would meet in another of their modules.

For S1, the value of 0.33 above is obtained by adding $\frac{144}{455}$ and $\frac{4}{455}$ from Table 1.

0.97 is the probability of winning £5 given that you have won something. This is an example of conditional probability which can be explained intuitively as

$$P(\text{£}5|Win) = \frac{P(Win\,\text{£}5)}{P(Win)} = \frac{144}{144+4}.$$

It could also be pointed out that it is actually using Bayes' Theorem, $P(A|B) = P(A \cap B)/P(B)$.

The values for S2 in the tree are calculated similarly.

From the tree diagram it can be seen that with S1 you are more likely to win than with S2. However, if you win, you will expect to win more with S2 than with S1. Hence which strategy you choose should depend on your attitude to risk. If you want a higher chance of winning something you should choose S1. If you want a smaller chance of winning something, but a higher chance of winning a large amount you should choose S2. This could be phrased as;

- If you are Risk Averse, choose Strategy 1 i.e. select different numbers;
- If you are a Risk Seeker, choose Strategy 2 i.e. repeat the numbers.

This can lead onto discussions of attitudes to risk and some possible factors. For example, Powell and Ansic (1997) contend that females are less risk seeking than males in financial decision making. In turn, the idea of a utility function can be touched upon, which the students at CU will meet in another module.

Going back to why it was predicted that S1 would usually come out on top in this particular session, it is due to the fact that we have such a small sample size e.g. only five groups applying each strategy. As the overall chance of winning anything with S2 is so low, in the short term S1 will win more often than S2 (although of course this is not guaranteed!).

1.4. Computer Simulation

Having discussed the shortcomings of drawing conclusions based on small samples, the idea of using a computer to simulate a large sample of lottery draws is introduced. Hence a spreadsheet was created (shown in Figure 3) for the students to do this. (This Excel file is available upon request from the email address at the start of the article).

At CU the session is conducted in a computer lab so each student individually generates their own set of results. They randomly select four sets of numbers using Strategy 1 and four sets of numbers using Strategy 2 by clicking on the 'Select Numbers' tabs. They can then simulate as many draws of the lottery as they want by continually clicking on the 'Do Lottery Draw' tab. The total winnings for each strategy are displayed in the 'Running Total' boxes, and the average winnings are shown on the graph. In my experience, the students have found the interface user friendly and hence no clarification on what to do has been needed. However the lecturer should circulate during this part to ensure the students think about what the values and the graph are telling them.

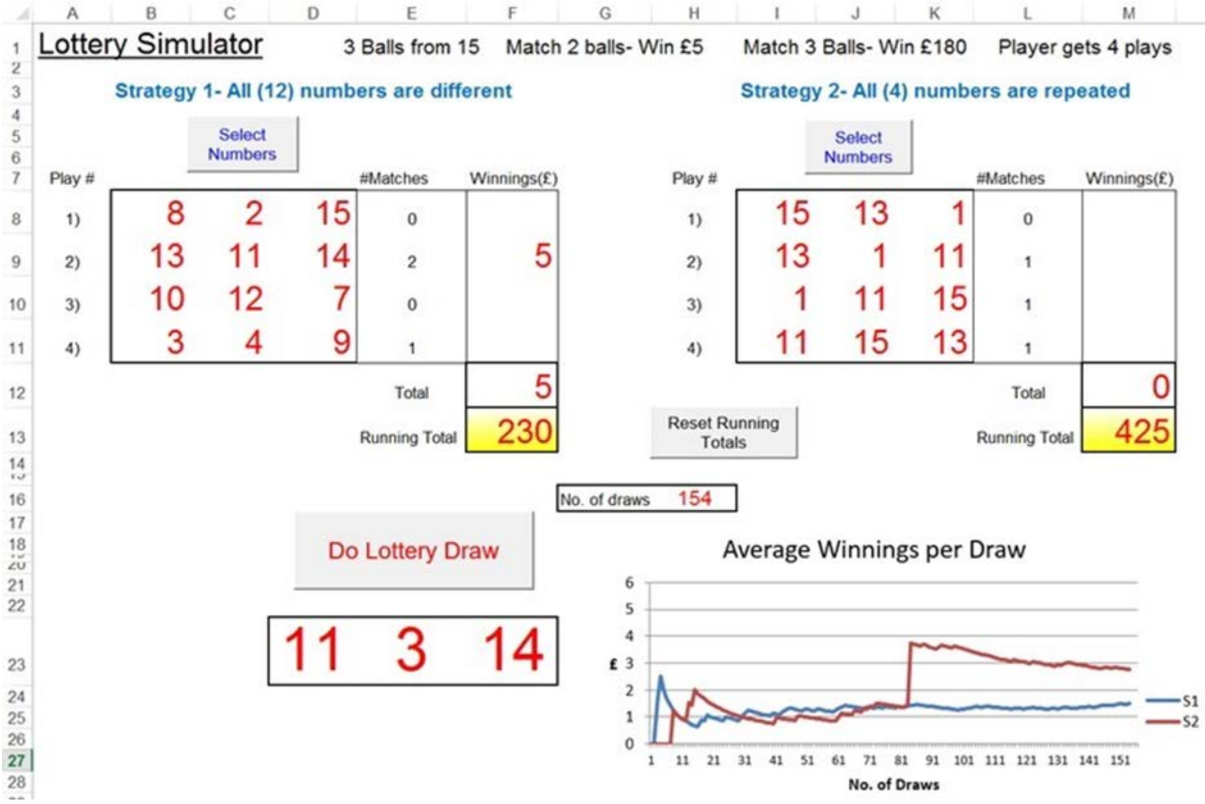

Figure 3. Simulation of Strategy 1 and Strategy 2

Once finished, the findings of the students are shared and discussed. From the graph, it is often seen that both strategies' winnings will eventually tend towards the expected value of £3.16 calculated earlier theoretically. Also, once the lines have settled down (after the first 50 plays say), the fluctuations in the S2 line tend to be larger than the fluctuations in the S1 line supporting the theory that S2 will give a higher variance.

1.5. Using the Lottery Machine Again

To finish off, armed with all their new found knowledge, the students now play another lottery, with the chance of winning an actual prize! The format is different from earlier, as follows:

- 2 balls are drawn from 10;
- £1 a play to pick 2 numbers;
- 1 match wins £1, 2 matches wins £16.

For this the students should be split into groups of 3, so they get 3 plays per group.

They can choose any strategy they want- S1, S2, divine inspiration, anything. (For extra information, the lecturer could also choose to display the probability distributions for S1 and S2 winnings in this version of the lottery). The group that wins the most money wins the prize (a few sweets will normally be enough motivation).

As before, the lottery machine and visualiser are used, and judicious pauses can build the suspense. Once the 2 balls have been drawn, the prize is given to the group with the highest total winnings. If there is a tie, another draw is conducted just with those winning groups. The winning group are then asked what strategy they used. Interestingly, in this case, S2 would probably have been best as the aim is not just to win something, but to win the most.

1.6. Wrapping Up

The findings are then summarised, e.g. Risk seekers should repeat the numbers; the risk averse should select different numbers. Also the students are reminded of the statistical topics / terminology encountered.

And of course, it is important for the lecturer to point out that they are not condoning gambling. Clearly it can be seen from the first lottery activity that for an outlay of £4 they only expect to get £3.16 back! An expected loss is typical in the playing of a lottery. Indeed in the UK National Lottery you can only expect a 48% return (The National Lottery, 2015). So it should really only be played for fun, and if affordable. Nevertheless, I always mention to the students that if they do play the lottery and win a million, I would be happy to receive half the money due to the expert advice I've given them during the session!

3. Adaptability

3.1. Varying the Parameters

The activity could be repeated with different numbers of balls. If so, the associated winning monetary amounts can be calculated as follows:

Let n be the number of balls in the draw, d be the number of balls drawn (and hence the number of selections per play), and r be the % rate of return (i.e. the % of stake money paid out in winnings).

Let us assume that there is a jackpot prize, J, for matching d balls, and a second prize, S, for matching d-1 balls. Considering one play, using the same reasoning as for Section 2.3;

$$\mathrm{P(Winning\ J)} = \frac{1}{\binom{n}{d}}, \quad \mathrm{P(Winning\ S)} = \frac{\binom{d}{d-1}\times\binom{n-d}{1}}{\binom{n}{d}} = \frac{\mathrm{d(n-d)}}{\binom{n}{d}}\,.$$

It can be seen that winning S is $\mathrm{d(n-d)}$ times more likely than winning J. Hence for a 'fair' game it would not be unreasonable to set J at $\mathrm{d(n-d)}$ times the value of S. This would then result in the expected total payouts in second prizes equalling the expected total payouts in jackpot prizes.

Assuming that it costs £1 for a play, then the expected total amount paid out in prizes per play is $£r/100$. Thus the expected amount paid out in jackpots per play is $£r/200$. As $\mathrm{P(Winning\ J)}$ is $1/\binom{n}{d}$, it follows that

$$J = £\frac{r\binom{n}{d}}{200}\,.$$

Hence,

$$S = £\frac{r\binom{n}{d}}{200\mathrm{d(n-d)}}\,.$$

S and J should then be rounded to an appropriate level of precision e.g. the nearest £1 or £5 etc.

Illustrating this for the values for the first draw described in Section 2.2 earlier:

$n = 15$ and d= 3. I had set r = 80%.

So, $J = \frac{80\binom{15}{3}}{200} = 182, \quad S = \frac{80\binom{15}{3}}{200\times 3(15-3)} = 5.05$, which were rounded to £180 and £5.

3.2. Different Audiences

As outlined, at Coventry University this activity has been used with incoming first year mathematics undergraduates. Also it has been used as an outreach activity for local school students in year 12 currently studying maths A-level. The idea is to give them an idea of what a university lesson might be like, to get them to think above and beyond a topic that they are currently studying, and to engage them so that they are encouraged to study in Higher Education. For those students, in the activity I tend to go into less detail on the theory, as overall they tend not be quite as confident in the subject matter as the new undergraduates. For both types of cohort, I have found that the feedback has been overwhelmingly favourable, with many students commenting that they have enjoyed the session. Additionally, I consider that similarly by removing some of the probability theory, the session could be adapted for non-mathematicians for whom some of the ideas regarding risk could be relevant and interesting e.g. finance students, psychologists.

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CASE STUDY

Teaching mathematics to Business and Enterprise students in a module based around Excel

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Abstract

Within this paper, a case study of a mathematics module ‘Information Analysis’ for Business and Enterprise students will be presented. The assessment for the module consists of four coursework assignments that are all done within Excel. The content of the module, which includes financial mathematics and data analysis, was carefully selected to be relevant and useful to the students further on in their degree and beyond. The module is based around the development of skills such as IT and communication. The students are required to pay attention to how they use Excel, how they present their work and their explanations. Comments from students are generally positive about the opportunity to develop skills within the module and they recognise the benefits surrounding employability. In addition to lectures and computer tutorials, the students have access to a collection of short video tutorials which contain examples of the Excel techniques. In this case study, the challenges of teaching this module will be explored, including teaching students with different abilities, the limitations of the classroom environment and the problem of mathematics anxiety. Details of the content of the module will be provided along with descriptions of the assessment methods and the teaching methods.

Keywords: Mathematics service teaching, skills development, employability, coursework.

1. Introduction

The students taking courses based in the Business and Enterprise subject area are all required to take the module 'Information Analysis' in their first year of study. Usually the cohort consists of 80-100 students of various mathematical abilities as A-level mathematics is not a requirement for them to undertake their courses. The module was primarily designed around the development of skills rather than the mathematical topics. As mentioned by Cox and King (2006), “*universities now need to focus on employability, preparing students for work*” and the success of their department’s redesign was due to “*using employability as the starting point for the redesign, rather than as a checklist to be referenced once design had begun*”. The module 'Information Analysis' was designed in a similar way, and consequently the content will not be presented first within this paper. Following the consideration of the skills aspect and assessment methods, the content was carefully selected to be relevant to the students taking the module. Material was embedded in real-life applications throughout in the belief that “*the process of addressing the client-driven problems with real-world contexts may also impact students’ beliefs about the usefulness of mathematics*” (Cardella, 2008). The portfolio style assessment adopted encourages learning within assessment rather than just assessment of whether learning has taken place.

2. Assessment methods

The assessment for the module is entirely through coursework tasks. The students do four pieces of coursework and are required to submit each one in an Excel file. In addition, they are asked to submit a separate portfolio file of all their work from the entire year. As mentioned by Dochy and McDowell (1997), portfolio assessment is one form of assessment that will “*encourage students to engage continuously and foster a deep approach to learning*”. They say that “*key elements of these approaches are reflection, feedback, and integration of learning and assessment*”.

At the end of every assignment, the students are asked to write a reflective piece. They include simple reflections on how the module is going, why they think that is the case, how they plan to remedy the situation if it is going badly, areas they need to work on before the next assignment, what they would have done differently, how they used the feedback from the previous assignment, and an estimate of their grade. They are asked to write a slightly longer reflection for the final piece of work, which also includes what skills they developed, how we could improve the module, and how they intend to keep on developing their quantitative and logical approaches to information analysis in the future. Comments from the students' reflections at the end of the 2014-15 academic year have been used throughout the paper.

The students make good use of the feedback throughout the module. One student reported that they "*found the feedback forms very useful as [they] could reflect on [them]*". Several of the students mentioned that they used the feedback in subsequent assignments to improve. Typical comments were that they "*applied the feedback into the next assignments, reducing the amount of problems in [their] work*" and that the feedback would "*help [them] to improve on the next [assignment]*". Some students mentioned that they planned to make use of feedback beyond the end of the module. One student commented that they "*intend to use feedback more productively, which will help [them] to achieve the best of [their] ability*" and another said they "*intend to use feedback effectively in the future also because it is evident that it has benefited [their] work progression in [the] module*".

3. Development of skills

The module is built around the development of some skills that are valued by employers. As reported by Archer and Davison (2008), amongst the most important skills when recruiting new graduates are communication skills (ranked 1st), planning and organisation (7th), numeracy (9th) and IT skills (14th).

The particular IT skills that are practised throughout the module are mainly within Excel, a tool used a lot within industry. Comments from the students included that being able to analyse and present data in Excel "*could put [them] at an advantage against other applicants*" and that "*being able to use Excel can be an advantage for [them] compared to someone who has less knowledge around it*". There is an introductory Excel task within the first assignment, but the students' skills in this area are developed throughout the module in all the exercises. The students are encouraged to use Excel for all the calculations, including using built-in functions and Solver. An example of how the student can use Solver is to answer the following question:

You invest £500 in a savings account with a compound interest rate of 3% per annum. Given that the interest rate is fixed, how long will it take for the amount in the bank account to double?

A quick method of getting a very accurate answer is to use solver to work out the number of years. This requires no use of logarithms and exponentials, a topic that can be very confusing to students.

The students are given a great deal of credit for how they present their work. One student commented that they "*liked how presentation was a large part of the module*" and how "*not many courses/ modules emphasise this*". As well as making use of Excel, they are marked on the overall appearance of their work. Figure 1 shows the different aspects considered.

		Comments
Contents page		
Hyperlinks		
Clear presentation		
Consistent presentation		
Good use of excel		
Efficient calculations		
Good use of graphs		
Explanations		
Appropriate number of sheets		
1 excel file		
Good use of colour		

Figure 1. Presentation marking grid

The students develop their written communication skills within the module as they are asked to explain all their work to demonstrate understanding. This can be them simply describing what they have done within a calculation or how they have used Excel to carry a task out. The students are expected to give concise explanations that contain enough information.

The students value being able to develop skills throughout the module, particularly ones around organisation and planning. The students found that the module "*taught [them] valuable skills that no doubt will have an impact in later life such as time management*" and that the "*main skills that learnt from working on the Information Analysis assignments this year [were] time keeping and working towards a deadline*". One student said that overall they "*feel that [they] have been able to take a lot from [the module] which could really benefit [them] in the future when applying for jobs or when actually working in [their] placement*".

Students and staff are provided with a more thorough mark scheme which includes how many marks are available for each task and its presentation, often with half the marks available for the aspects mentioned above. Along with marking criteria, initial marking of coursework of one student from each group, followed by discussions about discrepancies, means that marking is fairly consistent between different staff.

A draw back of the module is that marking and ensuring all staff are clear about mark schemes is very time consuming. Otherwise staff are very positive about the module. The Business and Enterprise team find the development of skills very useful and have made it compulsory for all their students.

4. Content of the module

Relevant mathematical topics were carefully selected with the students in mind, and topics such as calculus were avoided. The mathematical content of the module is based on what would be useful to the students in their subsequent years at university and, in particular, in employment afterwards. As there are students with varying levels of mathematical ability, the module begins with basic numeracy such as BODMAS, percentages, ratios and general calculations.

Another topic the students look at is probability theory; initially looking at the basics including the use of probability trees, and then probability distributions in the following assignment. The students make use of Excel's built-in functions so that they can concentrate on looking at when to use the different distributions.

Statistics is a big part of the module as the students are taught how to present data using appropriate calculations such as mean and standard deviation in the first assignment. They also look at how to represent information graphically, beginning with when it is most relevant to use different types of graphs and are given practice at reading information from them. In the second assignment, the students are given a collection of data sets are asked to pick at least two to allow them to demonstrate using the techniques and graphs appropriately.

Within the second assignment, the students are introduced to financial mathematics. They explore topics such as interest rates, inflation and depreciation. In the third assignment, they are asked to research savings accounts and present recommendations for the investment of £5000. They are given very little information, so are encouraged to make a variety of recommendations based on different requirements and circumstances.

The other main topic taught within the module is mathematical modelling. The students are initially introduced to different types of graphs within the third assignment. They create interactive graphs using slider bars for linear, quadratic, exponential, logarithmic, trigonometric and combined models. They investigate what happens when you change the variables in the models and how this affects the outcome and conclusions drawn. As discussed by Alfieri et al. (2011), "*allowing learners to interact with materials, manipulate variables, explore phenomena, and attempt to apply principles affords them with opportunities to notice patterns, discover underlying causalities, and learn in ways that are seemingly more robust.*"

Also within the third assignment, the students fit models to some given data by using the least squares method with Solver and look at how to extend their models to make future predictions. The students do another research task in the final assignment, looking at investments into different commodities. They are encouraged to find appropriate graphs that can be used to predict that will happen to the markets using their modelling techniques. The students look at other factors that might affect the stability and use all the information to form recommendations to a company wanting to make an investment.

The students are asked to provide summaries for different audiences within the module. For example, for the savings account research task they are asked to present their findings and recommendations to a non-numerate graduate, so they have to apply their knowledge on mathematical finance but then have to provide a non-technical report. It was mentioned by one student that they are now "*able to present information at an informative level, as well as draw relevant conclusions from the information [they] have used*" and that "*tasks such as the savings accounts section of the third assignment was useful for this as [they were] required to do research and present [their] findings to suit an audience*". When looking at fitting models in the third assignment, they have to provide an explanation to a friend on the course why a model is most appropriate, an explanation for the tutor for another model, and an explanation for a not particularly mathematical guitarist friend for the trigonometric model. They are also given the opportunity to present information in a 500 word summary with illustrative graphs as if to a client in the final assignment when they do their commodities research task.

5. Teaching methods

The module is taught mainly through lectures and computer laboratories, but there is a great deal of support outside of the formal teaching time. Within the lectures, tools such as the assessment software Socrative were made use of. One student commented that they found Socrative "*a good way of learning and [it] improved [their] understanding*".

As there are no requirements to have done A-level mathematics for the course, there are students of various levels of mathematical ability within the class. The content and assessment ensure that many skills other than purely mathematical, such as Excel and presentation, are assessed in the module. Therefore, this stretches the more mathematically capable ones and does not disadvantage the weaker students. Also, no prior knowledge of mathematics is assumed and the module begins with basic numeracy. The students who have done mathematics at A-level are aware that initially they may find the content too easy and they are welcome to bring some of the set exercises along to lectures to work on. They soon discover techniques that they haven't encountered before.

There can be problems with mathematics anxiety within the group from those students who haven't studied any mathematics for a while or have found it difficult. Some students were "*really worried and nervous*", and had a negative attitude towards the module because mathematics is involved and thought that the module would be a "*massive drawback*". During the introductory lecture, providing details of where the marks come from and the level of support helps ease these fears. Support is not only available from the staff involved in the module, but there is a daily mathematics support service that the students can use. Other ways of combating mathematics anxiety includes providing reassurance and encouragement on a one-to-one level in tutorials. There is a significant decrease in the mathematics anxiety after feedback from the first assignment is received. One student who commented about being worried at the start of the module, described receiving their first assignment mark as "*incredibly overwhelming and confidence/motivation boosting*". It was the feedback in particular that helped the students, with one student mentioning that "*feedback was one of the things that help [them] personally grow in confidence in [the] module*". Another student commented that their opinion of the module "*changed as [they] soon learned that the resources [they] had available were of great benefit allowing [them] to be able to go on and get the [work] completed at the correct pace*".

There are limitations that the classroom environments has, especially for a module based around Excel. Providing a demonstration within a lecture can be improved by providing the students with handouts to annotate. Moving the examples from the lecture to the computer tutorials improved this slightly as the students could go through them at the same time, but it was quite time consuming as the students worked at very different paces and tutorial leaders would spend full sessions ensuring that all the students managed examples. This left very little time for feedback and other help within the tutorial sessions. From 2013-14, short video tutorials have been used for this module, which are produced using Screencast-o-matic. The students are able to use the videos as many times as they like, can work through the exercises at the same time, pause the videos and access them at any time. Since the introduction of the videos, there has been a significant change in the type of questions the students ask and the number of students attempting more challenging topics, such as working out the mean of grouped data, has increased.

The students described the videos as "*a very useful device in aiding learning*", that they "*really helped*", were "*a great aid in [their] studies throughout the year*" and were "*incredibly beneficial in helping [them] to complete [their] assignments*". They found that if there was "*anything [they] failed to understand in the lectures [they] would work with the videos on Blackboard at [their] own pace and understand the content and apply it to the assignment*". Comments also included that the videos "*allowed [them] to revisit [their] work whenever*", that "*watching the videos refreshed [their] memory of what was taught earlier in the week*" and they "*helped [them] to understand some of the topics that [they were] struggling with*".

6. Conclusions

The mathematics module for Business and Enterprise students was created so that they would develop employability skills and includes relevant mathematical content for that particular group. The portfolio style assessment method allows for a process of reflection and for learning to take place within the assessment itself. The students tend to have initial reservations, but are generally very positive about the module due to the level of support available and the feedback they receive. The problems surrounding teaching Excel within lecture rooms have been addressed by the introduction of short video tutorials, which the students make good use of in their studies. Having a mixture of abilities within the group proves a challenge, but having material that isn't covered by the A-level syllabus and having a large focus on skills, means that all students have content to stimulate them. Overall the module is received very well and student satisfaction is generally very high at the end of the year.

7. Acknowledgements

Neil Challis and Harry Gretton were responsible for originally creating the module discussed in the paper.

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RESEARCH ARTICLE

Rethinking the final year project report: cutting out the waffle

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Abstract

All final year students in the Department of Mathematical Sciences at the University of Greenwich undertake either a weekly placement or the research methods and project module. The assessment for the project module is made up of a group project, followed by an individual project. In 2012 the University's academic calendar and term structure was changed following recommendations during the UG-Flex project, which advocated the flexibility of a trimester calendar (JISC, 2012). This resulted in the research methods and project students having a significantly shorter period of time to write up their research. As a result, the individual project assessment was redesigned to incorporate a seven-page, 'research paper' style report, cognate to journal articles that students necessarily encounter as part of their research. This paper describes the format of the new report, and discusses findings and feedback from academic staff. In particular, external examiners have commented very favourably on this format and think other HEIs might benefit from adopting a similar approach to project reports.

Keywords: Mathematics, undergraduate, dissertation, project report, academic writing.

1. Introduction

Students studying undergraduate degrees in mathematics, statistics and OR subjects in the department undertake a project in their final stage (level 6). Some students opt to conduct a project while involved in a placement in industry or in a school (Undergraduate Ambassadors Scheme, 2009), but most undertake their project as part of the module: Research Methods and Mathematics Project. This module aims to develop the knowledge and skills that students require in order to undertake and report on an academic project, while working under the direction of a supervisor. It provides an opportunity for students to integrate and extend their knowledge from taught courses using research methods, and to critically assess their own work. An important element of the course is in personal development planning, where students undertake activities to enhance their communication skills, and reflect on their work in the context of career planning.

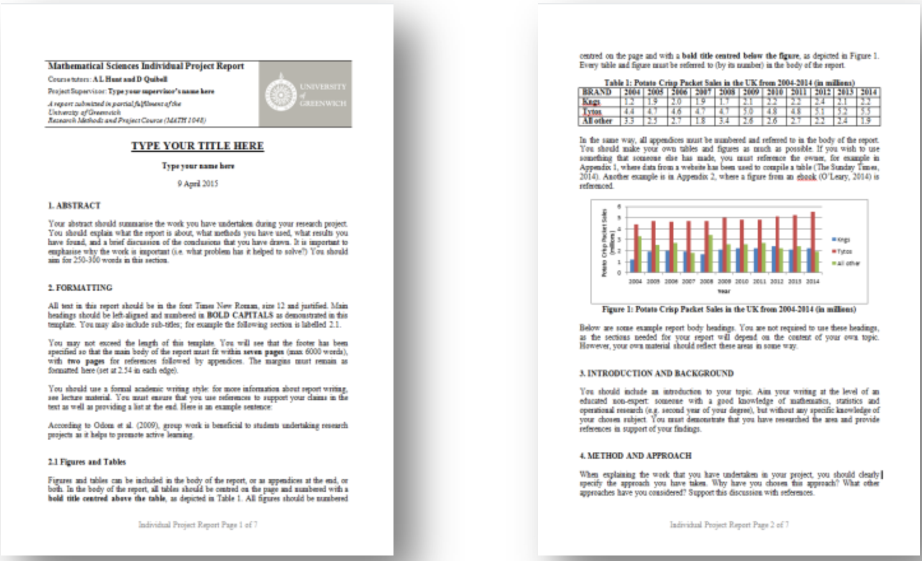
The assessment portfolio for the course is made up of a group project, followed by an individual project. The former task is designed to enhance employability skills as students reflect on their initial planning and research work as part of a group. Students are required to work with a mixture of individuals that they have chosen to work with, as well as those allocated by the teaching team (Bradshaw, 2009). Groups are then assessed on their written reports and on the communication of their results in group presentations, before embarking on their longer and more in-depth individual research. Throughout each project, students reflect on their progress, and skills gained, in an individual logbook.

In 2012 the University's academic calendar and term structure was changed following recommendations during the UG-Flex project (JISC, 2012). A new trimester calendar was implemented, prompting a departmental review of assessment schedules. The new calendar resulted in the research methods and project students having a significantly shorter period of time in which to submit their work. This impacted the second (individual) project, where the final project write-up time was reduced. As a result, the individual project assessment was redesigned to incorporate a seven-page, ‘research paper’ style report, cognate to journal articles that students necessarily encounter as part of their research.

This paper presents the new report specifications and template used, and explores the findings, challenges and lessons learned from the past two years of its delivery in the final year project course. Implications for teaching, assessment and learning outcomes will also be discussed, alongside staff and external perspectives on the impact of the change.

2. Report Specification

A new template was specified for the report with the intention to emulate the specifications of academic journal and conference publications. As displayed in Figure 1 the template prescribed rigid formatting requirements, including: font, spacing and margins, as well as conventions for tables and figures. The scope of the project remained the same: students were still required to report on a significant academic project undertaken in a topic of mathematics, statistics or operational research, integrating their knowledge from taught courses. However, in order to fulfil the new specification, student report-writing needed to be precise and strictly relevant.



Mathematical Sciences Individual Project Report
Course tutors: **A L Hunt and D Quibell**
Project Supervisor: **Type your supervisor's name here**
A report submitted in partial fulfilment of the University of Greenwich Research Methods and Project Course (MATH 1048)

UNIVERSITY of GREENWICH

TYPE YOUR TITLE HERE

Type your name here

9 April 2015

1. ABSTRACT

Your abstract should summarise the work you have undertaken during your research project. You should explain what the report is about, what methods you have used, what results you have found, and a brief discussion of the conclusions that you have drawn. It is important to emphasise why the work is important (i.e. what problem has it helped to solve?) You should aim for 250-300 words in this section.

2. FORMATTING

All text in this report should be in the font Times New Roman, size 12 and justified. Main headings should be left-aligned and numbered in **BOLD CAPITALS** as demonstrated in this template. You may also include sub-titles; for example the following section is labelled 2.1.

You may not exceed the length of this template. You will see that the footer has been specified so that the main body of the report must fit within **seven pages** (max 6000 words), with **two pages** for references followed by appendices. The margins must remain as formatted here (set at 2.54 in each edge).

You should use a formal academic writing style: for more information about report writing, see lecture material. You must ensure that you use references to support your claims in the text as well as providing a list at the end. Here is an example sentence:

According to Odom et al. (2009), group work is beneficial to students undertaking research projects as it helps to promote active learning.

2.1 Figures and Tables

Figures and tables can be included in the body of the report, or as appendices at the end, or both. In the body of the report, all tables should be centred on the page and numbered with a **bold title centred above the table**, as depicted in Table 1. All figures should be numbered

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centred on the page and with a **bold title centred below the figure**, as depicted in Figure 1. Every table and figure must be referred to (by its number) in the body of the report.

Table 1: Potato Crisp Packet Sales in the UK from 2004-2014 (in millions)

BRAND	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Kngs	1.2	1.9	2.0	1.9	1.7	2.1	2.2	2.2	2.4	2.1	2.2
Tytos	4.4	4.7	4.6	4.7	4.7	5.0	4.8	4.8	5.1	5.2	5.5
All other	3.3	2.5	2.7	1.8	3.4	2.6	2.6	2.7	2.2	2.4	1.9

In the same way, all appendices must be numbered and referred to in the body of the report. You should make your own tables and figures as much as possible. If you wish to use something that someone else has made, you must reference the owner, for example in Appendix 1, where data from a website has been used to compile a table (The Sunday Times, 2014). Another example is in Appendix 2, where a figure from an ebook (O'Leary, 2014) is referenced.

Figure 1: Potato Crisp Packet Sales in the UK from 2004-2014 (in millions)

Below are some example report body headings. You are not required to use these headings, as the sections needed for your report will depend on the content of your own topic. However, your own material should reflect these areas in some way.

3. INTRODUCTION AND BACKGROUND

You should include an introduction to your topic. Aim your writing at the level of an educated non-expert: someone with a good knowledge of mathematics, statistics and operational research (e.g. second year of your degree), but without any specific knowledge of your chosen subject. You must demonstrate that you have researched the area and provide references in support of your findings.

4. METHOD AND APPROACH

When explaining the work that you have undertaken in your project, you should clearly specify the approach you have taken. Why have you chosen this approach? What other approaches have you considered? Support this discussion with references.

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Figure 1. The new project report template

The template allowed for seven pages of report writing (approximately 4000 words), two pages of references, and unlimited appendices. This format encouraged students to be concise and focussed in their reporting, while still including full data-sets, algorithms, and code in the appendices. For example, students undertaking projects in data analytics may describe their work in the body of the report, including visualisation of the key findings, and fully document all analysis in the appendices. Similarly, students programming as part of their project can submit their program, and full code as supplementary material, while the body of the report focusses on analysis and discussion.

In this format, the process of reading academic journals, and learning about peer-review and appropriate research sources, informs students’ understanding about the technical writing style and format expected. It also allows for convenient exemplars for students; it is straightforward to set a classroom activity around a seven-page piece for peer discussion. Throughout the module, as part of their personal development planning, students were also encouraged to consider the development of this succinct academic writing technique as a crucial skill towards their future career/future study.

3. Findings

In the past two years, we have found that students learned how to structure their research according to this concise format, and communicate their findings in a succinct manner. In many cases this effectively focussed the students' writing in the main body of the report and found students could still demonstrate their work comprehensively using appendices and other deliverables such as programs.

Student feedback was largely positive, with 86% of students agreeing that the assessments enabled them to demonstrate their learning. However, this included their experience of the group project which may have clouded the judgement of some students who find group work difficult. Tutors noted that embarking on the write-up seemed less daunting for students, particularly for those with dyslexia and dyspraxia. Students also commented favourably on the use of exemplars, i.e. the ease of reviewing previous years' work given the accessibility of the format.

When marking these submissions supervisors commented that the succinct report style enabled discrimination between the varying quality of work: students have "*nowhere to hide*" when there is little room for superfluous information in their reporting. The following comments are from a Reader in the department, who has supervised projects in a number of institutions for 15 years:

"With these new reports, you can test their ability to write briefly and directly, asking them to put their work in a format that will benefit them should they go into research, or industries where they have to write executive summaries and reports. It also benefits staff as it reduces the material that we have to go through, and grading is focussed on the quality, not quantity of work."

It was felt that students were dissuaded from 'padding' their reports with as much material as possible, and instead focussed on the project work itself.

Traditionally, project assessment is particularly onerous, and there can be a conflict about the effective use of tutors' time (Brown et al., 2013). When using the new format, supervisors and markers commented that it was easier to establish the crux of the project work undertaken. External examiners and the moderation panel found that the standard and topic difficulty were comparable with previous years. One external examiner commented on the potential for the "*research paper*" style report and recommended:

"…staff involved in co-ordinating the project module to monitor and 'fine-tune' (if necessary) the changes they have introduced, and to consider disseminating this innovation to the wider MSOR community."

It was also seen by staff as an effective way to showcase student work, as reports are readable, accessible and easily collated. Employers and visitors to our graduate showcase, including academics from other HEIs, commented that the general quality of projects was very high.

Furthermore, it was found that those students conducting their individual research in response to an employer brief produced reports in this format that were fit-for-purpose in conveying their findings to an end-user or client. A number of employers in the private sector and in the civil service have disseminated these reports internally, indicating that they are deemed appropriate for communicating findings to staff. In the past two years, many students working to an employer brief received job offers as a result of their project work.

4. Discussion

The report specification and teaching and learning activities have gone through minor modifications. For example, peer review of exemplars has proved to be successful in informing the students' understanding of the assessment requirements, and in discussions of topic feasibility.

There has been internal discussion about the potential downsides to a shorter report, for example whether provides less opportunity for students to explore different approaches: they may be discouraged from deeply researching alternative solutions in their topic, as the reporting space is likely to focus on the work undertaken (as indeed an academic paper would be). It may also be the case that there is less opportunity for students to compensate for mistakes, i.e. by demonstrating a fundamental misunderstanding early on in the report, and not pursuing other routes. However these should be addressed in the associated logbook submission, where students reflect on their progress and learning throughout the project: the depth of their research is evident in such a log. Also there are opportunities for exceptionally able students to submit papers to journals and/or to present their work at the annual undergraduate conference, *Tomorrow's Mathematicians Today* run by the Institute of Mathematics and its Applications (IMA).

We have found that many mathematics students dislike or resist writing, as it is seen as a secondary skill to their subject. The new format has made the process less daunting for them, but this could also mean that some students are complacent about the task at hand, delaying the start of the write-up. More work is needed to instil the necessity of work-planning, in students' projects, and as a general professional skill.

Our change to the project report has been highly effective. Students, academics, externals and employers have commented favourably and there has been little impact to the quality of student work. Students have continued to progress as usual to MSc and PhD programmes at a variety of institutions and student work has been published as a result of the report being written in this format.

There are a number of upcoming developments to the project module, to support the on-going development of the assessment portfolio, including marking schemes that emphasise orthogonal elements to more clearly benchmark grade boundaries, and exploring the potential for flexibility in the length of the report.

What began as a response to a University-wide calendar shift, has led to an exciting innovation that is popular with students and academics, and projects that have enabled students to pursue further academia and graduate employment. We look forward to reporting on the next phase of the assessment development.

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CASE STUDY

An undergraduate uses O.R. to improve final exam schedules at her university

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Abstract

Final examination scheduling is typically a complex problem that impacts students, faculty, and administrators at every university. In this paper, we describe how an undergraduate student, for her senior project at Kutztown University, analysed the final exam schedules at Kutztown University to see if she could improve them. Specifically, she wanted to see if she could reduce student conflicts defined to be a student having three exams scheduled on the same day. The approach that she developed, based on a balanced bin packing algorithm, was very appealing because it could be implemented manually by a staff member of the Registrar's office, requiring at most 30 minutes to generate the schedule. Testing this approach using actual data from the Fall 2015 semester resulted in a 42% reduction in student conflicts. This approach, because of its simplicity and intuitive appeal, was widely accepted by the Kutztown University faculty and administrators and is being implemented for the Fall 2016 semester.

Keywords: Final examination scheduling, operational research applications, balanced bin packing algorithm, undergraduate student projects.

1. Introduction

Typically, Kutztown University (KU) posts a final exam schedule for both the fall and the spring semesters before knowing any of the students' class schedules. These final exam schedules are usually the same for both semesters. The current posting of the exam schedule does not take into account the number of students that take an exam on each day (There are three two-hour exams scheduled each day). If a student is scheduled for three exams in one day, this is considered a conflict and the student has the right to get one of these exams scheduled on a different day. This is obviously both a nuisance to the student as well as the instructor. In this paper, we will discuss how an undergraduate student, as her senior project, developed an approach for final exam schedules that tends to minimize student conflicts. Her approach could be manually (done in less than 30 minutes by a staff member of the Registrar's office) implemented using only readily available (at the beginning of each semester) knowledge of the number of students in each class meeting time.

In the next section, we will briefly mention some final exam scheduling approaches that appear in the literature. This will be followed by a discussion of KU's current exam schedules and constraints. After that we will remark on how a sample of student classes and exam times motivated the balanced bin packing algorithm for final exam scheduling. Subsequently, student data for the entire Fall 2015 semester will be used to compare the number of student conflicts caused using the actual fall final exam schedule versus the final exam schedule generated using the student's balanced bin packing approach. Finally, implementation details of the balanced bin packing algorithm will be outlined.

2. Approaches in the Literature to Final Examination Scheduling

There is a vast literature of research dealing with the final examination scheduling problem. For background on the final examination scheduling problem, we suggest the reader consult the paper by Mohmad Kahar and Kendall (2015). This paper also contains an extensive list of references on the subject. In this section, we will simply give two examples of approaches used to attack this problem.

In their paper titled, Heuristics for the Exam Scheduling Problem, Zhaohui and Lim (2000) proposed a solution to scheduling exams for the National University of Singapore in which they attempted to maximize the amount of time each student has between each of their exams in order to have more time to study. In their paper, Zhaohui and Lim focused on this specific constraint to the exam-scheduling problem by applying a graph colouring technique, which they called "*Iterative Greedy.*" Each node represents an exam and the edges between the nodes represent the conflict between the exams so that the nodes cannot be coloured the same colour or else it would result in one student having two exams at one time. The authors also used a Tabu Search to find an even better solution when attempting to further optimize the spread of the schedule. A direct use of the value of Average Gap between exams is used to solve the exam problem with a Tabu Search.

Akhan Akbulut and Guray Yilmaz (2013) conducted their research on the exam scheduling problem and the implementation of a graph colouring algorithm as well. To begin their approach, Akbulut and Yilmaz created a ratio control that shows the common percentage of students between two exams. The ratio control is checked when placing two exams on one day. Like Zhaohui and Lim, each node in Akbulut and Yilmaz graph colouring algorithm is an exam, and the edges between the nodes represent the conflict between two exams. Each node is coloured differently for the time period that exam will take place so that two adjacent nodes cannot have the same colour. Once one colour is used, that colour will not be in the domain of usable colours for the other nodes. This process is continued until each node has a specific colour and there are no overlapping colours.

3. Current Final Examination Schedules at KU

Currently at KU, the final examination schedule has remained the same for a number of years. A primary consideration (constraint) in the schedule is that classes that meet on Mondays, Wednesdays, and Fridays (MWF) must have their final exams scheduled on either a Monday or a Wednesday or a Friday. The same situation holds for classes that meet on a Tuesday and Thursday (TTH). This constraint appears to be motivated, at least in part, by commuting students who, for logistical reasons, only schedule classes on Mondays, Wednesdays and Fridays or only on Tuesdays and Thursdays (With more online classes, students are more and more limiting their visits to campus). There are 15 final exams scheduled over five days (Monday through Friday) - one week. Classes that meet in the evenings or on Saturdays make up a very small percentage of the student body and are not considered in this study.

The student began her analysis by organizing the class times of both Monday, Wednesday, and Friday (MWF) classes and Tuesday and Thursday (TTH) classes into chronological order and assigning each class time to ordered periods shown below:

Table 1. Class Time Periods

Class start times	Periods
MWF 8:00AM	1
MWF 9:00AM	2
MWF 10:00AM	3
MWF 11:00AM	4
MWF 12:00PM	5
MWF 1:00PM	6
MWF 2:00PM	7
MWF 3:00PM	8
MWF 4:00PM	9
TTH 8:00AM	10
TTH 9:30AM	11
TTH 12:00PM	12
TTH 1:30PM	13
TTH 3:00PM	14
TTH 4:30PM	15

She did this to organize the data in order to effectively show the calculations and make the tables easy to understand.

As stated previously, KU keeps the exams for TTH classes on either Tuesday or Thursday and the same for MWF classes because of possible scheduling conflicts with the students who have other obligations. This can be seen in the current University's exam schedule shown below:

Table 2. Current Exam Schedule

Exam Days	Class Time Periods
Monday	2 3 5
Tuesday	11 12 14
Wednesday	4 6 7
Thursday	10 13 15
Friday	1 8 9

This table shows which class periods' exams are held on each day.

In terms of the objective of reducing student conflicts (a student having three exams on one day), the final exam scheduling for MWF classes can be handled separately from the final exam scheduling for TTH classes. In fact, for MWF classes, the problem reduces to looking at partitioning nine things into three sets of three items each. This number of partitions is $\frac{C(9,3)\times C(6,3)\times C(3,3)}{3!} = 280$. For TTH classes, the problem reduces to looking at partitioning six things into two sets of three items each. This number of partitions is $\frac{C(6,3)\times C(3,3)}{2!} = 10$. Remember that we are focused on reducing student conflicts. The Registrar's office has the flexibility to decide which exam time is scheduled 1st, 2nd and 3rd for a given day. Also, which day (MWF or TTH) the exams are given does not change the number of student conflicts. Hence, in theory, computer programs could be written to analyse all 280 possible partitions for exams for MWF classes and select the partition that minimizes student conflicts for those exams and the same approach could be used for the 10 possible partitions for the TTH classes. However, with approximately 9,000 students, the computing resources required to develop the programs, maintain them, and execute them each semester are non-trivial. The student decided to see if there was a more efficient way that would not require any computer programming and could be done manually by a member of the Registrar's staff in under 30 minutes (usually less) using existing class enrolment information.

4. A New Final Examination Scheduling Approach for KU and Its Experimental Results

To get some idea if student conflicts could be reduced in the final exam schedules at KU while still adhering to the constraints that final exams for MWF classes are scheduled on either Monday or Wednesday or Friday of the exam week and that final exams for TTH classes are scheduled on either Tuesday or Thursday of the exam week, the student decided to analyse the class and final exam schedules of 154 anonymous KU students from the Fall 2015 semester. She meticulously calculated the number of student conflicts for each of the final exam days. Without getting into specific numbers, what the student found was that there were an uneven total number of final exams scheduled on each day with more conflicts occurring on days when more final exams were scheduled. She wondered what would happen if the exams were spread out more evenly across the five days of exam week, but still obeying the MWF and TTH constraints. To this end she viewed the three days (MWF) as 'bins' and she developed a 'balanced' bin packing algorithm to 'fill' these bins in a balanced manner. She used the same approach for TTH classes, but only two bins are 'filled'.

Balanced Bin Packing Algorithm (BBPA) for MWF classes:

- Step 1: Calculate the number of students in each class time period for MWF classes (This information is available from existing computer systems);
- Step 2: Sort the class time periods in descending order by the number of students in each period;
- Step 3: Take the class period at the top of the list, schedule that period on the exam day with the fewest number of students already assigned to that day (bin);
- Step 4: Continue this until all MWF class time periods have been assigned. Make sure that exactly three exams are assigned to each day.

The BBPA for TTH is analogous. The second part of Step 4 is necessary if there are class times with very small enrolments. Amazingly, when this approach was used to schedule final exams for the 154 student test data set, the number of student conflicts (over the five exam days) dropped from 19 to only 8.

Based on these encouraging results, we requested assistance from KU's Institutional Research Department to analyse data for all students for Fall 2015 (approximately 9000 students). Institutional Research provided the class enrolment information needed for Step 1 of the BBPA. Also, they calculated all student conflicts (by exam day) for the actual Fall 2015 final exam schedule. Using this information the BBPA was applied to determine a new final exam schedule for Fall 2015. The schedule generated by the BBPA was then provided to Institutional Research. Institutional Research calculated the number of student conflicts for this schedule. A side-by-side comparison of the two schedules with the number of student conflicts for each schedule is given in the table below.

Table 3. Comparison of Two Exam Schedules

Exam Days	Actual Schedule	Number of student conflicts	Balanced Schedule	Number of student conflicts
Monday	2 3 5	483	3 8 7	150
Tuesday	11 12 14	395	11 14 10	145
Wednesday	4 6 7	244	2 6 1	194
Thursday	10 13 15	29	12 13 15	72
Friday	1 8 9	34	4 5 9	129
Total conflicts		1185		690

The final exam schedule generated manually (in a few minutes) based on the BBPA resulted in only 690 student conflicts versus 1185 student conflicts in the actual schedule. This is a 42% reduction in the number of student conflicts.

5. Implementation

These results and the Balanced Bin Packing Algorithm were initially presented to the Registrar and members of his staff in fall of 2015. Based on the intuitive appeal and ease of implementation of the BBPA, they immediately bought into having the Registrar's office use this approach. Next, the chairs of all the academic departments unanimously approved the BBPA approach for final exam scheduling (early spring semester 2016). The final step was the endorsement by the appropriate administrative departments (April 2016) to use this approach starting with the Fall 2016 semester.

6. Conclusions

In this paper, we discuss how a student, for her senior project, applied operational research techniques to develop an algorithm that significantly reduces student conflicts of three final exams scheduled in one day. This approach is actually being implemented at her university to generate final exam schedules starting with Fall 2016. Unfortunately, being a senior and having graduated in Spring 2016, she will not be able to enjoy the fruits of her labour.

7. Acknowledgements

We would like to sincerely thank, Ms. Natalie Snow, Director of the Institutional Research Department at Kutztown University for her very significant help in analysing the Fall 2015 semester data.

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WORKSHOP REPORT

The key role of tutors in Mathematics Learning Support – A report of the 10th annual IMLSN workshop

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Abstract

In this article we give a short description of the 10th Annual Workshop of the Irish Mathematics Learning Support Network (IMLSN) Workshop. The workshop theme was 'The key role of tutors of mathematics and statistics in Post-Secondary Education'. We briefly describe the aim of this workshop, discuss the presentations, and we close with some brief conclusions on this very successful event.

Keywords: Maths support, tutors, tutor training.

1. Introduction

The 10th Annual Workshop of the Irish Mathematics Learning Support Network (IMLSN) was held in the National University of Ireland (NUI), Galway, on Friday 27th May 2016. The theme of the conference was 'The key role of tutors of mathematics and statistics in Post-Secondary Education'. All presentations are available from the IMLSN website (http://imlsn.own.ie/imlsn10nuigalway). Forty-seven delegates from sixteen institutions attended this workshop including tutors and lecturers involved in Mathematics Learning Support (MLS), or in teaching and learning at higher education in general. The aim of the event was to discuss:

- professional development for tutors;
- the diverse teaching roles of tutors and the challenges they face;
- mathematics learning support centres (MLSCs) as rich learning experiences for tutors;
- tutoring as an opportunity for postgraduates and undergraduates to be part of the mathematics community.

The Vice-President for Student Experience at NUI Galway, Dr Pat Morgan, welcomed the delegates, and emphasised the importance of mathematics and MLS, particularly for students studying science based subjects. An overview of the remaining speakers contributions are provided below.

2. Keynote speakers

2.1. Michael Grove, University of Birmingham. The Strongest Link? Supporting the Teaching Assistant, Demonstrator, Marker, Advisor, Tutor,…

The first keynote opened with a suggestion that many postgraduates are expected to teach or tutor without necessarily being provided with sufficient training and support training. Over the past ten years in the UK a programme of activity to support Postgraduate Teaching Assistants has been implemented, and has been expanded to encompass those working in MLSCs. In 2005 the Maths, Stats & OR Network (MSOR) introduced one-day workshops for postgraduates. On-going development and refinement of these workshops included the incorporation of a session on presenting and communicating mathematics. Several iterations of these workshops led to the development and publication of the excellent *Teaching Mathematics - a guide for postgraduates and teaching assistants*, authored by the speaker and Bill Cox (2012).

From 2011, it was clear that MLS was increasingly being provided by postgraduate tutors and so **sigma,** the network for excellence in mathematics and statistics support, developed a programme of support including materials, workshops and ‘train the trainer’ events. Subsequently, a wealth of excellent resources for good practice in maths and statistics support tutoring are now available via the sigma-network website (sigma-network, 2013).

Based on his comprehensive experiences, the speaker suggested useful advice on recruiting tutors, including:

- the best recommendations for postgraduate tutors can come from the postgraduates themselves;
- at training events tutors should be made aware of the ethos of the centre and their role as ambassadors for the service;
- tutors are informed of the various learning styles, abilities and specific learning differences present in a support setting as well as strategies to adopt when problem solving or for when a tutor is unable to solve a student’s problem.

The importance of pairing new tutors with more experienced ones, building a sense of community among tutors, teamwork, informal discussions and social activities were also stressed.

The speaker continued with some reflection on the evaluation of the tutor-training programme. He pointed out that while the success of the workshops (i.e. feedback forms) has been evaluated, the opportunity to explore their impact upon the individuals longer-term was missed. Evaluation is important – but individuals might wish to consider how they can build upon an evaluation to undertake research. For the speaker, evaluation forms part of an “*educational enquiry spectrum”*.

The talk ended with an open question for the community to discuss: “*having seen individuals’ progress to academic careers after working in the MLSC, are these two linked, and is this of further interest and worthy of study?*”

Figure 2. Keynote Speaker - Michael Grove

2.2. Ciarán O'Sullivan, Institute of Technology Tallaght. Staff development in Mathematics Learning Support in Ireland: where are we now and where to next?

This keynote presentation started with a thorough overview of tutor training and MLS to-date. It referred to the excellent work carried out in the UK by **sigma** and others, for example the guide from Croft et al. (2011) and the work of Michael Grove, Joe Kyle and others in terms of tutor training sessions. In 2013, IMLSN Committee members Páraic Treacy, Ciarán Mac an Bhaird and Ciarán O'Sullivan, developed a series of four tutor training workshops based largely on the **sigma** materials. These were trialled at different institutions, and this project led to the establishment of an IMLSN Special Interest Group (SIG) – **'**Building Tutor capacity: Supporting tutors in MLSCs through an interactive training environment'. Further details about the SIG's work are available from Fitzmaurice et al. (2016).

The speaker then drew participants' attention to the National Forum for the Enhancement of Teaching and Learning (NFTL) and their work on a framework for the professional development of those who teach in Higher Education. (Further information is available via http://www.teachingandlearning.ie/priority-themes/benchmarking-professional-development/professional-development-consultation). He focussed on the significant benefits for tutors/staff involved in mathematics and MLS teaching and then put forward an in-depth proposal on four different badges/courses that could be taken as part of CPD. The four areas he identified are listed below with a brief indication of why he believed they were necessary:

1. Professional Knowledge and Skills for MLS tutors: This is needed to inform tutors of the fundamentals of their role while working in MLS and in particular to equip them with the best techniques for maximising the mathematical learning of students in the one to one scenarios and small group tutoring that occur in MLS. Also this badge is needed to educate tutors on how best to meet the learning requirements of additional needs students in MLS environments;
2. Professional Communication and Dialogue for MLS tutors: This is needed to develop the listening/questioning skills that are at the centre of student/tutor interaction in MLS. Also there is a need to develop academic 'critical' reading/writing skills so that MLS tutors can explore and learn from MLS literature. Also this badge is needed to give the tutor the skills and opportunity to participate in and contribute to MLS relevant study groups or communities of MLS tutor (online or otherwise);
3. Professional Identity, Values and Development for MLS tutors: This is needed to enable tutors to explore the understanding of their own learning in an MLS context, to develop reflective practice skills and to learn how to engage in evaluation of their MLS practice by peers;
4. Professional and Personal Digital Capacity of MLS tutors: This is needed to equip tutors with the knowledge of data protection and ownership/intellectual property issues relevant to their role in MLS. This badge is also needed to develop tutors' confidence and competence with digital tools in an MLS context so that tutors can help students use relevant materials and also so that tutors can develop the skills to create digital learning materials that enhance MLS.

The speaker went through these 4 badges in detail, identifying the areas where existing suitable resources were available, and the areas where resources needed to be developed. It was noted that NFTL also fund *All Aboard* - Digital Skills in Higher Education (see http://allaboardhe.org). Part of this project involves piloting and digital badges, and the speaker described provisional discussions with them to explore a collaboration between the IMLSN and the *All Aboard* project which would enable the four MLS badges to be supported from a technological point of view. The presentation closed with participants giving written feedback on each of the badges. The speaker will collate these and present the outcomes at the next meeting of the IMLSN committee so a decision can be made on how best to proceed.

Figure 3: Keynote speaker - Ciarán O'Sullivan

3. Contributed Talks

3.1. *Niall McInerney and Kevin Brosnan, University of Limerick. Challenges for tertiary level mathematics tutors with no formal education training: The experience of two practitioners*

In this presentation, two PhD students focussed on their experience of two different types of tutorials run in the University of Limerick. *Formal Tutorials* (FTs) run by the Department of Mathematics and *Support Tutorials* (STs) offered by the MLSC. FTs have 40-50 students from a module assigned to each one, and tutors present solutions to assignments. Tutors are often required to deliver these tutorials and are not paid. STs are announced by the MLSC for each course, they start with 15-20 students, students are responsible for the material content and tutors are paid.

The speakers described how, in their experience, FTs had poor student engagement and the tutors basically just transcribed the answers. It was suggested that tutors can also lack motivation because of this structure and due to the fact that they are not being paid. STs do not have the constraint of a problem sheet, and, at the start of the year, there is very high engagement between tutors and students. Due to their success, the numbers attending increase significantly, but as a consequence, their effectiveness decreases. In one course, only 60-70 of 300 students were attending lectures regularly but 150 were attending STs. The large class sizes often discourage the weaker student (who the ST is aimed at) from participating whether it be asking questions or engaging in discussions, and also inhibit the tutor to roam the classroom for personalised help.

The speakers discussed the role and position of MLS and STs in the student learning experience. They argued that MLS is not a replacement for traditional classes; that FTs would be much more effective if structured like STs, with smaller numbers and more interaction. This means moving away from the scribing of tutorial sheet solutions towards a more collaborative problem-solving environment, where the students attempt the traditional FT work outside of class.

3.2. *Ted Hurley, NUI Galway. Make it (Mathematics) stick!*

This broad ranging and entertaining presentation carried a number of important messages with regards to mathematics education. The speaker's main focus was on the negative perception of the teaching and learning of mathematics, and the attempts made to address the so-called 'issues'. He discussed his experience as a mathematics educator, both as researcher and as a teacher. He also discussed his considerable interactions with the general public in relation to mathematics, and in particular his media contributions.

An emphasis was placed on various ‘reforms’ which have been carried out in mathematics, e.g. in curricula, and in teaching and learning practices. For example, the syllabus reform ‘Project Maths’ which has been introduced in Ireland gradually since 2008. The speaker stated that these reforms often cause more harm than good, as they can ignore existing good practice and often seem to be carried out just for the sake of change.

The speaker also discussed a number of texts in the context of teaching and learning mathematics. For example, he discussed the book ‘Make It Stick’ (Brown et al., 2014) and advocated that it should be a required study for all teacher/tutor training courses. He emphasized the benefits of the techniques of learning as described in this book, which are not specifically related to mathematics, but can easily be adapted for learning and teaching mathematics.

3.3. Richard Walsh, University of Limerick. An analysis of pedagogy of mathematics support tutors

This talk described a project, run by the speaker and Olivia Fitzmaurice, which focussed on the training of tutors providing MLS. It started with a brief description of MLS provision at the University of Limerick, and recognised the key role of MLS tutors. They stressed the importance that students attending MLS have a tutor who can transform their own mathematics content knowledge into a form that students can understand and benefit from.

The project involved three MLS tutors who did not have backgrounds in mathematics education and they developed a framework which used Rowland’s Knowledge Quartet and General Pedagogical Knowledge. The tutors were videoed when they were providing MLS, and then the presenter analysed the videos using the developed framework and gave feedback to the tutors, after the tutors had also watched the videos of their own tutoring. A finding that was presented was that tutors lacked general pedagogical skills (e.g. unorganised blackboard work, spoke too quickly). Tutors also did not allow students to try any problems and classes were far too didactic to achieve any real learning from the students. A full paper on this project has been accepted for publication in the *International Journal of Mathematical Education in Science and Technology* and will be published in the near future.

3.4. Cesar Scrochi, University College Dublin (UCD). Tutoring in a Maths Support Centre as an enrichment experience for tutoring large groups

This speaker outlined how his large (30+ students) class tutoring has improved as a result of tutoring one-on-one or small groups in a MLS setting. His framework was based on the theory of Pedagogical Content Knowledge proposed by Lee Shulman (1986) and in particular on the six subdomains of Mathematical Knowledge for Teaching proposed by Deborah Ball et al. (2008). Through the use of examples on limits and continuity, the speaker highlighted how four of these six subdomains have improved his tutoring since joining as a tutor in the UCD MLSC a year ago. The subdomains covered during this presentation were: Common Content Knowledge (CCK), Specialized Content Knowledge (SCK), Knowledge of Content and Teaching (KCT), and Knowledge of Content and Students (KCS).

Through the use of students’ misconceptions, multiple representations and examples, the speaker showed that successful teachers need not only know the subject matter that they teach (CCK), but they should also know different ways that a student might approach a problem (SCK), predict the students' approach to a topic so they know what they might be (incorrectly) thinking (KCS), and combine the knowledge of mathematics and learning (KCT) in order to improve students' learning.

One of the examples presented focused on how important it is for tutors to identify the real source of students' mathematical errors when tutoring in a MLSC (SCK). A student might come in asking for help with finding the value of a limit only to realize that what he/she is really struggling with is factorizing polynomials. Insights like this on students' difficulties have helped the tutor improve his own tutoring practice (KCS).

3.5. Maura Clancy, Limerick Institute of Technology. Audit of mathematics learning support in Ireland in 2015 – the key findings

This speaker presented an overview of the results from a recent IMLSN survey of 32 Higher and Further Education Institutions in Ireland which received a 97% response rate. Responses included universities (32%), Institutes of Technology (39%), Further and Higher Education Institutes (13%) and Colleges of Education and Liberal Arts (16%); making it one of the more comprehensive nationwide surveys of its type. MLS is offered in 84% of institutions with 65% of those providing MLS through a dedicated centre. The speaker reported on developments of MLS in Ireland since the last audit of 2008 (Gill et al.). In that time the percentage of institutions offering MLS through a MLSC has risen from 38% to 65%. However, the percentage of permanent MLSCs only increased by 5%. It is interesting to note that funding for MLS within an institution (from a variety of sources), has risen from 54% to 92%, suggesting the recognised value of MLS across the entire institution. MLS tutors are increasingly sourced from postgraduates with the percentage of institutions using postgraduates rising from 38% to 56%. The survey highlights the extra staffing difficulties encountered by those institutions that do not have a constant and appropriate supply of such students. The survey reports on an extensive range of responses under the six themes of:

1. Availability and practical operation of MLS;
2. Staffing and tutors;
3. Types of support available;
4. Users of the service
5. Reporting and evaluation of MLS activities;
6. Challenges and developments

Full details will be published in the autumn of 2016 and be available online via http://imlsn.own.ie.

Of particular relevance to the theme of this conference was the fact that only 52% of institutions providing MLS offer a training programme to their tutors. When asked how their MLS could be improved, 54% of respondents referred to tutoring staff in various ways, namely, more tutors, permanent tutoring staff and tutor training. A common refrain among respondents was that tutors should be given longer term contracts and better salaries and that postgraduate tutors should be better supported through terms and conditions that encourage professional development and retention.

3.6. Julie Crowley, Cork Institute of Technology. Online e-assessment tool Numbas as a tutorial tool

The speaker, along with colleagues in Cork Institute of Technology (CIT) and University College Cork (UCC), received funding from the NFTL in 2014 for the project 'Transitioning to e-assessment in Mathematics Education' (see http://www.teame.ie). The presenter had originally been teaching a 'bridging course' in mathematics, and providing appropriate assessment was taking up a lot of valuable time. She attended a presentation on the e-assessment tool *Numbas* (available at https://numbas.mathcentre.ac.uk) at one of the CETL-MSOR conferences and immediately recognised its potential. This led to the application to the NFTL.

In CIT, *Numbas* was trialled as a tool in tutorials; students used it in class and then used it for assessment towards the end of the semester. Students and instructors both found it easy to use, and the speaker mentioned the benefits of being able to add hints, comments and extra resources. She further reported on an increase in attendance and engagement when compared with traditional tutorials, though it was noted that *Numbas* tutorials had assessments. Instructors observed that students in *Numbas* tutorials were more eager to ask questions if they were stuck, and that they liked the instant feedback. Instructors also stated that the automatic correction of assessments was of great benefit to reducing their workload. In UCC, the trial attempted to run the assessment from home, but students reported some technical difficulties. In order to address this, next year tutorials will be run at the start of the semester on how to use *Numbas*.

Finally, the speaker advised that workshops on how to use *Numbas* can be arranged with people from the project team before the end of 2016.

4. Concluding Remarks

The workshop talks were concerned with a broad range of aspects in higher education mathematics and statistics tutoring. The importance of subject related training for tutors was highlighted several times by contributing managers of MLSCs, lecturers and tutors. Particular challenges for tutors engaged in MLS were discussed as well as possible ways to support them in their everyday work and their professional development. Overall, the workshop provided delegates with a welcome opportunity to share ideas and experiences in supporting tutors engaged in higher education MLS, and to further consolidate links between academics and support staff.

5. Acknowledgments

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RESEARCH ARTICLE

Mathematics support sessions for second-level students

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Abstract

This paper reports on a free drop-in mathematics support service offered to secondary school students by Dublin City University. Pre-service mathematics teachers volunteered as tutors in the scheme, which was available to students from 1st – 6th year. Both students and tutors were surveyed to ascertain the benefits of the scheme to all parties involved.

Keywords: Mathematics Learning Support

1. Introduction

It is well researched and documented that there is a problem with the level of mathematics students possess as they begin higher education. This results in low attainment rates in courses that require mathematics, and courses that involve mathematics modules. Many Higher Education Institutes (HEIs) have confronted this problem by offering mathematics support to students outside of the usual lectures and tutorials. This support can take many forms and aims to bridge the gap between the mathematics that they learned in school and the level of achievement that is required in college (O'Sullivan et al., 2014).

In 2015, Dublin City University (DCU) began providing mathematics support sessions for students aged from 12-18 years old (1st – 6th year in secondary school). This was an initiative set up by the Maths Learning Centre, in conjunction with the School Liaison Office, and the sessions were free for students to attend. The support sessions were modelled on the traditional format of mathematics support, where students bring their own questions, work on them either individually or in small groups, and ask the tutors for assistance if and when they encounter a problem. Sessions ran for two hours one evening per week, and most students attended for the full two hours. Students were assigned to classrooms according to their year groups. The ratio of students to tutors varied but was usually one tutor for six to eight students. Although an online booking system was used, there was usually some discrepancy between the number who signed up and the number of students who attended the sessions. The School Liaison Office in DCU sent letters to secondary schools in the locality to make them aware of the drop-in sessions, as well as posting the information on online noticeboards and sending emails to relevant mailing lists.

The volunteer tutors were DCU undergraduate pre-service mathematics teachers, mostly in 3rd or 4th year of their studies. There were between 10 and 15 tutors in any given week, with an average of 70-80 students attending. The sessions were run on a trial basis for six weeks before Christmas, and due to strongly positive feedback from all involved, ran for a further eight weeks from February – April 2016.

Some tutors were apprehensive about the wide variety of questions that could be posed in a single session, citing lack of familiarity with the curriculum and lack of confidence to teach while unprepared. To ease these fears, some general notes from mathcentre.ac.uk were provided to tutors to use with students if needed. Some students also struggled with the concept of drop-in mathematics support. Senior cycle students (4th – 6th year) adapted more quickly, and were more likely to work on different topics themselves, while junior cycle students worked on the same topic as those around them. As a result, fewer tutors were required to work with the junior cycle students, where peer teaching was also much more evident, although many reasons could account for that fact.

Figure 1. Students and tutors working during a second-level drop-in maths support session in DCU

2. Literature Review

Learning support in mathematics can be defined as "*any facility or program providing extra optional assistance in mathematics and statistics for students during their enrolled study in a university degree program, with such assistance being outside the formally scheduled classes and activities for their enrolled course*" (MacGillivray, 2009, p.457). As the principle idea behind maths support is the same whether at second or third level, the characteristics are similar. The essentials for any type of maths support include a quiet relaxed atmosphere, with maths staff to provide support. Peer learning should also be accommodated. Some programmes will include one-to-one and group tuition, which usually occur in an open plan area with plenty of desks and some books/notes available (Patel and Little, 2006). Gallimore and Stewart (2014) highlight that each individual student knows their level of achievement and where they are struggling. They argue that students "understand what they need to do to improve, and they know how to make that improvement" (p.101). Lacking confidence and mathematical fluency can be a major obstacle for students as they strive to succeed in their studies (MacGillivray, 2009), so it is important that all parties involved encourage students.

The impact on the volunteer tutors is important to consider. Ní Fhloinn (2010) demonstrated the positive impact on third level tutors mentoring second level maths students by visiting their school for an hour once a week and providing one-on-one help in mathematics. The tutors were happy to share their love of maths and a few considered becoming maths teachers as a result. Patel and Little (2006) also referred to this motivation behind tutors volunteering: seeing improvements in students who struggled with maths as a result of their coaching. Gallimore and Stewart (2014) highlighted the importance of tutor appreciation: those who received recognition for the work they did benefitted more than they would have from just taking part. Hrastinski et al. (2014) agreed that "*the main driver of the coaches seem to be the desire to help students*" (p.88).

As the tutors in question were pre-service teachers, this tutoring can be viewed as a further learning opportunity. Teaching is something that must be learned over time, and on-the-job training is essential (Tzur, 2010). This corresponds with the common view that teaching someone else is the best way to learn (Hrastinski et al., 2014; Webb, 1989). Patel and Little (2006) and Hrastinski et al. (2014) also show that in supportive environments, both student and tutor learning can occur. It can be beneficial for tutors to work as a team, as this allows for discussion and consultation between them. It removes the sense of isolation that tutors can sometimes experience if they are not working in a supportive environment (Hrastinski et al., 2014). However, a study conducted by Collins (2005 cited by Gallimore and Stewart, 2014) highlighted that some volunteer peer-tutors thought it took time away from their personal study.

A large number of institutions in Ireland offer revision courses or exam tutoring for second-level students. In recent years, these have also become available online through websites such as irishgrinds.com ("grind" is commonly used for private tuition in Ireland), tutorhub.ie and positivemaths.ie. Some HEIs in Ireland offer types of mathematics support to second level students. For example, Maynooth University offer drop-in sessions, similar to those described in this paper (Maynooth University, 2016). In the Institute of Technology Tallaght, students work with pupils from local schools to support the development of their maths skills (Institute of Technology Tallaght, 2015). In University College Cork, students volunteer through UCC Plus+, providing homework clubs and extra revision sessions for examination years (University College Cork, 2016). Similar to the study conducted by Ní Fhloinn (2010), students in Dublin Institute of Technology also provided one-on-one maths support to second level students through a Voluntary Maths Tuition Programme (Dublin Institute of Technology, 2012).

3. Methodology

The aim of this research project was to determine how these sessions benefited both the students and the tutors. To carry out this investigation, surveys were given to both the students and the tutors. Students completed a paper-based survey during a drop-in session, while, for tutors, an online survey was conducted, using SurveyMonkey. The student surveys were completed in March 2016 and, in total, 97 students answered the survey. 20 tutors in total had volunteered at the support sessions over the two semesters, 15 of whom completed the survey.

In designing the surveys, surveys conducted by the university level mathematics learning support were consulted (O'Sullivan et al., 2014). This was used to get an idea of the types of questions that should be asked to get the best information from both students and tutors. It was observed from these surveys that closed questions, where respondents are given options to choose from, were the most popular. This was taken into account when both student and tutor surveys were designed.

4. Results and Discussion

4.1 Student Survey

The student responses were representative of those who attended, with about 60% from junior cycle (1st – 3rd years) and 40% senior cycle. A quarter had attended more than seven sessions, with 15 having attended between four and six sessions and the remainder between one and three sessions.

When students were asked to rank how much the sessions helped with their maths on a scale of 1 to 5, with 1 being 'not at all' and 5 being 'a lot', their responses were positive, with 64% of students answering a 4 or 5 and a further 24% a more neutral 3. When students were asked to rank how the sessions affected their confidence answering maths questions, with the same scale, 53% answered 4 or 5, with 33% answering a 3.

In response to a question asking "*Do you like choosing the topic you work on in the sessions?*" 90% of students replied positively. Reasons given included that they were able to work on topics with which they were struggling, and that they could revise topics for tests. Those who disagreed would have preferred structured classes. Overall, this showed that drop-in maths support was suitable for these students, in agreement with what was suggested by Gallimore and Stewart

(2014): that students know the areas they need to work on, and what is required of them to make that improvement.

82% said that tutors used different approaches to their teachers. This may be an indication that new methodologies have been introduced to pre-service teachers. Comments included that the tutors tried explaining things in different ways if they did not understand the first explanation. It must be noted that it is likely the tutors had more time than teachers to spend explaining topics, and some students mentioned this. Other students simply said that the tutors used language that was easier to understand. This was all positive feedback and supports the previous results which suggested that the students found the support sessions beneficial.

Students were asked if they participated in any maths activities outside of the classroom. Only 11% said yes, most of whom were in exam classes, getting individual tuition. Three students attended youth club maths classes.

Another question that generated interesting responses was "*Why did you decide to take part in the maths tutoring?*" The results are below in Figure 2. 41% of students said they made the decision to come themselves. This supports the opinion of Gallimore and Stewart (2014) that students are aware of what they need to do to succeed. The same number of students said that their 'parents encouraged me to attend' as 'friends were going'. Interestingly, only 16% of students said that it was the teacher suggested they attend. As contacting schools was the primary way the sessions were advertised, it was expected that this number would be higher. However, it may have been that the teacher mentioned the sessions, but the students themselves made the decision to come. This also suggests that students were taking responsibility for their learning.

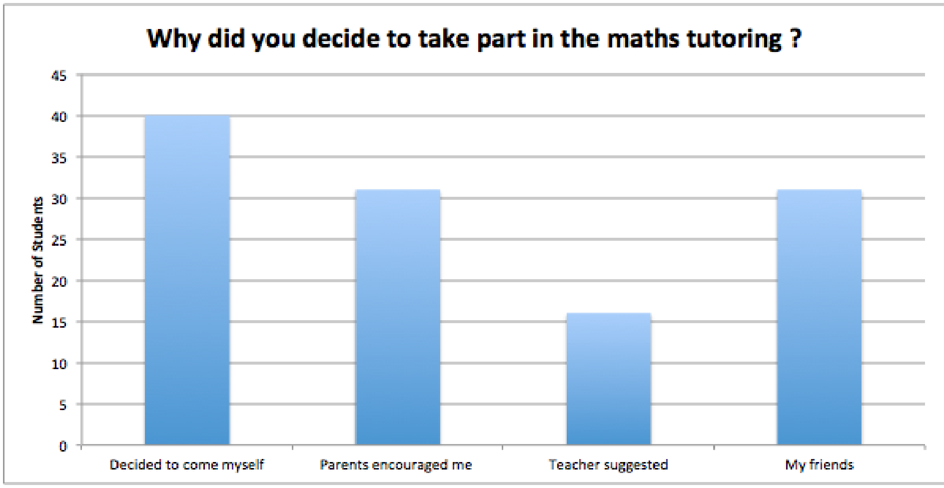

Figure 2. Student response to "Why did you decide to take part in the maths tutoring?"

Students were asked what it was about the sessions that they found useful. The results are displayed in Figure 3. Again, tutors featured highly in the responses with 64% of students saying that the helpful tutors were an important aspect of the sessions. 38% said that they like that the sessions were a quiet place to do work. This was somewhat unexpected as the sessions were not designated quiet areas, and a certain amount of noise was expected. Patel & Little (2006) also found that a quiet space was an important element for providing maths support.

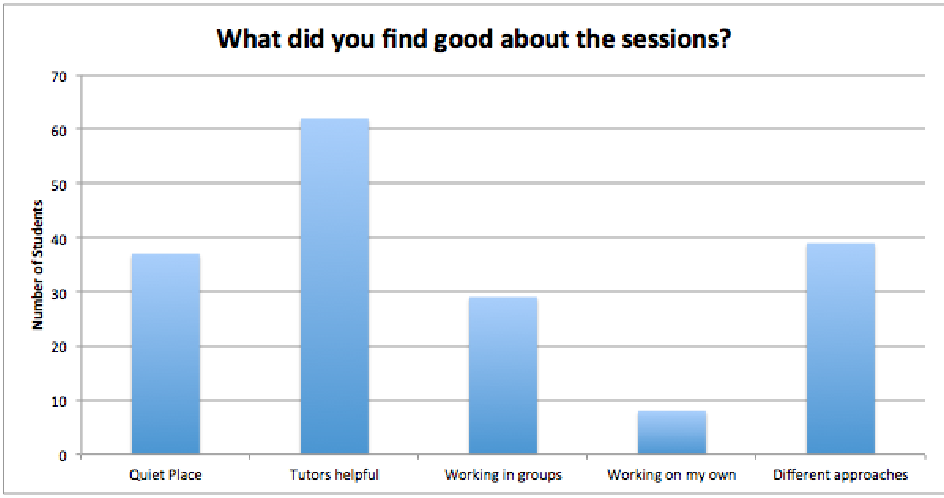

Figure 3. Student response to “What did you find good about the sessions?”

The overall feedback from the students was overwhelmingly positive. 90% of students said that they enjoyed attending the sessions, and 92% would recommend them to a friend or family member. Some students had already recommended them to friends and were now attending the sessions in groups.

4.2 Tutor Survey

The online tutor survey achieved a response rate of 75%. All tutors were pre-service teachers studying mathematics teaching in DCU. 40% were 4th year students, while 53% were in 3rd year, and 7% in 2nd year. Almost half of tutors who responded had volunteered more than 7 times. This result demonstrates the level of commitment involved for the tutors.

When tutors were asked why they initially volunteered, there were a number of interesting responses. Unsurprisingly, over 70% of tutors signed up to gain experience. It was anticipated that this would be a major reason behind the tutors volunteering. While pre-service teachers do complete long blocks of teaching placement, there is also a long time between placements where they do not have any interaction with students. The tutoring sessions allowed tutors to gain more experience dealing with students and their difficulties in between placements. One tutor volunteered *“to help students with problems, also to gain experience in dealing with the questions I would not have been prepared for”*. A few other tutors mentioned that they *“enjoy helping others with maths problems”*. This supports what Hrastinski et al. (2014) found, that the desire to help students is the main reason behind volunteering.

When tutors were asked if they would like to continue tutoring next year (for those in final year, if they would have liked to), 87% of students said that they would and most tutors would like the sessions to run for 8 weeks in each semester. The tutors also suggested that pre-service teachers in all years should participate. While this seems like a large commitment, the tutors generally suggested *“it did not take up too much time”.* This contrasts with the findings of Gallimore and Stewart (2014), who reported that some tutors would not volunteer as it was too time consuming. However, it should be noted that their study involved peer-mentoring instead, and the cohort involved were not pre-service teachers, which likely had an impact upon their perception of how time-consuming such volunteering was.

To discover how exactly the volunteering experience benefited the tutors, a list of options was provided, and the results are displayed below in Figure 4.

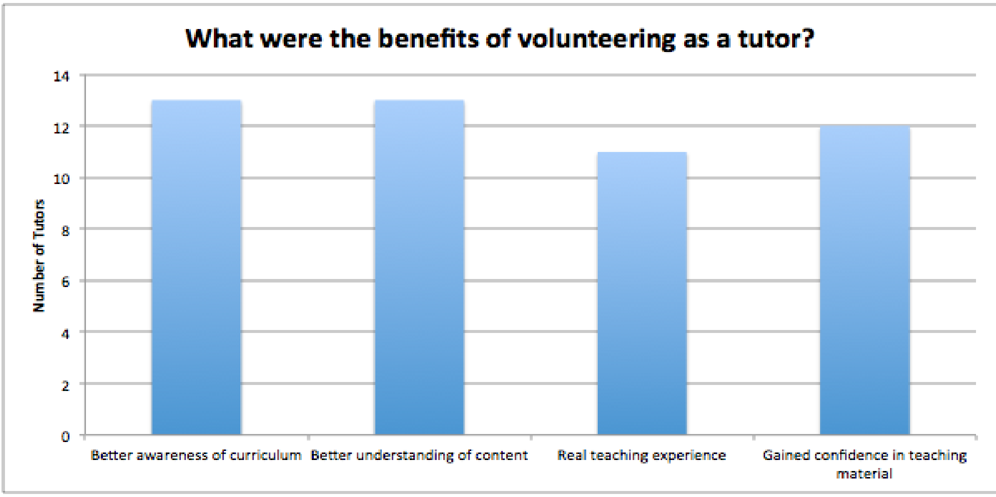

Figure 4. Student response to “What were the benefits of volunteering as a tutor?

In addition, a small number of tutors suggested other benefits. One stated *“Developing different methods to help students understand content”* which echoes comments from the student survey that tutors would use a variety of methods until they found the optimum approach. This supports the views of Tsur (2010), Hrastinski et al. (2014) and Webb (1989), that teaching is something that is learned from practice, and that the best way to learn something is by teaching. Another tutor stated *“Feel better about myself”* which supports Gallimore and Stewart (2014) who claimed that tutoring can result in an increase in tutor confidence. As pre-service teachers, the tutors had all been on teaching practice. This can be a difficult experience and can leave student teachers doubting their suitability for the job. In contrast, this experience seems to have had the opposite effect, and instead provided tutors with reassurance about their chosen career. The support sessions provided the tutors with an opportunity to practise interacting with students on a regular basis. The experience seemed to boost the tutors’ confidence in their ability to deal with students and their misconceptions.

The fact that tutors were unable to prepare for the session also raised some concerns among the tutors themselves. While most teachers will experience some off-topic questions in their classroom, being unprepared for an entire class is a situation that teachers should avoid. Most tutors found it *“daunting at first”*, and *“difficult not knowing what type of question the student might ask”*. However, 60% said that it was a good situation for a teacher to be in; that the tutor *“was seeing the question from a similar point of view as that of the student, in that we both didn’t know straight away how to answer it and had to think about what the best plan of attack was”.* A number of tutors mentioned that they felt comfortable asking another tutor for help, and that it was beneficial for students to see that tutors work as teams. As one tutor mentioned, there was a relaxed environment where students were comfortable to ask for help, but importantly, so were tutors. This supports the theory proposed by Hrastinski et al. (2014) that tutors benefit from working in a supportive environment, allowing tutor learning to take place. Many tutors moved from initial anxiety about teaching unprepared to seeing a benefit from it. The mathcentre notes provided were used a small number of times in early sessions. However, as the sessions progressed and the tutors’ confidence levels increased, they were no longer required.

When the tutors were asked if they believed their experience would benefit them in their future career, 100% responded “Yes”. There appears to be a similar positive impact on the tutors in this study as that previously found by Ní Fhloinn (2010). Seven tutors said that it was the best way to revise *“the content and the types of question asked”,* with two tutors also suggesting that they could set up something similar on a smaller scale in schools when they have qualified. A couple of tutors also mentioned that it would help when qualified when they need to provide students with *“individual help for a couple of minutes while the rest of the class are working”*, while also saying that the sessions *“helped to think on your feet and engage better with students.”* Being aware of student misconceptions before beginning their teaching careers is an advantage that should benefit them in applying for jobs.

Figure 5. Some of the students and tutors who participated in the second-level drop-in maths support sessions in DCU

When asked if the sessions had provided reassurance that they wanted to be teachers, 93% of tutors said that it did. This may provide the most concrete evidence that this is a programme that should be encouraged for all pre-service maths teachers. Comments also included the following: *“Positive feedback was encouraging”; “I enjoyed helping them work things out”;* and *“I think it is good to help students, and students are always very grateful when you help.”* Here, again, the importance of the appreciation the tutors received is highlighted. It meant a lot to the tutors that their time and efforts were appreciated by the students. This was a reoccurring theme throughout the literature (Gallimore and Stewart 2014; Hrastinski et al., 2014), and also throughout this project.

When asked if the tutoring had any impact on their academic course, 87% said no, despite them having a full timetable of lectures while volunteering. Again, this contrasts with the findings of Gallimore and Stewart (2014), who dealt with a cohort of non-teachers involved in peer-mentoring. The tutors in our study were all very positive about the support sessions and also about maths in general. When asked for any final comments, they said: *“It is worthwhile for those studying teaching to give them more experience when they are not on placement”;* and *“I have really enjoyed my experience as a volunteer tutor…We have an opportunity to help students and put our knowledge to some good use”.*

5. Conclusion

Through the questionnaires, it was established that there were many benefits for both the students and the tutors. The students benefitted as they felt their mathematical ability had improved and their confidence levels increased as a result of attending the sessions. The students responded well to the structure of the sessions. The students responded particularly well to the tutors and the methods they implemented. They liked that the drop-in sessions offered a quiet space for them to work independently or in small groups, with tutors available to assist them if help was required.

While the support sessions were initially set up for the benefit of the students, it became clear that there were also many benefits for the tutors who volunteered, such as gaining more teaching experience. Tutors also reported that they benefitted from being exposed to the curriculum and became more familiar with the content being taught in schools. They felt they benefitted from working as part of a team in a relaxed learning environment, where it was possible for them to learn as well as the students. An unexpected benefit was that the tutoring experience provided reassurance for the tutors that they wanted to be teachers. The sessions offered a real environment for tutors to interact with students and to become familiar with common misconceptions. The feedback from the tutors was overwhelmingly positive, with most saying they would like to continue tutoring. Their participation in the sessions also led to increased confidence levels in their ability to teach and to deal with students' misconceptions.

6. Acknowledgments

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CASE STUDY

The Pilot Maths Centre at the North West Regional College

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Abstract

This paper discusses the establishment in 2015 of the first Maths Centre in any Further and Higher Education College in Northern Ireland. In particular, it considers the rationale for its development, how it was set up and how it runs. It also presents initial figures and feedback, and plans for future developments.

Keywords: Mathematics, Maths Centre, Further Education, Higher Education.

1. Background

North West Regional College (NWRC) is a leading provider of Further Education (FE), Higher Education (HE) and skills training in Northern Ireland. The three main campuses in Derry-Londonderry, Limavady, and Strabane boast modern and industry-standard learning environments at which over 20,000 students learn and train on professional equipment using professional codes of conduct to achieve their personal educational goals through full and part-time study every year.

NWRC has seven academic schools:

- Business Services and General Education;
- Science and Technology;
- Media, Multi Media and The Arts;
- Craft Services;
- Early Years Childcare, Hairdressing and Beauty Therapy;
- Health and Social Care;
- Hospitality, Tourism and Sport.

The student population ranges from school leavers and mature students, to professionals and jobseekers, who wish to improve their skills and qualifications. Students originate from all parts of Northern Ireland and the Republic of Ireland. In recent years, NWRC has witnessed an increase in student numbers across its Level 2 Diplomas (equivalent to GCSE), Level 3 Extended Diplomas (equivalent to A-level) and HE provision.

Routes into employment include the Level 2 Diploma and Level 3 Extended Diploma options which blend classroom delivery with real-life work-based challenges. For those wishing to progress to university, these programmes provide direct access into honours options both locally and throughout the UK. NWRC's part-time portfolio continues to grow and includes hundreds of courses in areas such as Essential Skills (Numeracy & Literacy), hobby and recreation, return to study and professional development, as well as the traditional part-time vocational courses.

NWRC is one of the largest employers in the North West as well as an education and training provider. It is a lead partner in the local Workforce Development Forum, partnering representatives of industry and commerce and the local council, to provide and develop a comprehensive range of retraining programmes to suit the needs of local employers. NWRC works in partnership with local businesses, organisations universities and awarding bodies to develop and deliver bespoke training that will meet their individual requirements.

For some time, there has been research which assesses the provision of mathematics in primary and post-primary schools in order to establish the contribution made to the supply of people with science, technology, engineering and mathematics, e.g. the ‘Set for Success’ report from 2002 (Roberts, 2002). This report covered biological sciences, engineering, computer sciences, etc., in order to make recommendations on changes to the curriculum, qualifications and pedagogy for those aged 14 and over in schools, colleges and HE institutions. The aim was to give students the opportunity to acquire the mathematical knowledge and skills necessary to meet the requirements of employers and FE and HE. The key findings suggested that there was a shortage of specialist maths teachers and that, in general, maths teachers were not adequately supported and nurtured due to the lack of resources, infrastructure and culture of continuing development.

A review of mathematics and in particular GCSE Mathematics describes, that even though the proportion of young people achieving good grades has gone up in recent years, employers, universities and colleges are often dissatisfied with school leavers’ literacy and numeracy with around 42% of employers needing to organize additional training for young people joining them from school or college. The policy paper also states that “*We believe making GCSEs and A levels more rigorous will prepare students properly for life after school. It is also necessary to introduce a curriculum that gives individual schools and teachers greater freedom to teach in the way they know works and that ensures that all pupils acquire a core of essential knowledge in English, mathematics and sciences*”. (GOV.UK, 2015).

More recently, the above review, including a public consultation, resulted in the announcement by the Education Secretary in early 2013 of proposals for a comprehensive reform of GCSEs. The implementation of such reform is effective from 2016. The resulting review means that all students will have to master the basics of mathematics, with greater provision for concepts such as ratio, proportion and rates of change. The ‘new GCSE’ will set higher expectations, demanding more from all students and making it more challenging for those aiming to achieve top grades. The broader aims of the review will see students more prepared for life after school, ensuring that all pupils acquire a core of essential knowledge in English, mathematics and sciences. Hancock stated that:

- 40% of pupils do not get GCSE grades A* to C in English and Mathematics by age 16;
- 90% of those who don’t reach this basic standard by 16 don’t achieve it by 19;
- From August 2014, students who have not achieved a good pass in English and/or Mathematics GCSE by age 16 must continue to work towards achieving these qualifications or an approved interim qualification as a ‘stepping stone’ towards GCSE as a condition of student places being funded;
- From September 2015, the reformed GCSE Mathematics and English will begin being taught in schools with the first examinations being sat in the Summer of 2017;
- Between 2015 and 2020, these new GCSEs will be introduced into post-16 education in phases;
- Necessary ‘stepping stones’, for example functional skills qualifications, will be made available to support students on the path to GCSE (Hancock, 2014).

The NWRC has an obligation to make the importance of mathematics more clearly and visibly recognised in addition to ensuring the potential contributions of mathematics to the economy and society are appreciated. More importantly, it must create the necessary provision to ensure students facing difficulties within STEM subjects or courses as a result of underlying weaknesses in mathematics can get tutoring as a form of intervention to avoid failing/withdrawing from the subject or course (Cox, 2003). Furthermore, Maths is a core module in STEM courses, therefore the knowledge and application of it needs to be developed, particularly since staff had noticed that student skills gap in mathematics needed to be addressed to meet the expectations of FE and HE. Considering all of these factors, the College Board of Governors made the implementation of the Maths Centre (called ‘The Cube’) a requirement. We consulted with Joe English in Letterkenny Institute of Technology (LYIT) on best practice guidance (LYIT already has a Maths Centre on site) and we also reviewed existing advice documents, for example **sigma** (2015).

The Maths Centre was subsequently created to:

- give students the opportunity to improve their mathematical skills;
- develop student awareness of the applied nature of mathematics;
- gather information about the student cohort, enabling Curriculum Managers and or Heads of School to assess the changing nature of the student intake;
- provide teaching staff with information about gaps in the prior knowledge of the student group;
- identify particularly weak students within the group;
- provide key information for the acquisition of support materials within the Maths Centre.

Though this is the first Maths Centre in FE in Northern Ireland, maths support has been provided in some other FE colleges previously through different methods.

2. How the Maths Centre operates

The Maths Centre is situated in the Learning Resource area of the College. It is open 9a.m. – 7p.m. Monday to Thursday and 10a.m. - 4p.m. on Fridays, and is managed by the Curriculum Manager for Science and Mathematics. All students studying on the STEM programmes (Science, Engineering, Construction and IT) can access the Maths Centre. Currently, the service provided includes:

- one to one tutoring sessions centred on a learning plan determined by the result of a diagnostic test.
- small group tutoring sessions either recommended by a course tutor or by the students themselves.
- algebra workshops or workshops on additional topics identified as needed.

Diagnostic testing takes place at induction across campus. The test is currently paper based, however it will be electronic from September 2016 and students will have to complete the test as part of NWRC’s online registration process. It is compulsory for STEM students. The test consists of 20 GCSE Maths style multiple choice questions. The results are sent directly to the Maths Centre tutors; if they identify significant skills gaps, then they refer the student to the service. The use of diagnostic testing to promote or encourage student use of extra mathematics support is a well-established approach and there is evidence that suggests students can respond well to such tests and prompts (Ní Fhloinn et al., 2014).

To access the Maths Centre provision, a student is either referred by a tutor following diagnostic testing or self-referral, and a learning plan is developed at the initial meeting. Further details on each form of referral are provided below:

Tutor Referral:

- After diagnostic testing is complete, students with significant gaps in their mathematical knowledge are referred to the Maths Centre.
- At mid-semester student review, tutors are encouraged to direct any student who they identify as struggling with maths-related course content to attend the Maths Centre.
- Tutors within the Maths Centre develop a personalised plan to address the identified gaps in student knowledge.

Self-Referral:

- Students who score well in the diagnostic test but do not completely understand all of the topics and concepts are able to self-refer.
- Self-referral involves filling out a referral form which would then be sent to the Student Support Centre and an induction tutoring session arranged. The Student Support Centre provides support for learning needs and can direct students to the Maths Centre for tutoring.

A set of guidelines was developed by **sigma** (Network for Excellence in Mathematics and Statistics Support) which would establish the qualities expected of a tutor/mentor in the Maths Centre (**sigma**, 2011). The guidelines were distributed to NWRC staff as part of a staff development plan. The tutors are all staff members and subject specialists and all very experienced in the tutoring of mathematics; they also teach mainstream programmes including maths modules (Access, Level 3 Diplomas and Foundation Degrees).

Tutors are expected to create and deliver bespoke lesson plans which identify areas to be covered that address a student's difficulties within mathematics within their vocational area. They will inform the student of how the sessions will be structured, identifying clear session by session objectives and completing a work record for each session allowing for student feedback as appropriate. A typical session can run from thirty minutes to an hour, depending on the level of support needed. Tutors should encourage each student to take an active approach to their learning and to developing problem solving skills. Staff are also expected to establish the best method of communication for the time/location of a tutoring session and be consistent in dealing with situations where students are late or absent. They should be familiar with Learning Support protocols in the event that an underlying problem is identified and promote additional learning support as a strategy to enhance effective learning. NWRC welcomes students with a variety of abilities and specialist support is available for students with physical and learning disabilities, e.g. dyslexia, visual impairment, mental health or mobility difficulties. Tutors also need to review student progress and provide completed worksheets reflecting the progress made and they should encourage feedback from the student throughout the process and have them complete an evaluation form when their sessions are complete. The Maths Centre Tutors should work alongside other staff who teach on the vocational programmes to facilitate and enhance the learning experience of students.

The new Maths Centre was advertised through a range of media including:

- the Irish Mathematics Learning Support Network (IMLSN) website (see http://supportcentre.maths.nuim.ie/mathsnetwork/NWRClaunch);
- an official opening on the 16th of October 2015 during Maths Week Ireland (see http://www.mathsweek.ie);
- the **sigma** newsletter in December 2015. (see http://www.sigma-network.ac.uk/wp-content/uploads/2015/12/sigmanewsletter9_Dec15.html#NWRC).

At NWRC, awareness of the Maths Centre was promoted through emails to tutors, flyers on STEM notice boards and Webtexts to students registered on STEM programmes. The Maths Centre also has a dedicated web information site http://www.nwrc.ac.uk/mathscentre.

Based on a review of the first year of operation, there are plans to expand the services of the Maths Centre considerably, see section 3 for more information.

3. Results from the Pilot study

The pilot study ran from February to June 2015 and involved students from the following disciplines: Access (Science, Combined Studies and Health and Welfare), Computing, Construction, Engineering, Mathematics and Science. The students who took part in the pilot were those who were struggling with their vocational programme, because they found the application of mathematics difficult. (See Table 1 for student attendance figures in the pilot study.)

Table 4. A breakdown of student attendance figures.

Study Area	Number of students	Number of returners
Access / BSG	8	0
Computing / IT	3	2
Construction	2	1
Engineering	1	1
Health & Welfare	1	0
Maths	1	0
Science	15	8

Mathematical knowledge and the ability to apply those concepts in other curriculum areas is a common problem. It is noted that successful execution of applications reinforces the numeracy and mathematical concepts learned and has the potential to strengthen the learner's motivation and achievement (William, 2016). Based on lecturers' observations, the students had a conceptual understanding of the basic concepts, however, correct application of their mathematical knowledge in specific situations was largely absent, e.g. applying number theory in computing.

Some of the students found difficulty with only a small number of mathematical concepts and once these were addressed the student did not return to the Maths Centre. The returners were those students who had significant problems with the mathematical concepts they encountered and so continued to attend the Maths Centre until the end of the pilot. Students typically chose to return due to the high level of service received and they were motivated to progress with their studies. Some of the student comments are included below:

"I would have to drop out had it not been for the Maths Centre" - Student from Edexcel Level 2 Extended Certificate in Engineering.

"Have really benefited from the service, given different techniques and tips which have helped me greatly…I hope it will help me achieve the 71% (or more) grade I need for the entry to Podiatry at UU" - Student from Access Diploma in Science

"I had transferred from Northern Regional College and the course here was ahead so the Maths Centre helped me catch up" - Student from Certificate in Higher Education Applied Medical Science.

The students were given a paper based diagnostic test on entry to the Maths Centre that identified their skills gaps. Once this was completed, a scheme of work was established for every student by the tutors and relevant vocational question sets were also created. The students were given only those question sets which were relevant to their area of study. Online support was also set up through Moodle, where the students could practise questions and complete quizzes each week in order to reinforce the tutorial sessions and show their understanding. This model of maths support is currently being written up in more detail and will subsequently be reported on with a full analysis of its impact on students.

At the end of the pilot, students were given a mathematical skills test which aimed to record any improvement and the findings were reinforced by their vocational lecturers' reports which showed a significant increase in the students' vocational attainment. The following comments were made by the lecturers (note these are not the students' real names):

"*Ciarán established good structure for laying out collision questions, which makes understanding easier. Excellent progress"*

"*Michael can confidently work with differentiation, just needed some assistance with product rule/quotient rule and chain rule. Excellent progress"*

In the past, these students would have lost interest in their vocational programme due to their lack of mathematical skills and dropped out. Based on this pilot, the findings suggest that the Maths Centre provision enhances students' mathematical ability and overall performance on their vocational area of study although further research would need to be carried out to define if the Maths Centre is the causal link between an increase in mathematical ability and a high overall attainment on their programme of study. A paper on the impact of maths support tutorials states that "*Small group tutorials are an effective method of mathematics support to enhance student mathematics confidence, performance and ultimately employability. However, in a fast changing and increasingly digital HE environment, additional support in the form of e-learning might benefit those students that prefer this form of learning*" (NCBI, 2014).

The Maths Centre is very new, but engagement and feedback has been encouraging. In addition to the attendance data (see Table 1), each student is asked to complete a review form assessing the provision; each lesson plan offers a feedback section for the student allowing them to raise any issues relating to the provision at each tutoring session, and each student accessing the provision will have an additional diagnostic test run at the completion of their tutoring in order to gauge progression. For example, one of the feedback comments stated:

"I have a better understanding of the concepts underpinning my course" - Student from Edexcel Level 2 Diploma for Information Technology practitioners.

Students attended from across a range of disciplines. Of the 31 participants in the pilot study, Access and Health and Welfare students had no returners. This was likely due to the fact that they joined the pilot at a late stage for exam revision and therefore were not long term referrals. For the more mathematically demanding courses, e.g. Construction, Engineering and Science, 12 students returned up to 6 times. These students were accessing the Maths Centre on a weekly basis and found it a great help to them. All the students were finding the application of mathematics very difficult and were contemplating leaving their course of study. This was borne out by talking to the students and members of the programme team. Most of the students were referred by tutors. As a follow up to the pilot study, it was found that 29 out of the 31 students who attended the Maths Centre passed their course of study.

It was also found from the information recorded at the visits that the students could not apply algebra to their chosen vocational subject, so the Maths Centre staff developed tutorial lessons devoted to the application of algebra. Baruah & Greenhow (2006) found that students' errors in calculus questions are often due to consistent algebraic errors (mal-rules), which is largely supported by the evidence of their answer files. The algebra tutorials appear to have had a positive impact on student examination performance within their maths modules, however, again further analysis is required. Meetings were held with the course directors to look at the individual students who were attending the Maths Centre and it was noted that the ones that attended the Maths Centre improved their maths scores significantly.

Although this was a small study, it did show that the Maths Centre is a viable aid to students struggling with the application of mathematics at NWRC and it suggests a clear positive impact on retention and success data within the College. The initial analysis of the first full year of operation (September 2015-June 2016) supports this observation and is currently being prepared for a future report.

4. Recommendations

Although the Maths Centre has been in existence for only approximately one year and four months, the following initial recommendations are being considered in order to strengthen the service for students:

- Diagnostic testing should be completed by all students studying any element of mathematics (within their STEM programme) during induction week;
- Procedures should be put in place to refer students who are weak in all or most aspects of mathematics to the Maths Centre;
- A drop-in centre approach should be adopted for those students who understand the main mathematical concepts but still occasionally need help;
- Short online tests need to be completed throughout the academic year to gauge student progress - these should be carried out within the Maths Centre;
- Student progress reports need to be sent to Curriculum Managers and disseminated to the course team via coordinators.

These points will allow for greater collaboration between the Maths Centre and the Schools teaching the courses. They will also allow for increased effectiveness of the supports on offer, and for students to seek engagement with the Maths Centre as normal. In addition to these recommendations, based on the initial success of the Maths Centre, there are significant plans for development in the near future with measures put in place to ensure that the College can:

- open the Maths Centre to all Schools within the College;
- develop various mathematical education modules and community programmes;
- bring an international conference in STEM to the city with an emphasis on the mathematical sciences.

In addition, it is intended to continue to develop links with the IMLSN, including involvement with their Special Interest Group to provide CPD to Maths Centre tutors and hosting the IMLSN annual workshop in 2017.

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RESOURCE REVIEW

Using a Microsoft Surface Pro 3 tablet for mathematics support

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Abstract

This paper reviews the benefits of using a Microsoft Surface Pro tablet in a mathematics support setting. The context of its use is foregrounded and associated educational issues explored.

Keywords: Microsoft Surface Pro, tablet, skills support, independent learner, technology-enhanced learning.

1. A brief overview of the situation

Over the last 9 years, at the University of Bradford, the maths advisers (the author and his colleague, Helen Jackson) have not found technology, specifically laptops, netbooks, iPads or smart pens (e.g. Livescribe), to be very useful in helping with the face to face mathematics support, which is the core of the service. However, this year two Microsoft Surface Pro 3 tablets have been introduced, primarily for use in maths clinics (drop-ins).

To give some background and context, the mathematics and statistics skills development support at the University of Bradford is part of the University's Academic Skills Advice service, which is not affiliated with any specific faculty. The service is available for all and it seeks to be part of a system that encourages students "*to seek guidance when they require it*" (Thomas, 2002, p.439). Furthermore, the aim is to provide support which acknowledges that any student is studying within a specific discipline and they are the owners of their own skills development and the advisers are agents who can support them. If this is not established then students may well avoid the service because they will see it as "*lacking relevance to their course*" (Durking & Main, 2002, p.26) or worse, it may be teaching "*context-independent techniques*" (Wingate, 2007, p.394) which do not "*help students to assimilate into the practices of their discipline*" (Wingate, 2007, p.394).

For the mathematics support, it would be fairly typical for a student's first point of contact with an adviser to be in a maths clinic, which is a drop-in session where both advisers are usually present. Students from any discipline are welcome to the maths clinics which usually run three times a week. The clinics run out of general teaching rooms which the advisers have to book and advertised in advance. There is no permanent base. In addition, at other times, students are supported via a range of traditional and electronic resources as well as bookable appointments; all of which are well used. There is telephone and email advice available, but demand is low.

2. A wider context

Over the last three years, approximately, the entire service has undergone small but significant changes. The focus has been to try and maintain a welcoming 'can do' approach to students while also emphasising high quality practice and recognising that students "*have to become independent learners, taking responsibility for their own learning*" (Wingate, 2007, p.394). The ideal approach is to assume that all students are already taking responsibility and are developing independence and then to create environments and processes that support this assumption. This could be seen as focusing on the highest common denominator and emphasising the positives rather than the negatives. During this process, the team were introduced to the concept of heutagogy (Jones, 2014) via the CETL- MSOR 2014 conference in Cardiff. It seemed to fit well with the approach the team were already articulating and their reaction was similar to that of a conference delegate, who felt they could "*[k]eep developing my heutagogy methodology now it has a name*" (sigma Network, 2014). Broadly speaking heutagogy "*may be viewed as a natural progression from earlier educational methodologies*" (Hase & Kenyon, 2000). It is seeking to move on from pedagogic and androgogic approaches by incorporating self-directed learning and, beyond that, to have at its core the concept of "*truly self-determined learning*" (Hase & Kenyon, 2000).

To this end, one of the small changes trialled by the senior skills adviser (Russell Delderfield) was an increase in the use of screens – specifically the introduction of a projector with smart pen and also a large touch screen. Students were informed that any written work they brought with them needed to be in electronic form and it would then be viewed on a screen together with an adviser. There were, already, clear guidelines about working with live drafts in place but viewing student's work on a screen appeared to emphasise the distance between the adviser and the work itself in a way that had been hard to achieve with some students. The advisers had found that explaining how they work to the students had not always translated into understanding. Regardless of what was said to them, it had seemed for some students that handing a piece of paper over to the adviser led to an abdication of responsibility, as if some of their independence had been surrendered.

Very quickly, after starting the trial, the advisers noted a significant improvement. They found that students were getting the message without it needing to be articulated repeatedly. One explanation for this phenomenon is that viewing an electronic copy of something feels less tangible and therefore one gives it less weight or significance. Possibly because it allows one to be removed from it and to consider it differently. Another is that the electronic version can feel like a copy of the 'real' thing. There is evidence that "*screen-based reading behaviour is characterized by more time on browsing and scanning, keyword spotting, one-time reading, non-linear reading, and more reading selectively; while less time is spent on in-depth reading and concentrated reading, and sustained attention is decreasing*" (Liu, 2005, p.705) and that as a result, one engages with electronic text more superficially. This can be a good thing when the aim is to keep the emphasis on the learner who is the focus of the development and away from any individual piece of work. Whatever the reason, it was hoped that similar improvements could be achieved in the mathematics support setting too.

3. Patient zero – the case for a tablet

In 2014/15 an engineering student who regularly attended maths clinics demonstrated his sophisticated use of a Microsoft Surface Pro tablet (Windows 8) over a number of months. He made good use of the document retrieval and management features (past papers, formula sheets, tutorial notes) and he performed all of his working out and took all of his notes using the Surface pen (stylus) and the software, Microsoft OneNote. Each week he would revisit lecture 'handouts' and annotate electronic copies with the pen and, overall, his utilisation of this device seemed markedly different to other students' laptop and tablet usage. The lightweight nature, the speedy switching between documents and the ability to write smoothly, directly onto the tablet were all striking features. There even appeared to be some rudimentary maths-writing recognition features. Further research found similar stories online (Ong, 2015). It seemed to be a useful device to support personal learning and it seemed worthwhile to explore its potential in a mathematics support setting.

Ahern-Dodson & Comer's (2013) research into academic writing on a tablet provides further support. They start by wondering, themselves, whether "*a pad of paper could arguably achieve some of the same ends*" (p.67). However, they proceed to identify some features of tablets, specifically, that resulted in participants favouring them over the use of paper. For them it was primarily down to the flexibility offered. But they also raise the issue of "*visibility*" (p.68). In their case it is the visibility of writing notes that is under scrutiny but in the maths clinics it would be the visibility of the learning resources (of which there are a great many) particularly the ones developed ‘in house’. It would be interesting to see if they were more visible to the students, and therefore more accessible, via tablets than in physical folders. For comparison a photograph of the original paper resource folders is given in Figure 1, together with a screen-shot of the electronic resources as they are currently displayed on the tablets.

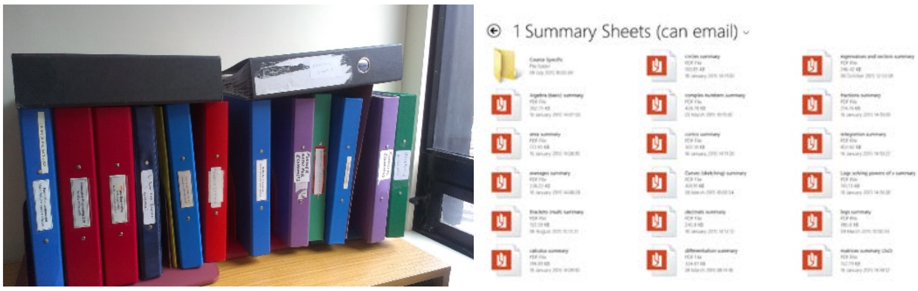

Figure 1. Paper based and electronic resources – before and after.

It is also pertinent that Ahern-Dodson & Comer (2013) concluded that the tablet was not just another computer. They found that it was something unique and they recommended that educators pay "*deliberate attention to the tablet as a unique technology*" (p.75). In their specific case it was distinctive because it had limitations that could have a negative effect on writing practice. However their advice, to consider it as something different within an educational context, seems sound. Furthermore they emphasise that the introduction of technology is not a neutral activity and what it does "*to us and for us*" (p.75) needs to be critically considered.

In addition to making the resources more visible, the University of Bradford has a strong environmental commitment but the mathematics support has traditionally used a lot of paper. It was hoped that the introduction of tablets would help to reduce paper consumption. On a very practical level it would also mean not having to transport overflowing folders, full of resources, on small trolleys to destinations far and wide on campus only to find the folder required was the one left behind.

4. Specific mathematics support issues

As part of the service improvements outlined earlier, underpinned by heutagogic principles, the frequency of the general maths clinics was increased to three times per week and discipline-specific clinics were removed from the schedule in 2014/15. Again it was intended to help raise the perceptions of students to the highest common denominator because it was noted that some students took more responsibility in clinics, when they saw how other students engaged with the process, than they did in appointments. In addition, over time, the subject specific clinics had unfortunately become identified with remedial support. Straight away it was clear that it had brought about improvements to the service. There was a reduction in the number of appointments booked and the attendance at the clinics noticeably increased. Historically, students who struggle with independence are relatively small in number but can be very hard to help. Often they are struggling to transition to higher education having been “*spoon-fed*” (National Audit Office, 2002, p.15) prior to coming to university. Focusing on the general clinic environment that communicates the need for independence without the need to keep verbalising it (and thereby drawing attention to it as a deficit) turned out to be a much more positive experience and it served everyone better.

One notable exception which typically occurs in the run-up to examinations is the demand for standard solutions to past papers. Although small in number, there are students who behave as though solutions are the most important aspect of their revision process. It is not an exaggeration to state that some students become almost obsessed with past paper solutions but are not generally receptive to advice that involves more sophisticated exam-preparation and other ways of revising. Typically it is the same students who report back after the exams, disappointed with their grade and declaring the paper to be unreasonably hard. It was this behaviour, in particular, that led to the consideration of changing the medium by which the materials were accessed and viewed (from paper to electronic). The hope was that it would have a similar effect to the changes reported by the advisers responsible for writing skills and study skills support.

5. The way forward: buying and setting up the tablets

Two Microsoft Surface Pro 3 tablets (i3 64GB) were purchased (summer 2015). Styluses (Surface Pen) are included in the price but Type Covers (keyboards) were also purchased. Microsoft offer a 10% educational discount. In the context of the maths clinics, the specific expectations and objectives were:

- To increase access to all resources;
- To reduce quantity of resources being transported;
- To do hand-written maths ‘on screen’;
- To provide option to easily copy, mark-up and distribute (email) varied materials;
- To cut down on amount of paper being used in accordance with University’s Green Commitment;
- To have the convenience of a full-powered and configurable laptop without the bulk/inconvenience.

During August and September, 2015, having purchased the devices, one of the advisers took responsibility for upgrading to Windows 10 and configuring the tablets and the other took responsibility for scanning as many hand-written notes as possible and generally organising the electronic documentation. Many of papers were dog-eared and were written on the very thin squared paper so they had to be hand-scanned otherwise they ripped or jammed in the scanner. Both of these roles were more time consuming than anticipated. A shared Microsoft account was created which gave access to a Microsoft Cloud service which, in turn, automated the synchronisation of documents between both machines.

6. Practical benefits

The good news is that the tablets have been useful and would be missed if they were no longer available. They have not been obtrusive, and, curiously, many of their most useful features are quite mundane. The amount of materials being transported to each clinic has dramatically reduced and this is very helpful. It also really helps that Windows 10 actually starts and wakes very quickly and that the screen is bright and very clear. The fact the tablets are lightweight and compact has been of particular benefit. It is no trouble to carry them around or physically pass them to a student. Also, they have a built-in, adjustable kickstand so they can sit on a cluttered desk very easily (see Figure 2).

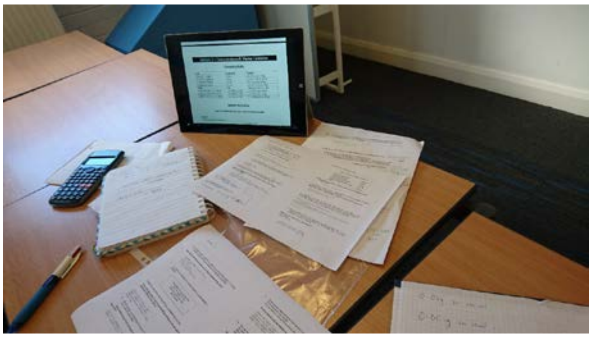

Figure 2. The tablet in a maths support clinic.

Reflecting on the use of tablets after the first semester (approximately 40 clinics held, averaging 2-3 hours each) it was felt they had been a success and the positives, in clinics, have been:

- increased access to the resources;
- perceived increase in student autonomy by both advisers;
- sense of increased efficiency in clinics;
- good for organising documents;
- used a lot to look at documents;
- easier access to the Virtual Learning Environment (VLE), websites and online graphing and these have all been done more than expected;
- fairly regularly emailing of documents to students, and the emailing does not take so long as to be prohibitive;
- booking follow up appointments via online diary system;
- a small footprint - lightweight, compact and stands easily on table – this has been a very valuable aspect of its ease of use.

These positive outcomes are despite the fact that there was quite a significant overhead in setting the tablets up. Many technical issues had to be overcome which did require technical experience and confidence. There are too many issues to list them all but it is worth noting that the keyboards are required even though they are sold separately and the 'Ink to Math' feature does not seem good enough, yet, to replace Equation Editor or Math Type (see Figure 3). It was surprising how little the unique feature of being able to write smoothly on the screen has been utilised in clinics although it has proved useful for taking notes in meetings and is still being explored for its potential with regard to screen capture and email advice.

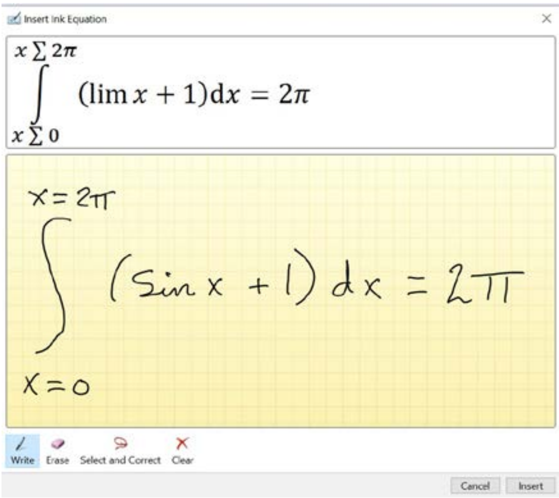

Figure 3. Microsoft Ink to Math feature.

7. Heutagogic Benefits

Returning to the idea of heutagogy, it was found that the tablets did support the ethos of increasing independence (raising to the highest common denominator). Whether for reasons already identified, or for reasons unknown, there was a clear improvement. For example, students focused less intensely upon the solutions to past papers in electronic form than they did in paper form. In previous years some students had tried to photograph the papers while they thought they were not being observed but there was not any commensurate behaviour with the electronic versions this year. Although copies cannot be taken, students are encouraged to compare their solutions to the standard solutions if it seems that it will help them in their development and students seemed to engage with this process very sensibly. Students also demonstrated awareness of the need to share the tablets with their fellow attendees. This seemed to lead to an organic process whereby students shared resources, including the tablets, with each other and group work and cooperation between students occurred in a mutually beneficial and socially appealing way.

Typically the model of support, within a clinic, is that advisers engage with a student and then move on to another, sometimes leaving the tablet with them. Each tablet almost represents the adviser in their absence and crucially interacting with the resources on the tablet seems to require more independence from the students. However it does not labour the message and thus, it manages the relationship boundaries more effectively than having the adviser actually point out to a student that they need to be more independent and do something for themselves. Crucially, with some students, it enables them to actively work on something, particularly when they arrive unprepared. For example they may be asked to log into their VLE or be given access to an appropriate resource. Previously it was easy to get bogged down in an interaction where a student just could not perform any independent work whatsoever. The adviser could become tied to them in the clinic setting and somehow this reinforced their helplessness. Although not necessarily "*immobilised by an expectation of failure*" (Hoyne & McNaught, 2013, p.110) students can exhibit levels of passivity in their education which is very close to this and they need help breaking out of it. The use of the tablets has helped with this and subsequently allowed for the advisers' time to be shared among everyone more equitably.

8. Summary

The introduction of the Microsoft Surface Pro 3 has been beneficial to the students and the staff, it had had clear practical benefits simply stemming from it being compact and lightweight and able to stand alone. The technology and operating system are fairly new which led to significant configuration and optimisation overheads but did not out-weigh the benefits. It was surprising that the features of the pen, which seem to make it a boon as a personal learning tool, were not well used in the clinic setting. Some of its benefits seem to be borne from the interaction between what it offers, how it is used and the context within which it is used and these have generally been educational benefits which gently reinforce the heutagogic approach.

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RESOURCE REVIEW

A review of free online survey tools for undergraduate students

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Abstract

Undergraduate students are often required to collect survey data as part of their studies, but they rarely receive any detailed guidance on choosing an appropriate free online survey tool. In addition, many universities do not provide undergraduate students with an institutionally supported and managed online survey tool. Because there are so many online survey services available, the lack of an institutionally managed survey tool coupled with a lack of proper guidance on their selection and use can cause a great deal of stress and possible expense to students. In order to alleviate this problem, ten prominent free online survey services were reviewed in order to give students, particularly undergraduate students in higher education, some guidance in this matter. Three essential criteria were borne in mind when evaluating the tools: ease of use; ability to export data, and; UK Data Protection Act compliance. Although this paper is predominantly focused on UK students undertaking surveys which collect data that could personally identify a respondent, conclusions are generalised to include recommendations for surveys collecting non-personally identifiable data, and for students studying outside of the UK. Based on the findings of the review, students needing to use a free online survey tool are recommended to use eSurv for all surveys, unless they are given alternative directions by academic staff or others at their institution. In addition, we further recommend that both eSurv and Quick Surveys are appropriate for surveys collecting non-personally identifiable data.

Keywords: Online Survey, Questionnaire, Survey, Market Research, eSurv.

1. Introduction

The University of Northampton (UoN) does not currently provide any central advice or guidance for undergraduate students regarding the use of free online survey tools. Furthermore, the University does not subscribe to or licence an online survey tool which is available for use by undergraduate or taught postgraduate students. However, following discussions with colleagues in other universities, it was found that UoN is in the majority amongst UK HEIs. Moreover, a review of the existing literature available uncovered only one paper, from Sao Paulo University (Rosa, Bressan, & Toledo, 2012), that compared the features available of eight free online survey tools. The lack of academic guidance and research on this subject may be due to the changing nature of online surveys, however, it does not help students navigating the potential minefield of choosing an appropriate free online survey tool from the many that are available. Added to this problem is advice in some research methods books (e.g. Bell and Waters, 2014) which, in a few cases, might be regarded as less than helpful. For example, when discussing Survey Monkey, the most popular online survey tool, Bell and Waters (2014) state; "*The free version is more than adequate for 100 hour projects*" (p.157). Following this kind of advice has led to many students being unable to export their survey data into a statistical package and being limited by the number of questions and responses. Additionally, where information has been obtained in the survey that might lead to the identification of an individual respondent, the data held by Survey Monkey may be deemed as not complying with the UK Data Protection Act. In case of the former this has resulted in students spending considerable time inputting the data from scratch, paying a monthly premium to upgrade their free account or relying solely upon descriptive statistics. Such experiences have caused considerable upset and distress amongst students, as none of these options are desirable and the lack of ability to export raw survey data often comes as a surprise to them. This paper is intended to support students by helping them to choose an appropriate free online survey tool and providing them with an independent review of some of the tools available.

2. Method

This study is based on a review of ten free online survey tools. Five of the ten tools were chosen due to their frequency and prominence in search engine results, (Google, Yahoo and Bing). To be included in the study, free online survey tools had to be visible on the first page of all three search engines when searching for 'free online survey tools'. The free online survey tools derived from this process were Survey Monkey, Smart Survey, Kwik Survey, Free Online Survey, and Question Pro. Five further free online survey tools were selected based on recurring recommendations from colleagues at UoN and via the JISCMail lists of the Sigma Network (Excellence in Mathematics and Statistics Support) and ALT (Association for Learning Technology). The tools chosen by this method were eSurv, Poll Daddy, Google Forms, Qualtrics, and Quick Surveys. Although we looked at a number of features to evaluate the free online surveys tools, it was decided that there were three essential criteria a free online survey tool would have to meet in order for the authors to recommend it to a student. They were;

1. Be easy to create and deploy surveys with no limitations as to number or type of questions and responses;
2. Give free access to view and download the raw survey data;
3. Be compliant with the UK Data Protection Act (DPA).

Each component of an online survey tool was rated on a three point scale, which ranged from good, acceptable and not acceptable. If any online survey tool received a 'not acceptable' for any of our essential criteria it would be automatically discarded from our main recommendations. The ease of use was determined by an undergraduate student who compiled the same questionnaire on each of the survey tools reviewed. The ability to access and export raw data was self-reported by each individual survey tools' own website and was verified by our student. UK DPA compliance was determined by the UoN's Data Protection Officer based upon the statements made on each individual online survey's own website.

In a recent development, October 2015, European Advocate General Bot (2015) has found in his opinion that the Safe Harbour scheme, which allows American companies to self-certify to adhere to EU privacy policy (Export.gov, 2015), is invalid. Furthermore, this opinion has been subsequently supported by the European Court of Justice (2015) who conclude that when discussing the transfer of data to the United States; "that country does not afford an adequate level of protection of personal data" (p.3). Therefore, any online survey tool which transfers data from the EU to the United States is considered, in terms of our rating system for free online surveys tools, not to be acceptable given our requirement that the survey tool be compliant with the DPA.

Since October 2015 the EU and the US have been working on a new protection to replace Safe Harbour. The EU College of Commissioners approved the new EU-US Privacy Shield arrangements in February 2016 and it is planned to operationalise the new process between 2016 and 2018. However until US survey companies sign up to the Privacy Shield they will still not be suitable tools for handling personal or otherwise confidential data for European students and researchers. US students will have fewer responsibilities to protect personal data in surveys carried out wholly within the US.

Legislation regarding the collection of non-personal identifiable information is much less stringent and all the survey tools reviewed in this paper would be acceptable as long as respondents are made aware before responding that IP addresses will be collected by the survey company and these could be used to identify individuals.

Therefore we have provided two sets of recommendations. One set of recommendations are for free online survey tools that are currently appropriate for the collection of personal data. We further add to this set of recommendations to include those free online survey tools that are appropriate for the collection of non-personal data

When considering whether or not a survey is likely to contain personal data, students and others creating and deploying surveys need to be aware that the definition of personal data is wide ranging, and is not limited only to data which contains obviously personally identifiable information, such as the name or email address of the respondent. Where information about a person's age, gender, ethnicity, etc., could be combined in order to identify a particular person (which may be likely if the survey population is small) this will constitute personal data (ICO, 2016). Survey creators are also reminded that any free text survey responses could contain personally identifiable data, even if it is not asked for in the response. Because of this, we recommend that, when in doubt, it is best to act on the assumption that personal data may be being collected, and to err on the side of caution and choose a UK DPA complaint survey tool.

3. Limitations

The information presented in the tables below (see Tables 1, 2 and 3), is considered to be correct at the time of submission (May 2016). However, due to the fluid nature of online surveys this is subject to change. Furthermore, due to the size of this study only ten online survey tools have been reviewed and therefore it is possible that alternative tools not reviewed are appropriate. It may also be possible that a survey company is acting in line with the Data Protection Act but have failed to reference it clearly on their web pages. Finally, this study is only concerned with free online survey tools and has not evaluated any versions which require payment from the outset, or any features of free online surveys which are available only as a paid upgrade to an initially free service.

4. Review

It must be stated from the outset that all survey tools reviewed offered some excellent features to the free user. However, many were either compromised by limitations, such as total number of questions or responses, or were outweighed by more serious issues, such as an inability for the user to freely access and download the raw data, or a lack of DPA compliance. Based on our essential criteria, for personal data, only two of the ten surveys passed this stage (see Table 1); namely eSurv and Qualtrics. However, whilst Qualtrics had some excellent features (such as the quality of the export to SPSS) it only offered the free user a trial of 250 responses before payment was required, and while this might be adequate for an individual project, it would not be suitable for a student wishing to carry out multiple surveys. Thus, while eSurv was not necessarily the highest rated tool in every component, it was the only remaining free version of an online survey tool we reviewed that obtained at least 'acceptable' with our three minimum requirements in that it was: (1) easy to create and deploy surveys with no limitations as to number or type of questions and responses; (2) gave free access to view and download raw data; (3) UK DPA compliant. In addition, eSurv offered additional benefits such as the use of branching/logic, simple generation of shortlinks and QR codes, mobile friendly, and (upon request) no adverts.

When we evaluated survey tools for non-personally identifiable data (see Table 1); in addition to eSurv and Qualtrics we would further recommend Quick Surveys. Again, Quick Surveys has the added benefit of exporting directly into SPSS. Furthermore, Kwik Surveys and Google Forms also met all of our requirements except student experience. Although we stand by our recommendations we acknowledge that is based on the student undertaking this research and therefore recognise these tools might be suitable for other students. Our recommendations are based on our findings of the essential features (see table 2) and our desirable features (see Table 3).

Table 1. Overall Recommendations of 10 Free Online Survey Tools

	Survey Monkey	Smart Survey	Kwik Survey	Free Online Surveys	eSurv	Question Pro	Poll Daddy	Google Forms	Qualtrics	Quick Surveys
Recommendations										
Recommended for use (personal data)	No	No	No	No	Yes	No	No	No	Yes*	No
Recommended for use (non-personal data)	No	No	No**	No	Yes	No	No	No**	Yes*	Yes

It should be noted that:

- * Qualtrics gives you a free trial of 250 responses before a subscription is required
- ** Google Forms and Kwik Survey are not recommended (for non-personal data) due to student feedback but both meet all other requirements

Table 2. Results of Individual Essential Features of 10 Free Online Survey Tools

	Survey Monkey	Smart Survey	Kwik Survey	Free Online Surveys	eSurv	Question Pro	Poll Daddy	Google Forms	Qualtrics	Quick Surveys
Essential Features										
Meets UK data protection standards	No	Yes, good	No	Yes, accept-able	Yes, accept-able	No	Yes, accept-able	No	Yes, accept-able	No
User friendly interface	Yes	Yes	Okay	Yes	Okay	Okay	Okay	Yes	Yes	Okay
Raw data exporting	No	No	Yes, csv	No	Yes, csv	No	No	Yes, csv	Yes, csv and sav	Yes, csv and sav
Maximum number of questions	10	15	No limit	20	No limit	10	10	No limit	No limit	No limit
Maximum number of responses	100 per survey	100 per survey	No limit	50 per survey	No limit	100 per survey	1000 per survey	No limit	250 total	No limit
User friendly experience and set-up	Okay	Poor	Poor	Okay	Good	Okay	Okay	Poor	Good	Good

Table 3: Overall Results of Individual Desirable Features of 10 Free Online Survey Tools

	Survey Monkey	Smart Survey	Kwik Survey	Free Online Surveys	eSurv	Question Pro	Poll Daddy	Google Forms	Qualtrics	Quick Surveys
Desirable Features										
Schedule the survey start date	-	No	-	-	Yes	-	-	-	Yes	Yes
Customise the survey	No	No	Yes	No	Yes	No	Yes	-	Yes	Yes
Easy survey integration with social networks	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
Survey views well on a mobile phone	-	Yes	Yes	-	Yes	Yes	Okay	-	Yes	Yes
Upload multimedia to the survey	Yes	Yes	Yes	Yes	Yes	No	Yes	-	Yes	Yes
Logic / branching	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Custom message	-	No	-	-	Yes	No	No	-	-	-
Storage time	-	Poor	-	Okay	Good	-	Poor	-	-	-

It should be noted that cells including '-' indicates that conclusive information was not available

5. Conclusion

Where students need to carry out online surveys, and where academic staff do not have a preference as to which tool the students use, this review currently recommends that students use eSurv (see http://esurv.org).

eSurv is funded by six universities; three in the United States, two in Europe and one in Canada (eSurv, 2015). It is DPA compliant (eSurv, 2016a), does not charge for access to raw data, and has none of the limitations or restrictions associated with many of the free online survey tools. Although the surveys deployed using eSurv do carry adverts, these can be removed at no cost by making a request to eSurv. There is no option to purchase additional features or upgrades to eSurv and all users are able to access the full product (eSurv, 2016b).

eSurv is an appropriate tool for both personally identifiable and non-personally identifiable data, although if the data collected is only non-personally identifiable information we would also recommend Quick Surveys. However it must be emphasised the more personal information that is being collected, the more careful students and researchers need to be and the more limited set of survey tools should be considered. If and when the Privacy Shield is introduced and if and when Quick Surveys sign up to this then we would be happy to recommend Quick Surveys for all data collections.

Regardless of data compliance legislation this paper would not recommend undergraduate students to use the free versions of Survey Monkey, Smart Survey, Free Online Surveys, Question Pro, or Poll Daddy.

One final recommendation we would make is to encourage institutions either to financially support and promote eSurv to its students or to purchase a site license to allow undergraduate students free access to an appropriate online survey tool, such as BOS for example (BOS, 2016). This would avoid any unnecessary distress, time and/or cost caused to students by having to choose an appropriate tool themselves. Furthermore if a site licence was in place for undergraduate students then relevant support and guidance on both the survey tool and best practices could be provided centrally, thus benefitting students and enhancing the student experience.

6. Acknowledgements

This paper is based on the results of an URB@N project that was a collaborative effort involving the authors of this paper together with second year undergraduate student, Clive Howe. The authors thank Clive for his work on this project. The authors also thank Rachel Maunder for administration of the URB@N scheme and for awarding a bursary to Clive which allowed him conduct the research into the user experience of the various online survey tools which were reviewed.

7. Affiliations and Disclaimer

Please let it be noted that the above recommendations are the personal opinions of the authors and not a representation of the authors' institution. Furthermore, the authors have no affiliation to any of the free online survey tools highlighted in this review. The review of the online survey tools was carried out between January and May 2015, and some of the features of the tools may have changed since that time. Additionally, some of the criteria, particularly 'user friendly interface' and 'user friendly experience and setup' are entirely subjective and based on the experience of a first-time user. All decisions made on Data Protection compliance were based on the information given on the providers' websites. The content of webpages helped to highlight the value providers put on such compliance and their understanding of the legislation. The authors have, to the best of their abilities, tried to provide an honest and accurate view of a complex and changing set of tools for a specific audience (UK higher education students and academics) and it should not be inferred from this paper that the survey tools not recommended will not be useful to other people in other institutions or in other contexts. While every effort has been made to ensure the accuracy of the information in this paper, if the providers of any of the survey tools listed feel that we have been unfair or have provided information that, at the time of the review, was not accurate, then we are happy to discuss this with them and to update the information in our paper accordingly.

8. Appendix

Addresses of the survey tools reviewed in this study are provided below:

- eSurv: http://esurv.org
- Free Online Surveys: https://freeonlinesurveys.com
- Google Forms: https://www.google.com/forms/about
- Kwik Survey: https://kwiksurveys.com
- Poll Daddy: https://polldaddy.com
- Qualtrics: https://www.qualtrics.com
- Question Pro: http://www.questionpro.com
- Quick Surveys: https://www.quicksurveys.com
- Smart Survey: https://www.smartsurvey.co.uk
- Survey Monkey: https://www.surveymonkey.co.uk

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