A Quantitative Exploration of the Statistical and Mathematical Knowledge of University Entrants into a UK Management School

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Abstract

Mathematical and statistical skills are increasingly important for securing fruitful employment in the modern world. Regardless of the increasing demand for such skills by employers, witnessed at present is a drop in the mathematics and statistics knowledge of university entrants. This paper uses a British university as a case study and exploits the induction week to collect primary data on the mathematical and statistical knowledge of entrants into two degree programmes. The data is then analysed using statistical techniques to identify the current patterns relating to the mathematics and statistics knowledge of students with a view to developing appropriate methods for enhancing their mathematical and statistical knowledge. Our findings indicate statistically significant differences in the mathematical and statistical knowledge of students entering this British university based on the chosen degree programme, gender and educational qualifications.

1 Introduction

Science, Technology, Engineering and Mathematics (STEM) are widely recognised as crucial areas for the development of modern society (Dalby et al. 2013; Brown 2009) via its contribution to innovation, economic growth and progression (Newman-Ford et al., 2007). However, as noted in Manning and Dix (2008), Tariq (2003) and Todd (2001), many studies have confirmed the weakening mathematical knowledge of undergraduates, even when some level of mathematical skills are required in all university courses (Galligan and Hobohm, 2015). As such, the main concern of this paper is on one component of STEM, namely mathematics (including statistics). As Truss (2013) eloquently asserted, through the directing of cars on the streets, planes in the skies and shopping to our doors, algorithms are entwined into the core of our lives.

Notwithstanding the importance of mathematics, it is well known that there is a gap in the mathematical and statistical knowledge of entrants into the UK Higher Education Institutes (HEI) and this problem has been in existence for some time now (Dalby et al., 2013). This is

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more evident where the courses include use of advanced mathematics and statistics for which a sound foundation is required. It is interesting to note that even physical geography students have identified the need for including statistics for data analysis in the school curriculum (Mathison and Woodward, 2013; Hill and Jones, 2010). The disjuncture in mathematical and statistical skills result from a variety of issues. Firstly, the transition from secondary to tertiary level in mathematics has been identified as problematic owing to lack of preparation and mathematical rigour, among other problems (Brandell et al., 2008; Hillel 2001; Hoyles et al., 2001; Wood, 2001). Secondly, the under-preparedness of students taking up higher education courses has been cited as another reason for the existing disjuncture by many authors (Luk, 2004; Hourigan and Ó Donoghue, 2007; Kajander and Lovric, 2005; Lowe and Cook, 2003). Thirdly, this under-preparedness was worsened by the fact that for example, in comparison to 1989, by the year 2004 there was a drastic decline in the number of entries for Advanced Level (A-Level) mathematics (Grove and Lawson 2006). However, according to ACME (2012), recently there has been an increase in the numbers taking up mathematics at A-Level and in fact it is able to challenge the many negative preconceptions in literature up until 2012. Finally, many students experience difficulties with connecting mathematics to real world applications (Chang 2011) and this too adds further to the deterioration and declining interest in mathematics skills.

In a world where organizations seek those with sound mathematical and statistical skills (ACME, 2012) to ensure increased productivity and value for money, there are added implications on the employability of students lacking such skills. According to the Parliamentary Committee Publication (2012), in UK there is an inadequate level of numeracy knowledge in pupils studying mathematics post age of 16. These students then enter university and find it increasingly difficult to cope with the expected mathematical and statistical demands of their programmes. In response, a number of changes have been implemented over the years in order to improve the level of mathematical knowledge of British students. For example, in 2000 a major change was implemented to the curriculum and examination process via the 'Curriculum 2000', but this resulted in a drop in students studying mathematics at A-Level by 20% (Vorderman et al. 2011). Those interested in examining the 'Curriculum 2000' changes in detail are referred to Vorderman et al. (2011, pp. 71). A more successful and noteworthy attempt is the role played by the Sigma Mathematics and Statistics Support Network[1] in funding and supporting the establishment of mathematics support centres across the UK HEI.

Issues pertaining to poor mathematical foundations and its negative impact on university entrants has been a problem which has surfaced over the years. For example, see Ireson (1996), Sutherland and Pozzi (1995), Gonzalez-Leon (1980), and Baker et al. (1973). Gill (1999a) considers students undertaking science and engineering courses at King's College London and identifies some key points which help explain the deteriorating mathematical and statistical skills in university entrants. Firstly, the mathematics syllabuses at schools are no longer tailored as feeders for university entrants following the introduction of GCSE and A-Levels. Secondly, students rarely identify a relationship between mathematics and their main subject studies. This leads to a lack of confidence in mathematics and worsens the already problematic situation (Parsons et al., 2009). Therefore, it is prudent for universities to assess and provide additional support to entrants who do not have either GCSE or A-Level mathematics in particular. Gill (1999b) considers the problems that physical science and engineering students face with mathematics and these include difficulties in understanding graphs and adapting to the different learning styles at HEI. Difficulties with adapting to different learning styles was also noted in Nardi (1996). Whilst it is arguable that the above research is outdated, more recent research

[1]http://www.sigma-network.ac.uk/

suggests that the problems still continue with the likes of Gill et al. (2010a) and Lawson et al. (2012) noting that the Mathematics problem is still common in HEI across UK and Ireland. As such, it is evident that emphasis should be placed on delivering mathematical content in a manner which helps the students see and understand the relationship it has to their main course of study.

In this paper we aim to provide a definitive answer to the proposition (based on feedback from academics at this particular university) that there is a decline in the mathematical and statistical skills of entrants into Bachelor of Business Studies (BABS) and Bachelor of Accounting and Finance (BAAF) frameworks at their Faculty of Management, and that there is a need to provide additional mathematics and statistics support. More specifically, this paper aims at providing answers to the following research questions. a) Are there any differences between the basic statistical and mathematical knowledge of students entering the BABS and BAAF frameworks at this British university during the 2013/14 intake? b) Are we able to differentiate between the basic statistical and mathematical knowledge of these cohorts based on gender? (This is important as gender gaps in maths have been of interest in previous research, see for example, Niederle and Vesterlund (2010), Else-Quest et al. (2010) and Lindberg et al. (2010)). c) What is the impact of educational qualifications on the basic statistical and mathematical knowledge of students entering this British university? In order to provide comprehensive answers, during the analysis stage we compare the scores between the two frameworks and between genders both within and between the two frameworks of BABS and BAAF.

The topic itself is timely and important for several reasons. Firstly, as Shukla et al. (2014) states, two prominent researchers and practitioners in developmental education, i.e. Casazza, (1999) and Maxwell (1979) believe that there will always be university entrants who are poorly prepared and academically weak. This claim is further strengthened by Abdulwahed et al. (2012) who states that most STEM higher education students enter university with gaps in the mandatory prerequisite knowledge pertaining to mathematical topics. Secondly, issues arise due to students noticing that the mathematical elements of their degrees are more than what they had anticipated (Rafik, 2004). For this issue, universities should share the blame for accepting students who do not meet the requirements of the published assumed knowledge for a particular degree (Gordon and Nicholas 2013a,b). Thirdly, the problems created by gaps in mathematical and statistical knowledge of university entrants have also impacted the unit content and delivery of lectures as noted in Parsons (2004) whereby the author states that module content had to be re-written and the examination styles had to be changed. Such scenarios most certainly can lead to a lowering of standards at Universities, and being able to identify the problems in advance will enable universities to provide additional support for students as opposed to lowering standards. In fact, Shukla et al. (2014), Casazza (1999), and Maxwell (1979) all agree that mathematically weak students can succeed with additional assistance. Moreover, surveys undertaken on first year lecturers in Australia by Skalicky et al. (2010) and Taylor et al. (1998) went on to show that the entry requirements of certain programmes did not match with the lecturers expectations of the required mathematical knowledge. All these factors justify the importance of considering the impact of educational backgrounds on the statistical and mathematical knowledge of university entrants as we do in this study. Fourthly, it is important to bear in mind that modern day employers demand graduates who are numerate (Hoyles et al. 2002) and the failure to produce graduates with sound numerical and analytical skills will lead to hindering the employability of university graduates, and also reflects negatively on the universities concerned. In addition, there is comparatively limited research on the mathematical and statistical knowledge of university entrants into Management Schools in UK and we hope this paper will encourage more researchers to delve into this topic in future. Finally, given that the provision of additional mathematics support is now standard in UK HEI (Fitzmaurice et al., 2015) this study is aimed at justifying the setting up of such support for students at this particular University.

Using basic statistical concepts and techniques, we analyse the actual mathematical and statistical knowledge of entrants into two selected frameworks at a Management School in a British University. Accordingly, our research differs to Gill (1998a,b) where consideration was given to Engineering and Physics students whilst here we consider students in Business Studies and Accounting and Finance courses. We believe this research has the potential for creating a case to set up additional support and resources to help students with their mathematical and statistical foundations so that they may obtain a more meaningful and enriched university experience. To achieve this objective, during the academic year 2013/14 we decided to monitor the mathematics and statistics knowledge of the new entrants into the two frameworks known as BAAF and BABS. During induction week, a specially prepared mathematical and statistical paper with the most basic questions (such that it covers the basic knowledge assumed in a university entrant) was distributed to the students from BAAF and BABS. Here, induction week refers to the week before commencement of classes at this university. During induction week there are various sessions organized to help students with their transition into the university's academic life and we exploited this opportunity to test the students' mathematical and statistical knowledge. Having considered the diagnostic test in Heck and van Gastel (2006) as a starting point, we tailored the questions to suit the level of mathematics and statistics relevant to Faculty of Management's entrants at this university by considering the mathematical and statistical components of the units they are expected to take up in the first year. Accordingly, the questions we developed covered basic algebra, powers, roots, logarithms, measures of central tendency and deviation, and normal distribution.

Several authors have previously used diagnostic tests for evaluating deficiencies in the mathematical skills of university entrants. Examples from the University of Limerick include Gill et al. (2010b) and evidence in Faulkner et al. (2011), whilst Kurz (2010) reports the use of a mathematics test at the University of Applied Sciences Esslingen in Germany. Miller and Goyder (2000) report the use of a 'Mathematics Preparedness Test' whilst Parsons (2004) too relied on a similar diagnostic test. In our case, the first test was a multiple choice question (MCQ) paper which was then followed by a written examination whereby the same questions were repeated. Multiple choice diagnostic tests have been previously used in Manning and Dix (2008), and Wilson and Macgillivray (2007). The reason for including identical questions in both the MCQ and written exam were to enable understanding whether the students guessed the correct answers to the MCQ or whether they actually knew the underlying workings to arrive at those final answers.

Diagnostic tests previously carried out in both the Ireland and the UK have also found deficiencies in the mathematical knowledge of university students (see for example, Cleary, 2007; Ní Fhloinn, 2006; LTSN MathsTEAM, 2003). According to Gill (1999a) the failure to correctly address the growing concerns relating to the mathematical knowledge issue has led to even more complicated situations. It is clear that the decision to carry out such a test can provide crucial information for academics and enable them to help students improve. Evidence from literature shows that the University of Glamorgan had noticed the unpreparedness of students entering their Engineering department and sought to resolve this problem by introducing in 2005 a course aimed at bridging this gap (Newmand-Ford et al., 2007), whilst at the University of Amsterdam additional mathematics support is provided to university entrants to help with the transition (Heck and van Gastel, 2006). Moreover, university entrants at this particular university, like the students in Ireland (Carr et al., 2013) and those at the University of Southern Queensland (Dalby et al. 2013) for example, gain admission via several different routes and as such there is likely to be a clear disparity in the level of their skills.

The remainder of this research article is organized as follows. Section 2 presents the methodology and summary of the data that was gathered for this study, whilst the statistical analysis and discussion is reported in Section 3. The conclusions are presented in Section 4.

2 Methodology

2.1 Research Philosophy

This research embraces the stance of a natural scientist as we subscribe to the epistemological position of a positivist. The study is concerned with the collection and analysis of facts, which we believe are comparatively less biased and in turn more supportive of the ontological position of objectivism whilst enabling law-like generalizations. The study itself is deductive as we seek to find answers to specific research questions which have a strong grounding within the literature. The chosen strategy is that of a case study which is quantitative and cross-sectional in nature.

2.2 Data Collection

The data collection for this primary research study considered the 2013/14 new entrants enrolled in two frameworks known as BAAF and BABS at a British university. There were two reasons for this selection. Firstly, based on past experience, lecturers had noticed a decline in the standards in these groups of students and suspected it would be the same during the period under investigation. Secondly, the degree programmes related to these two groups have a significant component of mathematics and statistics involved. The overall process was initiated during the students' induction programmes which were carried out in September 2013. Initially, all students in each framework group were asked to complete a diagnostic test in the form of a multiple choice questionnaire with 15 questions, using TurningPoint software to maximize student engagement. Thereafter, they were asked to provide answers to the same 15 questions by demonstrating the logical process they adopted. The 15 questions were carefully selected covering basic mathematics and statistics concepts considered of relevance to students enrolling in BAAF and BABS courses, as explained in the introduction[2]. It is noteworthy that the students had not been warned of the forthcoming test, and there was no expectation or requirement to let them revise as the point of the study was to evaluate and understand the statistical and mathematical knowledge of those who have been granted entry into these two frameworks.

The use of two tests in the form of MCQ and a written exam were opted to ascertain whether the students who score high at the MCQ do so as a result of sound knowledge or as a result of a lucky guess. For example, if a student was able to answer a particular question accurately at the MCQ test, then this same student should be able to provide the correct workings and obtain the exact same answer to the identical question found in the written exam. Failure to do so implies the MCQ result for that particular student was a result of a lucky guess as opposed to a sound understanding of the mathematical or statistical concepts. Such an approach enables one to obtain a richer understanding of the mathematical and statistical knowledge of the students. The selected questions represent the basic understanding of statistics and mathematics which would be required of students entering the Faculty of Management for a bachelors degree. The answer options for the MCQ test were selected in a way that in addition to the correct answer there would be another answer which appears correct but is in fact incorrect alongside two other incorrect answers. As in O' Donoghue (1999) both tests were marked by hand which enabled

[2]Please see Figure 2 in Appendix for list of questions.

closer inspection of a script where necessary. Each question was weighted with 1 mark and so in both tests the total marks obtainable were 15. These were then converted into percentages. Both forms of data collection and the answers to the questions can be found in the Appendix.

The results from this study are tested for statistical significance using a variety of tests. In all instances we subscribe to probability values of either 10% (0.10) or 5% (0.05). Where the results are significant at the 10% level, this means we have 90% confidence in the findings and where the results are significant at the 5% level it means that we have 95% confidence in our findings. However, it is important to bear in mind that given this research takes the form of a case study, the findings cannot be generalized to the population. As such, where we find statistically significant outcomes, it is possible to generalize the findings only to the current cohort of students being surveyed and those likely to enter the BAAF and BABS frameworks at this university in future.

2.3 Data

Presented in Table 1 is a summary of the data collected through the primary research study. In total there were 389 students enrolled in the two frameworks. There is a higher demand for the BABS framework overall as it houses more students than the BAAF framework with 65% of all students opting to enrol in the BABS course. There are more males than females in each of the frameworks. In fact, the BAAF framework has 2 males for every female enrolled whilst the ratio is lower in BABS. Out of the total students enrolled in BABS and BAAF courses, 58.61% are males whilst 41.39% are females. A Chi-square test for association confirms that there is a statistically significant association between gender and selection of frameworks at a p-value of 0.05 suggesting that more males significantly prefer both frameworks in relation to females.

Table 1: Summary of student enrolments during the 2013/14 intake.

	Sample Size	% Sample	Males	Females	% Males	% Females
BAAF	138	35	92	46	66.67	33.33
BABS	251	65	136	115	54.18	45.82
Total	389	100	228	161	58.61	41.39

3 Statistical Analysis and Discussion

The statistical analysis of this paper has been carried out using the R software. In what follows, in each analysis we consider the minimum, maximum, mean, median (med.), interquartile range (IQR), standard deviation (SD) and skewness of marks scored. In line with best practice, we also test the data for normality. Given that we encounter both small and large sample sizes, where the sample size is less than 50 we rely on the Shapiro-Wilk test for normality and where the sample size exceeds 50 we have considered the Kolmogorov-Smirnov test for normality. However, in large samples the tests for normality are known to be over sensitive. As such, we also consider histograms, mean and median values when assessing the distribution of the data in order to provide a more reliable analysis.

Table 2 presents some descriptives for analyzing and comparing the marks scored by the students in their MCQ test and written examination. Figure 1 presents the distribution of marks based on framework and gender. In fact, looking at the mean and median for the whole sample given in Table 2, these values are close and do not indicate high skewness and parametric tests are known to be robust to small departures from normality where sample sizes are large.

3.1 Analysis of MCQ marks

Our initial analysis revolves around the descriptives alone. We begin by considering the distribution of the MCQ marks. Based on our analysis, we conclude that MCQ marks scored by males, females and both genders (all) in the BAAF and BABS frameworks, and overall (i.e. all male students, all female students and all students) are normally distributed. Accordingly the analysis of marks are mainly centered around the mean. The normal distribution of marks itself suggests that most of the students have scored an average mark of around 50%. Initially, we consider the overall situation relating to the MCQ results. The minimum and maximum data for overall shows that there has been at least one student who has scored 0 in this examination, and also that there has been at least one student who has scored full marks. The overall average mark scored by all students reads 48.84% with a standard deviation of +/- 20.49% which suggests that most students have found the MCQ test difficult. Based on the mean we can conclude that on average male students have scored higher than female students at the MCQ and there have been both male and female students who scored 0 in this exam. Furthermore, we can see that the highest mark obtained by a male student in the MCQ test is 93.33% whilst the student(s) who scored full marks happens to be a female. Next, we consider the performance of the BAAF and BABS students in the MCQ test. The minimum and maximum marks scored by the BAAF students are consistent with those reported for the overall scenario for males, females and all. In terms of the BABS framework, whilst the minimum marks are consistent with those reported for the overall scenario, the maximum marks differ. Here, no student has succeeded in scoring full marks in the MCQ test with the highest mark attained being 86.67% between both males and females. These results indicate that the student(s) who scored full marks in this examination are from the BAAF framework. The average marks scored by BAAF males and female students are 59.53% and 57.84% respectively. In contrast, the average marks scored by the BABS males and females are considerably lower at 43.56% and 42.94%. In the BAAF framework, the average marks scored by all students in the MCQ test is higher than the average marks scored by all BABS students by approximately 15% and both report standard deviations which are very close to each other. Once again, based on the mean alone it would appear that the BAAF students have performed better than the BABS students in the MCQ test.

Table 2: Descriptive for marks scored on MCQ's/(**Written Examination**).

	Min	Max	Mean	Med.	IQR	SD	Skew.	Normality (p)
BAAF								
Males	0.00	93.33	59.53	60.00	26.66	20.06	-0.53	<0.01†
	(6.67)	**(80.00)**	**(42.68)**	**(40.00)**	**(33.33)**	**(18.31)**	**(-0.03)**	**(<0.01)**†
Females	0.00	100.00	57.84	60.00	21.56	18.92	-0.44	0.42*
	(6.67)	**(73.33)**	**(42.03)**	**(46.67)**	**(33.33)**	**(19.52)**	**(-0.32)**	**(0.03)**
All	0.00	100.00	58.97	60.00	26.66	19.63	-0.50	<0.01†
	(6.67)	**(80.00)**	**(42.46)**	**(43.34)**	**(33.33)**	**(18.65)**	**(-0.14)**	**(<0.01)**†
BABS								
Males	0.00	86.67	43.56	46.67	23.62	19.96	-0.53	<0.01†
	(0.00)	**(86.67)**	**(30.34)**	**(26.67)**	**(26.67)**	**(19.76)**	**(0.50)**	**(<0.01)**
Females	0.00	86.67	42.94	42.22	20.00	17.36	-0.25	0.10*
	(0.00)	**(73.33)**	**(27.19)**	**(26.67)**	**(26.67)**	**(17.93)**	**(0.67)**	**(<0.01)**
All	0.00	86.67	43.28	46.67	22.23	18.78	-0.42	<0.01†
	(0.00)	**(86.67)**	**(28.90)**	**(26.67)**	**(26.67)**	**(18.97)**	**(0.59)**	**(<0.01)**
Overall								
Males	0.00	93.33	50.01	53.33	26.67	21.44	-0.41	<0.01†
	(0.00)	**(86.67)**	**(35.32)**	**(33.33)**	**(26.67)**	**(20.08)**	**(0.23)**	**(<0.01)**
Females	0.00	100.00	47.20	46.67	26.67	19.00	-0.15	0.09*
	(0.00)	**(73.33)**	**(31.43)**	**(26.67)**	**(26.67)**	**(19.53)**	**(0.38)**	**(<0.01)**
All	0.00	100.00	48.84	48.89	25.83	20.49	-0.30	<0.01†
	(0.00)	**(86.67)**	**(33.71)**	**(33.33)**	**(26.67)**	**(19.92)**	**(0.30)**	**(<0.01)**

Note:* indicates data is normally distributed based on a Shapiro-Wilk or Kolmogorov-Smirnov test at p=0.05.
† indicates that where the Shapiro-Wilk test and Kolmogorov-Smirnov tests fail to identify a normal distribution, based on the histogram, mean, median and skewness statistic we consider the data to be normally distributed.

Finally, an evaluation of the BABS students' performance shows that on average they have obtained 46.67% in the MCQ examination which is not only worse than the BAAF average, but also below the overall average mark obtained. Furthermore, none of the BABS students scored full marks in this examination. As seen in the BAAF framework, a first look at the descriptives suggests the males in the BABS framework have on average obtained higher marks than their female counterparts.

However, as it is not possible to provide statistically significant conclusions based on descriptives alone, we consider testing the data as reported in Table 3. In terms of the overall comparison, a Welch two-sample t-test fails to find any evidence of a statistically significant difference between the average MCQ marks obtained by males and females at the 5% level, and thus we conclude that the difference in the average mark between gender overall is a chance occurrence. When we test the performance based on gender between frameworks we have the following results to report. Firstly, we find statistically significant evidence to suggest that there is indeed a difference between the average MCQ marks scored by all BABS and BAAF students based on a two-sample Welch t-test, whereby we can conclude that on average BAAF students are more likely to outperform the BABS students in the MCQ test. Secondly, we perform an ANOVA test followed by the Tukey HSD post-hoc test[3] which reveals the following. There are statistically significant differences between the MCQ marks scored by BAAF males and BABS

[3]Whilst there are many different pairwise comparison post-hoc tests, we consider the Tukey HSD in this research as the assumption of homogeneity of variances has been met and Tukey HDS continues to be cited as a popular option, see for example *inter-alia* Tantanatewin and Inkarojrit (2016), Levin et al. (2016) and Pilegard and Mayer (2016).

males, BAAF females and BABS females, BAAF males and BABS females, and finally, BAAF females and BABS males. As such we can conclude with 95% confidence that at the MCQ test, on average, BAAF males perform better than BABS males, BAAF females perform better than BABS females, BAAF males perform better than BABS females and BAAF females perform better than BABS males. Thus in terms of the two frameworks the MCQ results suggest those entering the BAAF framework have a comparatively better statistical and mathematical foundation in relation to those entering the BABS framework. In terms of the performance within frameworks, the ANOVA test fails to find any evidence of statistically significant differences between gender in either of the frameworks suggesting that within each framework all students appear to have a similar foundation relating to statistics and mathematics regardless of the gender.

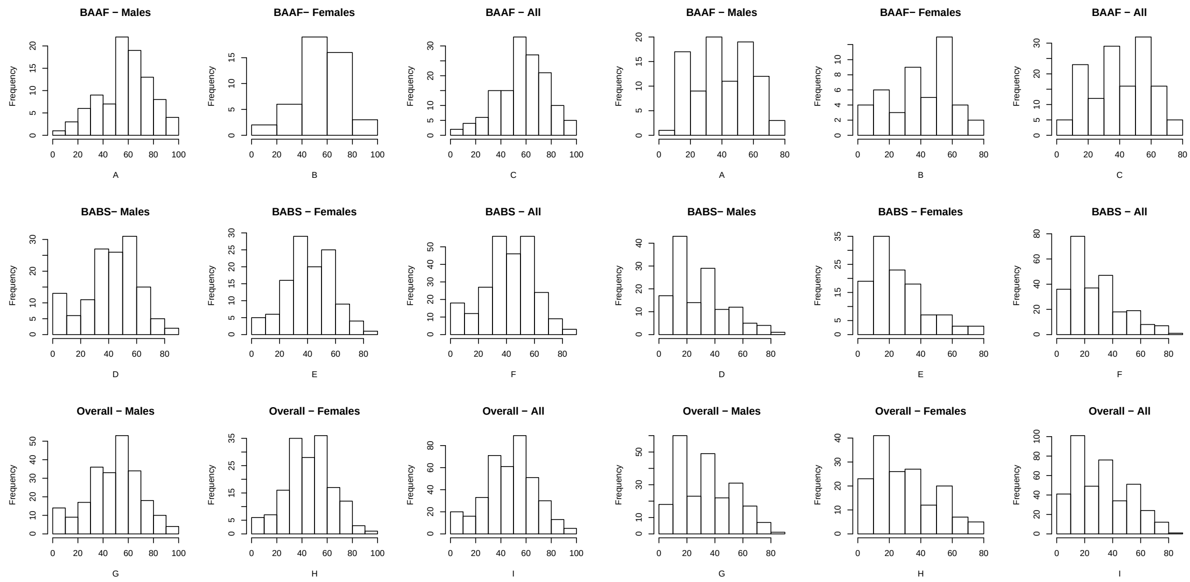

Figure 1: Distribution of MCQ marks (left set) and distribution of written exam marks (right set).

A closer analysis of the data also showed that there has been at least one student in each framework who has failed to understand that a MCQ with four options carries a 25% probability of attaining the correct answer if he/she opts for a random choice as there were students who had not provided answers to certain MCQs. This further suggests a lack of basic statistical knowledge relating to basic probability which students entering university are expected to have. It is however not pertinent to rely on MCQ test scores alone to determine which framework has students with the better mathematical and statistical foundation. This is because performance at the MCQ can be solely related to randomly picking the right answer out of four choices. As such we also take a look at the written exam marks in the next section and provide more comprehensive conclusions coupling these outcomes together.

Table 3: Tests for comparing the differences between and within frameworks in terms of MCQ and written examination marks.

Null Hypothesis	Test statistic	p-value	Test
Comparison within Frameworks			
BAAF			
True difference in mean MCQ marks between males and females is 0	1.686	0.96	Tukey HSD
True difference in mean written exam marks between males and females is 0	0.65	0.99	Tukey HSD
BABS			
True difference in mean MCQ marks between males and females is 0	0.624	0.99	Tukey HSD
True difference in mean written exam marks between males and females is 0	3.15	0.99	Tukey HSD
Overall Comparison			
True difference in mean MCQ marks between males and females is 0	1.3607	0.09	Welch Two Sample t-test
True location shift in written exam marks between males and females is 0	20341	0.06	Two Sample Wilcoxon test
Comparison between Frameworks			
True difference in mean MCQ marks between BAAF and BABS is 0	7.6583	<0.01*	Welch Two Sample t-test
True difference in mean MCQ marks between BAAF males and BABS males is 0	15.97	<0.01*	Tukey HSD
True difference in mean MCQ marks between BAAF females and BABS females is 0	14.91	<0.01*	Tukey HSD
True difference in mean MCQ marks between BAAF males and BABS females is 0	16.59	<0.01*	Tukey HSD
True difference in mean MCQ marks between BAAF females and BABS males is 0	14.28	<0.01*	Tukey HSD
True difference in mean written exam marks between BAAF and BABS is 0	6.8224	<0.01*	Welch Two Sample t-test†
True difference in mean written exam marks between BAAF males and BABS males is 0	12.34	<0.01*	Tukey HSD
True difference in mean written exam marks between BAAF females and BABS females is 0	14.84	<0.01*	Tukey HSD
True difference in mean written exam marks between BAAF males and BABS females is 0	15.49	<0.01*	Tukey HSD
True difference in mean written exam marks between BAAF females and BABS males is 0	11.69	<0.01*	Tukey HSD

Note:* indicates a statistically significant difference between the compared means at a p-value of 0.05. The Levene's test for equal variances reported a significance value beyond 0.05 which in turn confirms the applicability of the Tukey HSD Post-Hoc test. Where Tukey HSD has been used the test statistic shows the mean difference. † indicates a similar conclusion was obtained when the median differences were tested using a two sample Wilcoxon test.

3.2 Analysis of Written Examination Marks

The analysis of the written examination marks begins with a discussion of the distribution of the marks scored. Based on our in-depth analysis which considers not only normality testing via SW and KS criterions, but also the mean, median and skewness statistics along with histograms, we can report that except for BAAF males and BAAF all distributions, the rest of the written exam marks are skewed. The minimum and maximum data for all participants shows that no student scored 0 in the written examination, and also that no student scored full marks. The overall median mark scored by all students was considerably low at 33.33% whilst the inter-quartile range (IQR) suggests that the middle 50% of the students have a difference in marks scored of approximately 26.67%. The IQR remains constant irrespective of the gender in the overall case stating that there is equal variation. Furthermore, we can see that the highest mark obtained by a male student in the written test is 86.67% whilst the highest mark attained by a female student was 73.33%. Based on median marks, it appears that overall, males have performed better than females in the written examination.

Next we consider the performance of the BAAF students in the written examination. Interestingly, in the written examination, the minimum mark scored is 6.67% and the highest mark attained was 80% which was scored by a male student(s). The highest mark obtained by a female student(s) in the written examination was 73.33%. Overall when considering both male and female students, the average score in the written examination is 42.46% with the males reporting a mean score of 42.68% and the females reporting a median score of 46.67%. Based on the median/mean marks scored it appears that females have performed better in the written examination in comparison to the males in BAAF framework. Moreover, based on the overall average and median marks scored it is clear that the BAAF framework has performed much better than the BABS framework in the written examination (as was the case with the MCQ).

Finally, an evaluation of the BABS students' performance shows that (both overall and by gender) they have obtained a median mark of 26.67% in the written examination which is not only worse than the BAAF median and mean, but also below the overall average mark obtained. The highest mark scored of 86.67% is by a male and exceeds the highest mark scored by in the BAAF framework. The highest mark attained by a female(s) was 73.33% and identical to the BAAF framework. Interestingly, in the BABS framework, based on median marks scored in the written examination, it appears there is no difference between gender. The constant IQR suggests there is equal variation in the middle 50% of the data between genders and overall in the BABS framework.

Once again, instead of relying on the descriptives alone, we consider formal statistical tests to determine significant differences in marks scored. Firstly, a two sample Wilcoxon test provides no evidence of statistically significant differences in overall marks scored by males and females in the written exam. A Welch two sample t-test shows that there exists a statistically significant difference between the mean marks scored by BABS and BAAF students which in turn confirm that BAAF students have performed significantly better than the BABS students. An ANOVA test was then carried out, and based on the post-hoc Tukey HSD test we are able to make further conclusions. When comparing written exam marks scored within frameworks, we find no evidence for statistically significant differences between males and females in both BAAF and BABS. This result which is consistent with the MCQ test result outcomes confirms that both frameworks have recruited students with similar statistical and mathematical foundations. When comparing between frameworks, we find evidence for the existence of statistically significant differences in the average written exam marks scored by BAAF males and BABS males, BAAF females and BABS females, BAAF males and BABS females, and BAAF females and BABS males which confirms that in each case BAAF students have indeed performed significantly better than the BABS students. However, it is noteworthy that the performance in the written examination (based on mean and median marks scored) makes it clear that majority of the students do not have sound statistical and mathematical skills as the average marks (and median marks) obtained are considerably low when compared with the MCQ test. It is clear that the comparatively high scores in the MCQ test were likely to be a result of students taking a chance and ticking the best looking answer out of the four available options.

The results indicating that BAAF males significantly outperform BABS females is interesting as previous studies have mostly indicated that male students fall behind female students not only in school but also in higher education (Conger and Long, 2010; Ewert, 2012). Whilst one might argue that BAAF students performing better than BABS is expected, it is not something that could be ignored when evidence increasingly suggests that employers demand highly numerate graduates (Hoyles et al. 2002). Finally, another interesting point to consider is whether given that we live in the age of technology, is it more appropriate to develop the need to interpret mathematical and statistical results than to carry out calculations and functions? We believe that it is important to understand the calculations underlying mathematical and statistical results in addition to being able to interpret same as otherwise it would hinder the development of mathematics and statistics itself to mere interpretations of existing techniques as opposed to innovative new methods which can cater to the ever changing global economic environment.

3.3 Analysis of Educational Qualification and its Influence on Mathematic Skills

During the 2013/14 intake, this university has recruited students from 11 different educational backgrounds. These are, General Certificate of Secondary Education (GCSE), A Level (A), A Level Applied Math (Stats. and/or Mechanics) (AAM), A Level Pure Mathematics (APM), Diploma (D), International Baccalaureate (IB), National Vocational Qualification (NVQ), A Level Economics (AE), A Level Other Subjects (AOS), Foundation (F), and A Level Further Mathematics (AFM). Table 4 presents information on the number of students with these qualifications enrolled in both BAAF and BABS frameworks. This enables the reader to obtain an understanding in relation to the nature of students who are interested in applying to this British university for BAAF and BABS courses at present. We see that majority of the BAAF students are from APM, AAM and GCSE backgrounds. In contrast, a great number of BABS students are from AOS and GCSE backgrounds. This could explain the comparatively inferior performance of the BABS cohort in relation to the BAAF cohort as most of the students have not pursued advanced level mathematics.

Table 4: Number of students and the corresponding educational qualifications.

Education	BAAF	BABS
A	8	33
AAM	25	9
AE	-	6
AOS	-	75
APM	31	17
D	-	23
GCSE	30	73
IB	2	8
NVQ	3	4
FM	-	1
F	-	1

Next we perform an ANOVA test to ascertain whether there is a significant difference in the marks scored by students based on their educational qualifications. The ANOVA test confirmed that there exists a significant difference in the average marks scored between at-least one combination of educational qualifications which prompted us to perform a Tukey HSD post-hoc test. The statistically significant outcomes are reported in Table 5. Let us first consider the

MCQ related results. Here, for the BAAF framework we find statistically significant evidence of differences in the statistical and mathematical knowledge of students from AAM and GCSE, AAM and NVQ, and APM and GCSE. For the BABS framework in terms of the MCQ marks we find similar evidence between A and AOS, A and D, A and GCSE, AOS and APM, and APM and D. However, as mentioned earlier the performance at the MCQ could greatly relate to lucky guesses and as such the most important result would be those relating to the written exam where the students could only score if they actually knew the working to the related question.

Table 5: ANOVA test result for marks scored based on educational qualifications.

Significant Outcomes	MCQ (p-value)	Written Exam (p-value)
BAAF		
AAM and GCSE	0.001*	0.001*
AAM and NVQ	0.098**	0.823
APM and GCSE	0.001*	0.001*
A and AAM	0.475	0.004*
A and APM	0.507	0.001*
BABS		
A and AOS	0.017*	0.066**
A and D	0.019*	0.032*
A and GCSE	0.069**	0.614**
AAM and D	0.286	0.066**
AOS and APM	0.080**	0.001*
AOS and IB	0.980	0.032*
APM and D	0.049*	0.001*
APM and GCSE	0.190	0.003*
D and IB	0.871	0.011*

Note: * indicates statistically significant mean difference in marks scored based on Tukey HSD at $p = 0.05$.
** indicates statistically significant mean difference in marks scored based on Tukey HSD at $p = 0.10$.

Accordingly, in terms of the performance at the written exam, we find evidence for statistically significant differences in the statistical and mathematical knowledge of entrants based on educational qualifications as follows. In the BAAF framework, students from AAM and GCSE, APM and GCSE, A and AAM, and A and APM has reported significant differences in their statistical and mathematical knowledge. Likewise, in the BABS framework, we find evidence of significant differences in the mathematical and statistical knowledge of students from A and AOS, A and D, A and GCSE, AAM and D, AOS and APM, AOS and IB, APM and D, APM and GCSE, and D and IB backgrounds.

4 Conclusions

In this paper we have used a British university as a case study and focused on students enroled in BAAF and BABS frameworks at the Faculty of Management to understand, and analyse the mathematical and statistical knowledge of new students entering university. First and foremost, the data collected shows a trend that is consistent with the reports in Dalby et al. (2013) where they find that university entrants gain admission via several different routes. To be precise, at the university in question, students gain entry from more than 10 different educational backgrounds ranging from A-Levels to Diploma and NVQ. The differences in entry routes and their impact on higher education is worthy of discussion as in the case of this university, we find statistically significant differences between the marks scored by students depending on their educational qualifications. This in turn calls to question the need for such varied entry routes and whether universities should consider more strict entry criteria which in turn can ensure students are better equipped and able to tackle mathematics and statistics at university level. The data also shows a higher male to female ratio in the 2013/14 BABS and BAAF cohorts and a higher demand for the BABS course with 65% of the overall sample enrolling here.

The findings from this research can be used as evidence to portray the need for additional mathematical and statistical support for students at this particular university. For example, the Faculty of Management could easily consider the output from this study as evidence for submitting a likely successful application to the Sigma Mathematics and Statistics Support Network for funding to set up a dedicated Maths Support Centre within the university. The provision of such support could ensure that undergraduate students are given access to weekly statistical and mathematical support drop-in sessions, in addition to one-to-one sessions via appointments alongside the planned dissemination of unit specific resources to aid with their quantitative units at university. The potential to set up of a Maths Support Centre with the aid of the findings in this study could be recognized as a significant practical implication emanating from this research which will enable this particular British university to align itself with many other UK and international HEI (Perkin et al., 2012; Fitzmaurice et al. 2015).

In addition, this study has succeeded in providing answers to the following research questions. Firstly, are there any differences between the statistical and mathematical knowledge of students entering the BAAF and BABS framework during the 2013/14 intake? We find evidence of statistically significant differences between the the students entering each framework based on both the MCQ test and written exam. More precisely the BAAF students have a better statistical and mathematical foundation than the BABS students and this could be attributed to a majority of the BAAF cohort having undertaken advanced level mathematics whilst majority of the BABS students do not have such an educational background. This finding is of both value and relevance to this university for the following reason. Having recognized the importance of mathematics and statistics in the business world, this university has units which are heavily statistics based within both BAAF and BABS frameworks. The statistically significant difference between the two frameworks provides sufficient evidence to encourage and motivate the BABS students in particular to obtain additional mathematical and statistical support. Moreover, this also calls for the requirement to inform students applying for the BABS framework of the importance and necessity of statistics and mathematics within their university education. Secondly, are we able to differentiate between the statistical and mathematical knowledge of students based on gender? The answer to this question is three fold. If we are concerned with gender differences within each framework, then we do not find any statistically significant evidence of differences in the statistical and mathematical knowledge of these students based on gender. Likewise, if we consider the overall performance and differentiate it based on gender, we do not find sufficient evidence at the 5% level for statistically significant differences between marks scored whilst these are significant at the 10% level and shows that males are more likely to perform better than females in this cohort of students. However, if we consider differentiating student performance based on gender between frameworks, then we find evidence of statistically significant differences in the marks scored based on gender (at the 5% level) with BAAF males and females outperforming their counterparts. Finally, do educational qualifications have a varying impact on the statistical and mathematical knowledge of students entering this British university? The answer would be yes, as we do find evidence of significant differences in the statistical and mathematical knowledge of students depending on their level of education as reported in Section 3.3. Also, based on measures of central tendency, such as the mean and median for both the MCQ and written exams, it is possible to conclude that there is indeed a deficiency in the mathematical and statistical knowledge of students entering this particular university for the BAAF and BABS frameworks as these measures all fall below 60%.

Overall, this study has presented several implications for the Faculty of Management at this university. This research has made it clear that there is indeed a problem with the mathematical and statistical knowledge of students entering the university. The findings suggests the need for additional statistical and mathematical support to both frameworks, especially to those students from BABS (as the BAAF students performed better than BABS students). Failure to provide such support could lead to the students experiencing difficulties with units involving a significant statistical or mathematical component. The gender differences suggest that males in this cohort are comparatively better than the females in terms of their statistical and mathematical capabilities. Accordingly, these results show that it might be pertinent to encourage male and female students to mix in study groups such that the females could benefit with more appropriate knowledge sharing which can help reduce the gender gap which is visible at present. The big spread in mathematical backgrounds as evidenced in Section 3.3 once again calls for extra unit specific support to these students. In addition, these results also indicate that it is worthwhile for this university to invest in research on evaluating and enhancing their students statistical and mathematical knowledge by keeping track of student performance, developing new approaches for teaching, and encouraging student engagement in statistical and mathematical units. For example, such efforts could take the form of encouraging students to engage with their lecturers via pages dedicated to their respective units on social media sites such as Facebook which are widely used by students. This is important, especially as evidence suggests that traditional methods are usually embraced by lecturers when it comes to teaching mathematics in higher education (Abdulwahed, 2012) and it is important that lecturers too evolve with time and technology.

Furthermore, in future new students who fail to score above a certain percentage at a similar diagnostic test should be advised to, and provided with an opportunity to obtain additional Maths support (either via the setting up of a specialised centre for this purpose, or via re-allocation of current staff resources). Finally, it is pertinent to discuss the limitations of this study and avenues for future research. As a case study this research is not without its limitations. Firstly, the findings cannot be generalized to the population of UK universities and can therefore only be related to this particular university as it stands. Secondly, the study is cross sectional and does not follow the cohort of students over time. As such, it can only provide a snapshot limited to the time at which the primary data was collected. Thirdly, even within this particular university, the study only focussed on two of the prominent frameworks within the Faculty of Management. It is possible that other faculties might not experience the exact same issues in this case. In terms of future research, a similar study which is longitudinal can be greatly beneficial as it allows for the findings to be generalized easily and have more impact. In addition, future research should consider expanding beyond the Faculty of Management and include all faculties whilst capturing as many frameworks as possible, so as to determine whether the issues discussed in this study are only relevant to the Faculty of Management, or whether these are prevalent university wide. Moreover, following on from the findings of this research, future studies should consider in depth about whether or not mathematics syllabuses should be focussed on preparing students for University entrance, and if they were to be focussed, then how exactly we should distinguish between the different needs of different subject disciplines, and finally how we could develop numeracy skills for employment and the jobs market.

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Appendix

1. Simplify $\frac{1}{3} - 1$
2. What is the answer to the expression $\frac{(2)(-1)-(1)(4)}{(-1)^2}$?
3. Simplify $2x + 2h + 1 - (2x + 1)$
4. Which is smaller? 5% of 30 or 7% of 20?
5. Simplify $e^{t^2} * e^t$
6. Simplify $\ln(\frac{1}{2}e^{-4x})$
7. Simplify the rational expression $\frac{2\pi rh+h^2}{h}$
8. If $y = x^2 + x^3 + 1$, calculate $\frac{dy}{dx}$
9. Solve the equation $y - 3 = y^2 - y - 6$
10. In the equation: $(bx) + a = 0$, a and b are positive constants. The solution for x would be:
11. A company with 100 employees has a total labour cost of £50,000. What is the average labour cost?
12. You are told that products X and Y have a perfect positive correlation. Write down the value of the correlation coefficient (r) in this case.
13. Company X employs three people who are paid £100, £200, and £300 per month. What is the monthly average wage and standard deviation respectively?
14. Suppose the variance between the heights of 10 individuals is x. Write an expression to show the standard deviation.
15. The marks obtained by 100 students at a 2 hour maths exam had a mean of 16, median of 17 and a mode of 18. What would be the distribution of these marks?

Figure 2: Text from the written exam questions.

1. $\frac{1}{3} - 1$ can be simplified as:

   (a) $-\frac{2}{3}$ (b) $-\frac{3}{2}$ (c) $\frac{2}{3}$ (d) $-\frac{1}{3}$

2. The answer to the expression $\frac{(2)(-1)-(1)(4)}{(-1)^2}$ is:

   (a) 4 (b) 3 (c) -6 (d) -3

3. $2x + 2h + 1 - (2x + 1)$ can be simplified into:

   (a) $4x$ (b) $2h$ (c) $2x$ (d) $4h$

4. Which is smaller?

   (a) 5% of 30 (b) 7% of 20

5. $e^{t^2} * e^t$ is equal to

   (a) e^{t^2} (b) e^t (c) e^{t^3} (d)$-e^{t^3}$

6. The most simplified version of $\ln\left(\frac{1}{2}e^{-4x}\right)$ is:

   (a) $\frac{1}{2}\ln\left(\frac{1}{2}e^{-4x}\right)$ (b) $\frac{1}{2}ln$ (c) $\frac{1}{2}ln + \ln\left(e^{-4x}\right)$ (d) $\ln\left(e^{-4x}\right)$

7. The rational expression $\frac{2\pi rh+h^2}{h}$ can be simplified into:

   (a) h (b) 2πr+h (c) 2πr+1 (d) $h(2\pi r + 1^2)$

8. If $y = x^2 + x^3 + 1$ then $\frac{dy}{dx}$ would be:

   (a) $2x^2$ (b) $2x + 3x^2$ (c) $3x + 2x^2$ (d) $2x + 2x^3$

9. Solve the equation $y - 3 = y^2 - y - 6$

   (a) $y = -1{,}3$ (b) $y = 3{,}2$ (c) $y = 1{,}3$ (d) $y = -2{,}3$

10. In the equation: $n(bx) + a = 0$, a and b are positive constants. The solution for x would be:

    (a) $\frac{1}{be^a}$ (b) $\frac{a}{be}$ (c) $\frac{ba}{e}$ (d)$-\frac{b}{e^a}$

11. A company with 100 employees has a total labour cost of £50,000. What is the average labour cost?

    (a) £50,000 (b) £10,000 (c) £500 (c) £5,000

12. You are told that products X and Y have a perfect positive correlation. This implies that the value of correlation coefficient (r) is:

    (a) 1.00 (b) 0.001 (c) 100 (d) 0

13. Company X employs three people who are paid £100, £200, and £300 per month. Which answer represents the monthly average wage and standard deviation respectively?

    (a) £100, £100 (b) £200, £100 (c) £300, £200 (d) £200, £200

14. Suppose the variance between the heights of 10 individuals is x. The standard deviation would then be equal to:

    (a) x^2 (b) $\sqrt{x}$

    (c) $(\sqrt{x})^2$ (d) x^{10}

15. The marks obtained by 100 students at a 2 hour maths exam had a mean of 16, median of 17 and a mode of 18. What would be the distribution of these marks?

    (a) Normal distribution (b) Right skewed distribution

    (c) Left skewed distribution (d) Uniform distribution

Figure 3: Multiple choice questions.