Cambridge Assessment
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Test of Mathematics for University Admission Trial

Durham University 2015

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Research

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Contents

Executive Summary

This report summarises the findings of a trial into the Test of Mathematics for University Admission (TMUA) undertaken in October 2015. The trial took place during the development stages of this new admissions test, which is aimed at prospective undergraduate mathematics students. Participants were new first year undergraduates at Durham University, who took the TMUA under test conditions in the first week of study at Durham.

Overall, participants scored fairly well, as might be expected thanks to Durham's standard A-level requirement to study mathematics being an A* in A-level Mathematics. The TMUA was found to have good internal consistency. Good performance on the TMUA was associated with a participant achieving an A* in A-level Further Mathematics, and the TMUA had good predictive validity – participants who scored well on the TMUA trial went on to perform better in their first year university examinations than those who did not perform as well.

Some gender differences were identified, with women scoring lower than men in Paper 2 and, thus, overall. This finding was expected, as gender differences in mathematics have been found to exist towards the top end of performance in post-compulsory mathematics study. The differences only had a medium effect size, and the sample size was not sufficiently large to facilitate further statistical analysis to explore bias. No significant difference was found in the performance of participants who went to state schools and those who went to independent schools.

The outcomes of this trial suggest that the TMUA has the potential to be a useful tool for universities wishing to make their admissions process more reliable. In addition, the TMUA allows students to experience a mathematics assessment which can challenge them in a different way to A-level Mathematics or Further Mathematics.

1. Introduction

1.1 The undergraduate mathematics admissions landscape in England

In England, the usual admissions process for applicants wishing to study undergraduate mathematics involves them submitting a general application form via the Universities and Colleges Admissions Service (UCAS). This application form becomes common to all institutions that they apply to (out of a maximum of five), and contains information on their academic background, along with a personal statement and supporting academic reference.

Admissions tutors then select the best applicants using UCAS form information, along with an applicant's performance in any admissions tests or interviews, if their institution has sufficient resources. Students are typically made a conditional offer of a place, based on a requirement that they achieve certain grades at A-level, and perhaps in additional tests.

Most universities will require applicants taking A-levels to achieve a high grade in Mathematics, and a growing number require or strongly encourage participants to take A-level Further Mathematics. However, concerns regarding students having access to Further Mathematics due to mathematics teacher shortages and school budgets mean that some universities do not make this compulsory in order to widen participation.

Prior to 2017, many universities relied heavily upon applicants' AS-level UMS scores in conjunction with their GCSE performance and references when making decisions. Many found that AS UMS were a good predictor of whether an applicant had the potential to succeed, particularly when most applicants had achieved an A* in GCSE Mathematics. However, recent reforms to general qualifications mean that students' AS-level marks do not contribute towards their overall A-level result, and so few schools now have their students take AS-levels in addition to A-levels. This leaves mathematics admissions tutors with little information to base their decisions on, at a time when the number of applicants to mathematics degree courses is increasing.

1.2 Admissions tests

1.2.1 STEP, AEA and MAT

In addition to traditional secondary qualification results, a growing number of universities either require or encourage applicants to have taken an admissions test or an 'extension' paper, which can act as a means of demonstrating mathematical ability beyond that assessed in an A-level. Until 2017, the three most common were:

1. **STEP**: This is primarily used by the University of Cambridge as a compulsory part of its admissions criteria. There are three STEP papers: STEP 1 assesses knowledge from A-level Mathematics; STEP 2 assesses knowledge from A-level Mathematics and AS-level Further Mathematics; and STEP 3 assesses knowledge from A-level Mathematics and A-level Further Mathematics. STEP is taken in the summer of the final year of school alongside A-levels. Some other universities include STEP as part of their offer, usually requiring students to achieve certain STEP grades in order to be given a lower A-level offer. In 2017, there were 2,082 STEP 1 candidates, 1,427

STEP 2 candidates and 877 STEP 3 candidates[1]. This includes many candidates from China, who take it as a means of stretching themselves.

2. **AEA**: The Advanced Extension Award was originally introduced as a means of stretching students performing at the top end of A-level achievement. However, the introduction of the A* grade in 2010 meant that the AEA no longer serves its original purpose and instead is something students can do if they wish to challenge themselves. The AEA is based on A-level Maths content and is taken in the summer of the final year of school, alongside A-levels. AEA was taken by 401 candidates in 2018 (Joint Council for Qualifications, 2018).
3. **MAT**: This is primarily used by the University of Oxford and Imperial College London as a means of shortlisting applicants for interview. The MAT is taken in November of the final year of school and is based on A-level Mathematics knowledge.

Each of these tests have been found to assess a variety of different skills, which is unsurprising given they each have a different 'remit' and target candidate. STEP questions have been found to be most aligned with the skills required at undergraduate level, with the AEA having a strong focus on more intricate versions of routine procedures, and the MAT mainly focusing on atypical or problem solving type questions (Darlington, 2015).

A study by Darlington and Bowyer (2018) surveyed undergraduate maths students regarding their perceptions and experiences of AEA, MAT and STEP. They found that admissions tests are not just useful for universities in helping them to select students with the most potential to succeed in tertiary maths, but that they are also beneficial for students. Studying for and taking the tests provides students with an opportunity to be challenged mathematically, something which they may not necessarily experience through A-level study and assessment. Over 80% of participants who had taken STEP believed it had been useful preparation for their degree. This belief was held by around half of undergraduates who had taken MAT, whereas most who had taken the AEA described it indifferently.

1.2.2 TMUA

2016 saw the first live Test of Mathematics for University Admission (TMUA) take place. The TMUA was developed by Cambridge Assessment Admissions Testing in response to some high-level universities who felt they required an additional factor to base selection decisions on, but that was more accessible for students than STEP.

The TMUA consists of two 75-minute papers[2] of 20 multiple choice questions, which have different focuses:

- Paper 1: Applications of familiar knowledge and procedures in unfamiliar situations.
- Paper 2: Applying conceptual knowledge to construct mathematical arguments

This distinction was developed on the basis of some work by Smith et al. (1996), who postulated a Mathematical Assessment Task Hierarchy of three different groups of skills which could be assessed in advanced mathematics.

[1] For context, there were 1456 applicants for Mathematics at Cambridge that year. Cambridge also requires STEP for students wishing to study Engineering at some colleges.

[2] For this trial, each paper was allocated 60 minutes. However, on the basis of trial results and further development, each paper is now allocated 75 minutes (see Section 4).

The TMUA is based on AS-level Mathematics knowledge, with some additional logic questions. As this is not on the A-level syllabus, Cambridge Assessment Admissions Testing provides free resources on mathematical logic for candidates regarding this part of the specification to aid preparation. Each paper also contains a few introductory questions assessing more routine procedures. There are no penalties for incorrect answers, and candidates are encouraged to answer all questions.

Students take the test in the November of the final year of school studies. The test aims to encourage and widen participation, hence:

- The test fee is lower than other admissions tests. In cases where a student might not be able to afford it they are able to apply for a refund through providing evidence of hardship, such as if they are eligible for free school meals.
- The test is risk-free, in the sense that a student only 'releases' their result to a university after the student has seen their result. If they did not perform as well as they had wanted to, they can choose not to release the result, and the university will never know that the student had even taken the TMUA.

1.3 Contextual variables

1.3.1 Gender

Post-compulsory mathematics participation is male-dominated. In 2018, 39.3% of A-level Mathematics and 28.4% of A-level Further Mathematics candidates were girls. In the 2017/18 academic year, 35.8% of full time students of single honours mathematics in the UK were women (HESA, 2018b). However, trends in female participation in post-compulsory mathematics study, from A-levels (Joint Council for Qualifications, 2018) to undergraduate and postgraduate level (McWhinnie & Fox, 2013) have been found to be gradually increasing over time.

In terms of average results, girls outperform boys in mathematics; however, boys outperform girls at the top end. A greater proportion of boys achieve the top grade (A*) in GCSE and A-level Mathematics and Further Mathematics than girls. As these are the gateway qualifications to undergraduate mathematics study, it would not therefore be a surprise if the average female undergraduate mathematics applicant was slightly less qualified than the average male applicant.

Table 1 shows admissions statistics for Oxford and Cambridge, showing that women make up a smaller proportion of applicants and also convert their applications into offers at a lower rate than men. The proportion of women converting their offers into acceptances at Cambridge is much lower than Oxford. This may be because an acceptance is dependent upon performance in a STEP for Cambridge, whereas final offers for Oxford applicants who have passed an interview only rely on A-level grades.

Table 1: Applications, offers and acceptances to the Universities of Cambridge and Oxford by gender

	Applications	**Offers**[3]	**Acceptances**
Cambridge – 2017 admissions			
Male	74.6	72.7	83.7
Female	25.4	27.3	16.3
Oxford – admissions 2015-17			
Male	68.9	72.7	73.4
Female	31.1	27.3	26.6

Sources: University of Cambridge (2018) and University of Oxford (2018)

Men have been found to outperform women in mathematical science degrees (Barrow, Reilly, & Woodfield, 2009; McNabb, Pal, & Sloane, 2002). Reflecting what happens in high-stakes secondary mathematics assessment, there is also a greater spread of performance for men than women, with greater proportions of men achieving first class degrees and thirds than women (McNabb et al., 2002). Mellanby, Zimdars, and Cortina-Borja (2013) looked at differences in degree performance at the University of Oxford, and found that lower levels of self-esteem and poorer academic self-concept were associated with lower undergraduate examination performance, traits which are more common in women (see also Alcock, Attridge, Kenny, & Inglis, 2014; Pajares, 2005).

1.3.2 School type

It has been suggested that students from independent schools are given an unfair advantage over their state educated peers when it comes to admissions tests. Admissions tests tend to be used by higher ranking universities, such as those in the Russell Group, and privately-educated students have been found to be more than 22 times more likely to go to a high-ranking university than state students from deprived backgrounds (Sutton Trust, 2010).

Students from independent schools perform better than those from state schools on high stakes examinations. Independent schools have been found to produce greater 'value added' for students in terms of students' examination performance at most stages of education. For example, Ndaji, Little, and Coe (2016) found that the difference between independent and state educated students in their best eight GCSEs when prior ability, deprivation, school type and gender were taken into account averaged 0.64 grades. The difference was even greater for GCSE Maths. In 2018, 47.7% of students attending independent schools achieved an A* or A grade in their A-levels, compared to 26.4% of students nationally (Independent Schools Council, 2018b). However, the gap in A-level performance between state and privately educated students has been decreasing over recent years (Turner, 2017).

[3] It should be noted that the 'offers' proportions for both Cambridge and Oxford are the same here, and that this is not an error.

However, once at university, it has been found that privately-educated students lose their advantage over their state-educated peers. Numerous studies have found that privately-educated students in the UK perform less well than state-educated students in the final year of university study despite entering with higher school grades (Higher Education Funding Council for England, 2005, 2014; Hoare & Johnston, 2011; Naylor & Smith, 2004; Smith & Naylor, 2005, 2011; Thiele, Singleton, Pope, & Stanistreet, 2016). This includes at universities such as Cambridge (Parks, 2011), which have high proportions of privately-educated students compared to British universities as a whole. For example, whilst privately-educated students only account for 18% of students over age 16 (Independent Schools Council, 2018a), for 2017 admissions 24.4% of applications and 30.0% of acceptances to Cambridge were privately-educated students (University of Cambridge, 2018).

Hoare and Johnston (2011) suggest that privately-educated students are more successful at entering higher education because "independent schools are much more focused on preparing students for university entrance; their students thus obtain better A-level grades on average and so, if admissions are largely based on that criterion, they gain entry against poorer-qualified competitors" (p. 27).

According to Ogg, Zimdars, and Heath (2009), teaching effects at private schools inflate the qualifications obtained by their students. Moreover, the Higher Education Funding Council for England (2003) estimated that, excluding students attending the highest-ranking universities, a privately-educated student would achieve as well in their final degree as a state-educated students who had between one and four fewer A-level points. Looking at Scottish students, Lasselle, McDougall-Bagnall, and Smith (2014) even go as far as to say that

> *Private schooling provides an […] adverse signal of a student's degree potential beyond that provided by [an] indicator of school academic performance*
>
> (p. 308)

The reasons why state-educated students overtake privately-educated students by the end of their degree are unclear and likely complex. Generally, a level playing field is established once all students are at university. They have the same opportunities in terms of teaching, support and resources, regardless of their educational background. The Higher Education Funding Council for England (2003) has suggested that privately-educated students might underperform at university because they are more likely to take part in social activities. Budd (2017) reports that it is possible that privately-educated students "may not (feel they need to) pay as much attention to their studies as their state-educated peers, and this relates to issues that connect with employability" (p. 114).

1.4 Aims

A trial was planned with Durham University in order to ascertain how valid the TMUA would be as a university admissions test.

The trial aimed to investigate three things:

1. **Predictive validity**: To determine whether the TMUA is a good predictor of future performance. Good predictive validity occurs when good performance in a test correlates with good performance in other tests later on. If a student who performs well in the TMUA goes on to perform well at university, it would suggest that the TMUA is a good tool for admissions selection. To find this out, participants' results from the TMUA trial would be compared with their first year undergraduate examination results at the end of the academic year.
2. **Concurrent validity**: To see whether the scores on the TMUA are associated with students' performance in A-levels. Good concurrent validity occurs when test takers who score well on one test also score well on another test which aims to test the same knowledge and constructs. If a student who performs well on the TMUA also performed well on A-level Further Mathematics, it would suggest that the TMUA might be particularly beneficial additional information for admissions tutors for applicants who were (for whatever reason) unable to take A-level Further Mathematics. To find this out, participants' TMUA results would be compared with whether or not they achieved an A* in A-level Further Mathematics.
3. **Group differences**: To see whether there were any significant differences in performance between participants with certain characteristics which are of interest to stakeholders. In this case, the test takers' gender and school type. To find this out, participants' TMUA results were compared between different groups to see whether there were any significant differences.

2. Method

The trial was conducted in October 2015 at the University of Durham, invigilated as per normal high stakes testing environments. For the participants, the test itself was actually low-stakes as their result would not have an impact on summative assessment results in their degree, though they were encouraged to do their best as the results would be used by the University to target students who might benefit from extra support.

A student declaration contained a consent form, and outlined the nature of the test, and how their results and responses would be used for test development and validation by Cambridge Assessment Admissions Testing. Students were informed that supporting data on their background characteristics and performance would be linked to their TMUA results for the purposes of research. For example, A-level Further Mathematics grade, school type, and the results that they go on to achieve in their end of year examinations as part of their degree.

Participants' results were finalised within two weeks of the test, and were released to the University in cases where the participant had given their consent. The test materials have subsequently been made available on the Cambridge Assessment Admissions Testing website as part of the suite of test preparation resources available to prospective candidates.

3. Results

Caution should be applied when interpreting the results from this trial. It should be noted that the participants are likely very high ability, and had experienced an additional year of A-level Mathematics study compared to target candidates for the TMUA. The high ability nature of the sample means that the variance in scores achieved in the TMUA will likely be restricted to the top end compared to the target cohort for the TMUA.

3.1 Sample

The TMUA was taken by 152 students in total. The sample was reflective of the undergraduate mathematics cohort in England (HESA, 2018a), comprising 38.2% female and 59.2% male participants. The majority of participants (76.3%) had attended a state school (see Table 2).

Table 2: School types attended by participants

School type	Frequency	Per cent
Academy	54	35.5
Comprehensive school	27	17.8
Independent school	21	13.8
Sixth form college	20	13.2
Tertiary college	9	5.9
Grammar school	6	3.9
Language school	1	0.7
Unknown	6	3.9
Other	8	5.3
Total	146	100.0

In this cohort, 97.4% of participants had taken A-level Further Mathematics. Of those, 63.8% had achieved an A*. The remainder achieved an A.

3.2 TMUA results

Participants averaged a score of 12.03 in Paper 1, ranging between 5 and 20, out of a maximum possible 20 (see Figure 1). Participants did rather better in Paper 2, averaging 2 marks higher, with performance more skewed towards the top end (see Figure 2). Overall, the lowest score on the TMUA was 8, with the second lowest scoring participant achieving 16 out of a maximum 40 (see Figure 3).

Summary statistics for the results for each paper, along with the total for the whole TMUA are given in Table 3. For assessments of this kind, it is recommended that Cronbach's alpha be 0.7 or greater, which was achieved by the trial TMUA.

Table 3: Summary statistics of participants' results in the TMUA

	Paper 1	Paper 2	TMUA
Mean	12.03	14.11	26.14
Median	12.00	15.00	27.00
Mode	13	15	27
Minimum	5	3	8
Maximum	20	19	37
Cronbach's alpha	0.60	0.53	0.71

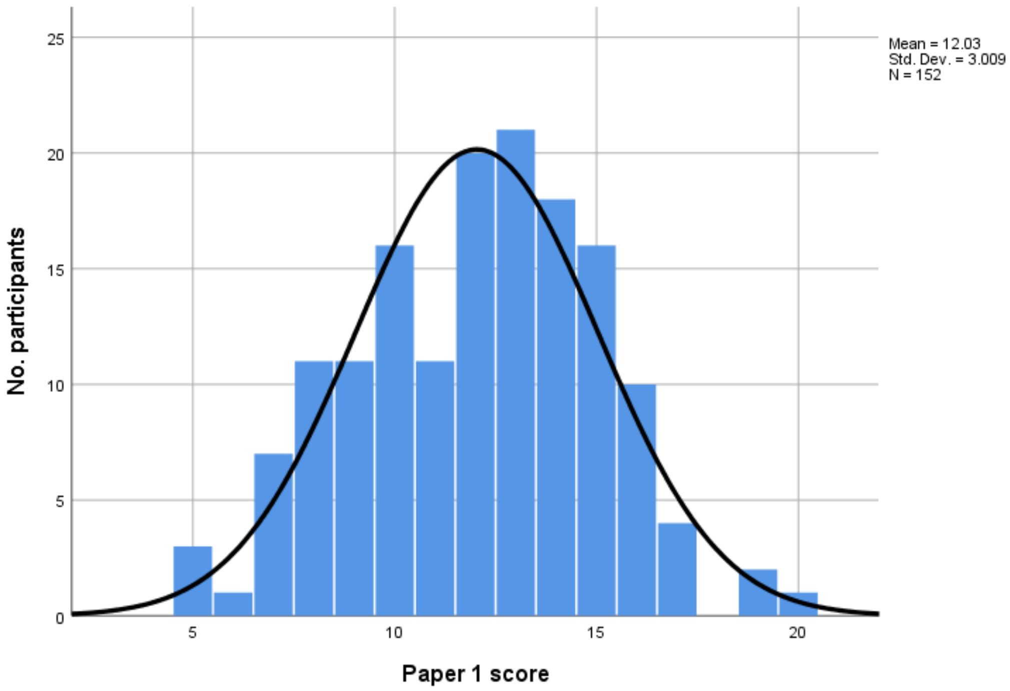

Figure 1: Histogram of participants' Paper 1 results

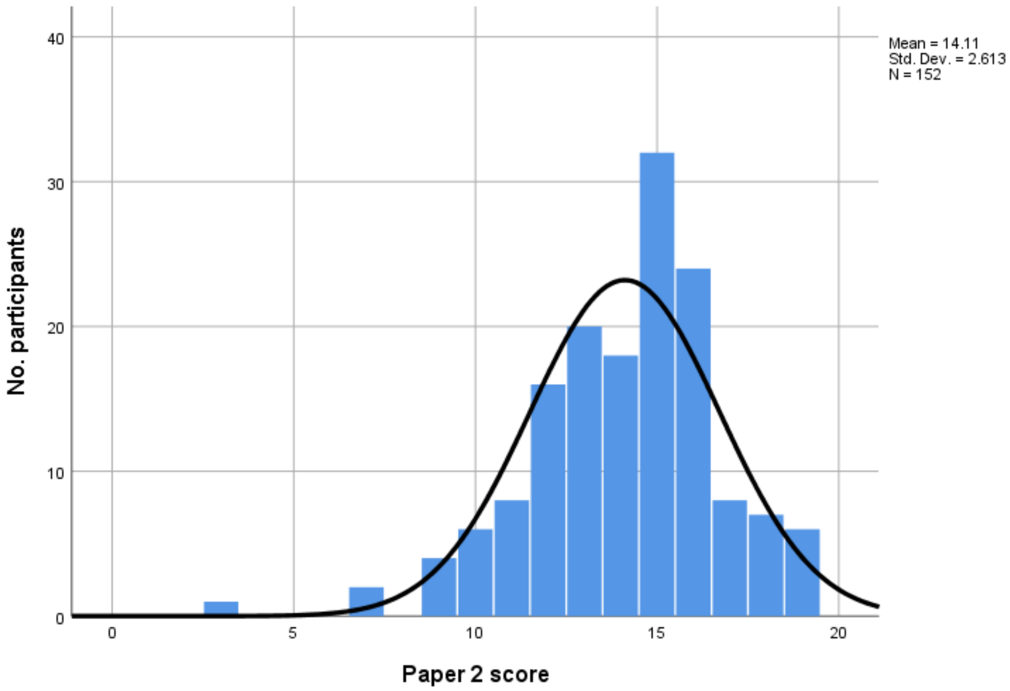

Figure 2: Histogram of participants' Paper 2 results

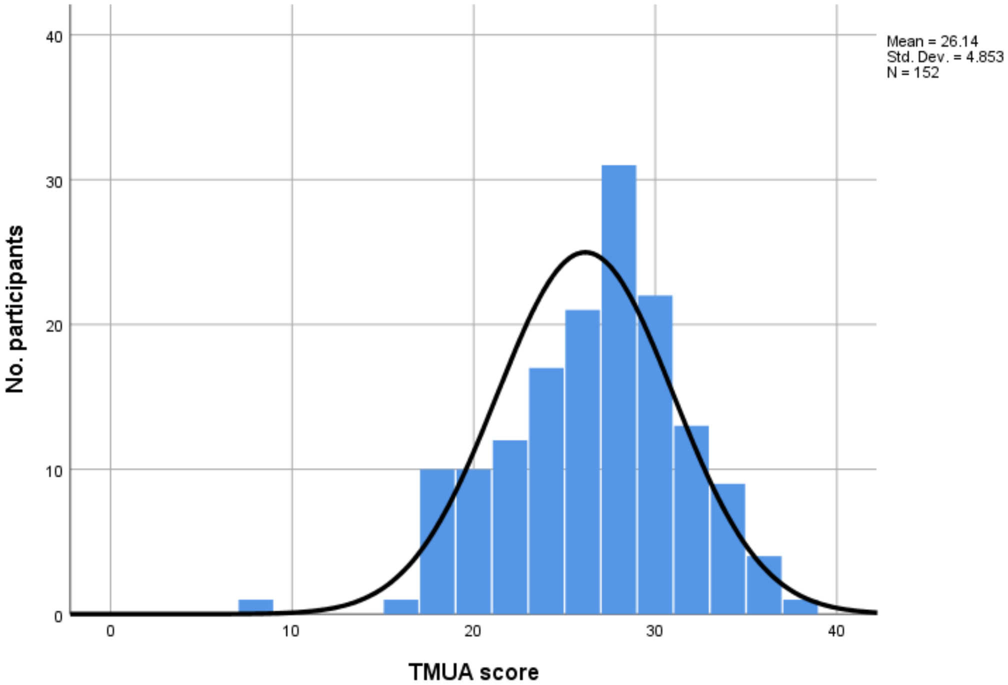

Figure 3: Histogram of participants' overall TMUA results

3.3 Omissions

Whilst there are no penalties for incorrect answers on the TMUA, a number of participants failed to answer all of the questions. There are several possible reasons:

- They ran out of time
- They did not realise that they had forgotten to answer a question
- They did not know the answer, and decided not to make a guess

Of course, the best strategy on a test like the TMUA is to make a guess. In fact, if a participant had guessed the answer to every question they would likely have scored 3.73 out of 20 in Paper 1 and 3.56 out of 20 in Paper 2[4] (7.29 out of 40 overall).

Over the two papers, 36.8% of participants failed to answer at least one question. Omissions were more common in Paper 1 than Paper 2 (see Table 4).

Table 4: Number of omissions

	Paper 1	Paper 2	TMUA
Mean	1.34	0.34	1.68
Median	0.00	0.00	0.00
Mode	0	0	0
Minimum	0	0	0
Maximum	10	4	11

Figure 4 shows that the proportion of participants who failed to answer each question increased throughout Paper 1, with many more participants failing to answer questions 16-

[4] The scores would be different between the two papers because, even though both papers had 20 questions, the number of response options for each question (ranging from 4 to 8) was not the same for each paper.

20 than other questions. Conversely, relatively few participants omitted answers in Paper 2, with Questions 4, 16 and 19 being the questions, which attracted the most omissions.

Participants who omitted at least one response tended to score lower on the TMUA than those who did not ($t(150) = 3.486, p = .001$), with a difference of 2.75 marks on average.

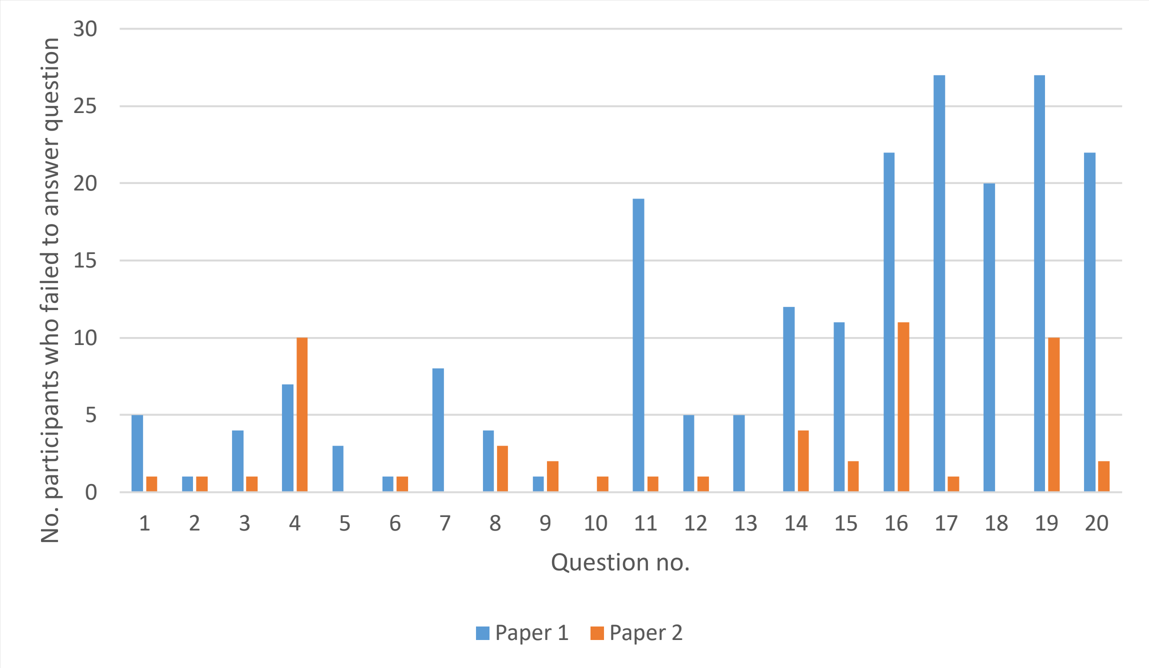

Figure 4: Number of participants who failed to answer each question

There were no noteworthy differences in the number of omissions by a participant and their gender or school type.

3.4 Concurrent validity

TMUA scores were compared with school performance in order to establish whether the TMUA has concurrent validity. A differentiating variable which was found to be most applicable to the participants given they all had strong mathematical backgrounds was whether they achieved an A* in A-level Further Mathematics (n=97) or a lower[5] grade (n=51).

Table 5: TMUA performance by A-level Further Maths grade

Result	Further Maths grade	N	Mean	Std. Deviation
Paper 1	A*	97	12.61	2.92
	A or B	51	10.96	2.96
Paper 2	A*	97	14.53	2.37
	A or B	51	13.45	2.83
TMUA	A*	97	27.13	4.62
	A or B	51	24.41	4.84

[5] Note: The lowest A-level Further Maths grade achieved by any participant was a B.

Table 5 shows that participants who achieved an A* in A-level Further Maths performed better than participants who achieved a lower grade. A* participants scored, on average, 2.72 marks higher overall than those with an A or B ($t(146) = -3.350, p = .001$). The difference was significant in both Paper 1 ($t(146) = -3.246, p = .001$) and Paper 2 ($t(146) = -2.450, p = .015$).

A logistical regression model was used to test whether a participant's TMUA score predicted significant variance in their chances of achieving an A* in A-level Further Maths. The model suggested that 7-10% of the variance in probability could be accounted for by the TMUA score (see Table 6).

Table 6: Results of logistical regression of A-level Further Maths grade on TMUA score

	β	Std. error	Wald's χ^2	df	Sig.	Exp(β)	95% CI for Exp(β)	
							Lower	Upper
TMUA score	.12	.04	9.74	1	.00	1.13	1.05	1.22

Figure 5 shows the predicted probability that a participant achieved an A* in Further Maths based on their TMUA score.

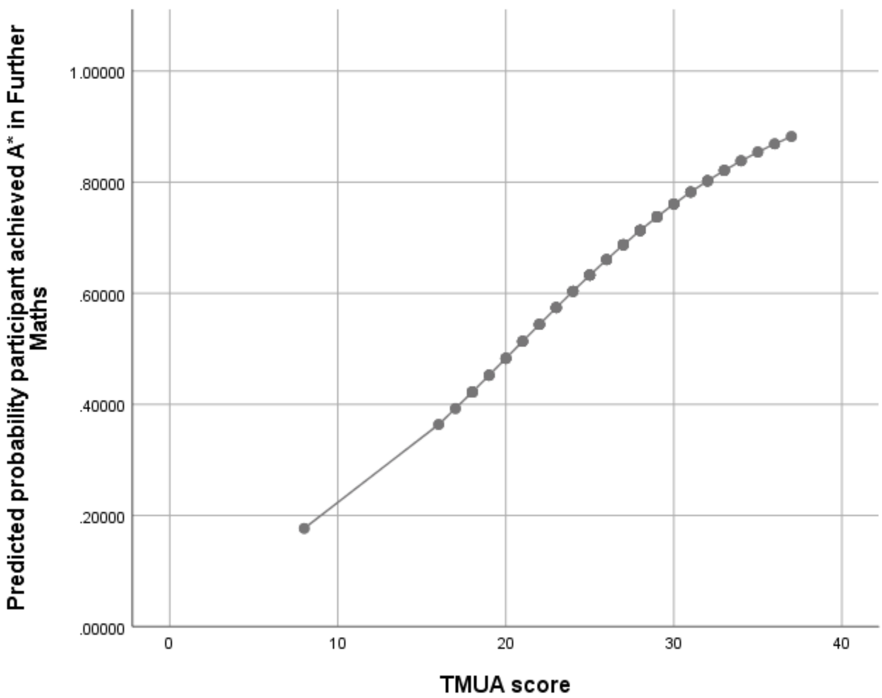

Figure 5: Predicted probabilities a participant achieved an A* in A-level Further Maths vs TMUA mark

Caution should be applied when interpreting the results reported in this section because:

- Participants in this trial do not necessarily reflect what is expected to be a typical TMUA cohort. They all gained excellent grades and were accepted into a high-ranking university. For a real cohort, candidates' performance will not necessarily be so high.
- Participants in the trial had already taken A-level Mathematics and, usually, A-level Further Mathematics. A typical candidate will only have studied AS-level

Mathematics, hence participants in the trial had more mathematics experience and knowledge.

- Participants had achieved, for the most part, the highest grades in A-level Mathematics and/or Further Mathematics. We anticipate that most TMUA cohorts and undergraduate mathematics application cohorts will have A-level attainment more spread out, with fewer taking Further Mathematics, and grades not necessarily so strongly skewed towards the top end.
- It was not possible to match all participants' trial results with A-level data because they did not take A-levels and/or because they did not consent for their data to be used for this purpose.

Hence it is not possible to make a reliable estimate of a student's probability of achieving an A* for low scores on the TMUA.

3.5 Predictive validity

In order to establish the predictive validity of the TMUA, participants' results were compared with their results in first year mathematics examinations at the University. These were in:

- Analysis I
- Calculus and Probability I
- Linear Algebra I
- Discrete Mathematics
- Programming and Dynamics I
- Statistics

Analysis, Calculus and Linear Algebra were compulsory modules for all first year students. As well as individual module results, each participant's overall result for the year was available.

Participants' results were converted into z-scores, this standardisation process giving adjusted scores which have a mean of 0 and standard deviation of 1. A Sharpiro-Wilk test indicated that all variables did not have a normal distribution; hence, Spearman's rank coefficients were calculated (see Table 7).

Table 7: Spearman's rank correlation coefficients for trial variables with undergraduate performance variables

	Paper 1 result	**Paper 2 result**	**TMUA result**	**A* Further Maths**
Year 1 average	0.365**	.329**	.415**	.193*
Compulsory average	.373**	.320**	.416**	.185*
Analysis	.374**	.322**	.410**	.155*
Calculus and Probability	.475**	.348**	.499**	.178*
Linear Algebra	.225**	.240**	.280**	.191*
Discrete Mathematics	.354*	.407**	.449**	.396**
Programming & Dynamics	.278**	.225**	.303**	.153*
Statistics	.315**	.297**	.348**	.164*

*Notes: * indicates correlation is significant at the 0.01 level** indicates correlation is significant at the 0.05 level*

These results suggest that achieving an A* in A-level Further Maths is a strong predictor of performance across first year undergraduate modules. This supports existing research which has found that good performances in A-levels are a good predictor of university outcomes (e.g. University of Cambridge, 2011; Vidal Rodeiro & Zanini, 2015).

TMUA score strongly correlated with performance in undergraduate modules (see Figure 6). In the context of assessment, coefficients over 0.35 suggest an assessment is very beneficial in a selection process[6]. The coefficients of 0.415 for the first year average and 0.416 for compulsory averages are therefore very encouraging, suggesting that the TMUA is a good predictor of first year undergraduate performance.

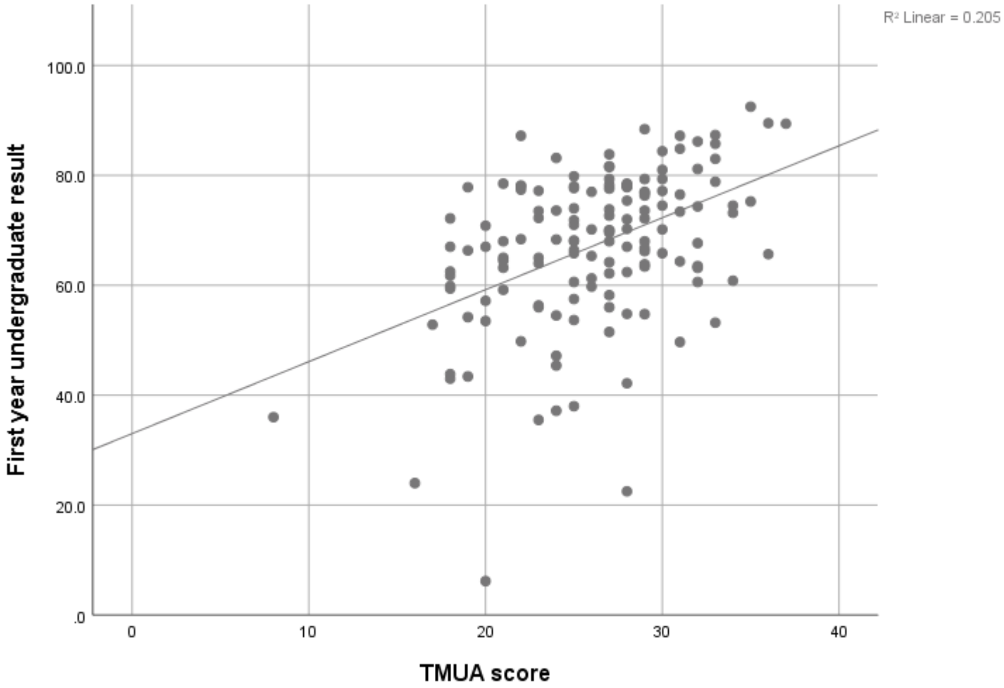

Figure 6: Participants' TMUA and first year undergraduate results

3.6 Gender and school type

3.6.1 Gender

Independent samples t-tests were used to establish whether there were any significant gender differences in performance on the TMUA and first year examinations.

Research in this area has found that boys tend to outperform girls at the top end in post-compulsory mathematics assessment, with analysis of the results in this trial finding that male participants scored on average around one mark higher on Paper 1 and Paper 2 (see Table 8).

[6] See, for example, US Department of Labor (2000).

Table 8: Undergraduate performance by gender

Mark	Gender	N	Mean	Std. Deviation	Std. Error Mean
Paper 1	Female	58	11.53	2.99	0.39
	Male	90	12.37	3.03	0.32
Paper 2	Female	58	13.50	2.61	0.34
	Male	90	14.58	2.48	0.26
TMUA	Female	58	25.03	5.09	0.67
	Male	90	26.94	4.58	0.48
1st year undergraduate	Female	54	66.56	12.11	1.65
	Male	89	66.53	15.18	1.61
Core modules	Female	54	68.28	16.05	2.18
	Male	89	66.81	18.66	1.98
Analysis	Female	54	64.69	12.83	1.75
	Male	89	64.27	17.45	1.85
Calculus & Probability	Female	56	71.28	21.25	2.84
	Male	89	69.82	18.81	1.99
Linear Algebra	Female	40	66.43	9.46	1.50
	Male	59	66.34	13.18	1.72
Discrete Mathematics	Female	54	65.63	12.22	1.66
	Male	89	62.95	13.86	1.47
Programming & Dynamics	Female	45	69.67	11.77	1.76
	Male	65	68.89	17.18	2.13
Statistics	Female	54	72.71	14.42	1.96
	Male	89	66.42	17.24	1.83

Gender differences in Paper 1 were not significantly different, though they were in Paper 2 ($t(146) = -2.527, p = .013$) and, subsequently, overall for the TMUA ($t(146) = -2.371, p = .019$). There were no significant differences in undergraduate performance between men and women, except in the results from the Statistics module where women scored an average of 6.29 marks more than men ($t(108) = 2.134, p = .035$).

Women omitted an average of 2.09 answers on the TMUA compared to men who omitted 1.43. This difference was not statistically significant.

The university used the results from the TMUA to determine whether any students might benefit from extra support during their transition to undergraduate study. That the gender differences did not exist in end of year performance indicates that these interventions may have been successful, rather than indicating that the TMUA underpredicts women's performance.

3.6.2 School type

Participant school types were split into state school, independent school or other (e.g. language schools). The majority of participants attended state schools (84.7%).
Table 9 shows that students from each group performed very similarly: state-educated participants averaged 26.28 on the TMUA compared to independently-educated participants who averaged 26.76.

Table 9: Participants' performance by school type

Mark	School	N	Mean	Std. Deviation	Std. Error Mean
Paper 1	State	116	12.18	2.91	0.27
	Independent	21	11.90	3.10	0.68
Paper 2	State	116	14.10	2.47	0.23
	Independent	21	14.86	2.35	0.51
TMUA	State	116	26.28	4.67	0.43
	Independent	21	26.76	1.96	1.08
1st year undergraduate	State	114	66.65	14.13	1.32
	Independent	21	68.95	12.37	2.70
Core modules	State	114	66.83	16.32	1.53
	Independent	21	68.48	14.30	3.12
Analysis	State	114	63.73	17.85	1.67
	Independent	21	65.10	16.35	3.57
Calculus & Probability	State	115	69.98	15.68	1.47
	Independent	21	71.71	13.98	3.05
Linear Algebra	State	83	66.21	19.52	1.82
	Independent	12	68.62	15.58	3.40
Discrete Mathematics	State	114	63.98	10.88	1.20
	Independent	21	64.08	17.31	5.00
Programming & Dynamics	State	87	68.57	13.49	1.26
	Independent	17	71.29	10.87	2.37
Statistics	State	114	67.87	15.94	1.71
	Independent	21	71.76	11.67	2.83

Differences did exist in participants' performance in end of year examinations at university; however, none of these differences were statistically significant.

4. Discussion

4.1 Summary of findings

This trial found that the TMUA is a good predictor of degree performance, and that there is evidence of concurrent validity with top grades in A-level Further Maths. Gender differences, whilst statistically significant, reflected gender differences which exist at the top end of performance in GCSE and A-level Maths (Joint Council for Qualifications, 2018), and there were no significant differences in the performance of state- and privately-educated students. Hence, it appears that the TMUA would be an effective means of selecting the best qualified applicants to study undergraduate maths when faced with applicants who all present with top GCSE Maths grades and little else to distinguish between them.

4.2 Limitations

This trial was conducted with students who had already achieved top grades in A-level Maths and, usually, Further Maths and had been selected to study at a high-ranking university based on those results. They had experienced approximately six months additional maths study to a genuine TMUA candidate. Hence, they are not reflective of the overall target cohort for the TMUA.

4.3 Developments since the trial

Further developments have resulted in the time allowed for each of the two papers being extended to 75 minutes from 60, as the time pressure had resulted in evidence which suggested that large proportions of candidates had been guessing answers to later questions in each paper.

4.4 Further research

It would be beneficial to conduct further trials with the TMUA. School-based studies of students who have studied all of the AS-level Maths material would be useful to gain an insight into a more broad spread of student performance as not all students will necessarily be considering progressing onto a maths degree. Further university research would also be beneficial, given the changes made to the timing of the two papers since the Durham trial.

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