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The impact of Covid-19 on mathematical entry competencies: one year on

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Abstract

The Covid-19 pandemic has affected the way we learn, teach, and support students in many different ways. In particular, the impact of the pandemic on the mathematical capabilities of students arriving at university are now starting to be seen and reported. Students arriving at UK universities in 2021, and having completed their A levels in 2021, had received disruption to almost all of their A level learning and it seemed likely that this might cause them to find the transition into higher education more difficult. Despite the disruption, the number of students achieving the top A level grade has more than doubled since 2019. In this paper, data from a diagnostic test that has remained the same for the past 30 years is considered to measure the mathematical preparedness of students starting their courses at one UK university in September 2021, updating the work of Hodds (2021). Furthermore, an ordinal logistic regression model predicting A level grade based on test performance and other factors is developed to help determine if grades were perhaps inflated as suggested. The results show that students entering in 2021 are significantly less prepared for the mathematics on their courses than their colleagues who entered in 2020 and pre-pandemic. The regression model predicts a higher probability of being awarded an A*/A for students with A levels awarded in the pandemic, despite far lower scores on the diagnostic test, and in particular in 2021 when A levels were awarded through teacher assessment of the topics covered and not necessarily the whole A level syllabus.

Keywords: Diagnostic Testing; Mathematical Understanding; University Mathematics; Engineering; Transition to University Mathematics; Teacher Assessed Grades; A levels

1. Introduction

The start of the 2021-22 academic year saw most students entering university in the UK with A level qualifications (which are qualifications taken by students in England and Wales in post-compulsory education, usually between the ages of 16 and 18) that were not based on formal summative assessment for the second consecutive year due to the ongoing Covid-19 pandemic. Once again, there was therefore serious concern that students arriving at university in September 2021 would be less prepared for their courses. In 2020, 14.3% of all students entering university achieved an A* grade (which is the top grade) in at least one of their A levels compared to 8% in 2019. In 2021 it had jumped to 19.1%, sparking grade inflation fears (Collinge, 2021). Furthermore, in mathematics specifically, 28.7% achieved an A* in 2021 compared with 23.8% and 15.9% in 2020 and 2019 respectively (JCQ, 2022). Golding (2021) also showed that a significant minority of teachers in her work expressed fears about comparability of grades across different educational settings and 23% felt under pressure to inflate their judgements.

However, issues surrounding grade inflation were not the only reasons why it was feared students would be less prepared. Recent publications have shown that both students and teachers found education challenging during the pandemic. Half of teachers in one study said they felt underprepared to support learning using technology (Mason, Grima, Redmond, Hill, Carter, Golding, and Meredith, 2021). Furthermore, technology has also been a global issue in providing mathematics and statistics support to students during the pandemic, once they had arrived at university (e.g., Mac an Bhaird, McGlinchey, Mulligan, O'Malley, and O'Neill, 2021; Gilbert, Hodds, and Lawson, 2021; Mullen, Pettigrew, Cronin, Rylands, and Shearman, 2021). Students therefore arrived at university less well prepared than prior to the pandemic and may have had difficulty in receiving support to try and rectify this due to technological issues faced during periods where only online learning and support was available. In turn, students therefore reported that they felt unable to cope with the pressures of university life and examinations, suffering from a lack of confidence.

To increase awareness of students' mathematical strengths and weaknesses, and in turn increase confidence through support, universities often use diagnostic tests, which measure a student's mathematical competency on entry to university. The test is usually tailored to suit the level of mathematics required by the course. Diagnostic tests have been shown to be effective at providing both staff and students with vital information regarding areas of strength and weakness (e.g., Hodds, Shao, and Lawson, 2020) as well as increasing pass rates in Engineering (Patel and Little, 2006) and Nursing (Hodds, 2020) when combined with tailored support packages. Due to the disruption to education caused by the pandemic, diagnostic tests are perhaps more vital than ever in helping staff to determine the true competency of students whilst also providing support in the best possible way on arrival at university.

2. Updating the work of Hodds (2021)

The work of Hodds (2021) provides an initial overview of the mathematical competencies of the first cohort of students to arrive at one UK university during the pandemic (i.e., those arriving at university in September 2020). These students had their education partially disrupted by the initial lockdowns in the UK in 2020 and had their A level grades assessed through centre assessed grades as part of a "triple lock" system (see Department for Education (2020) for more information on the "triple lock"). This is subtly different to the teacher assessed grades in 2021 where students were only assessed on the work that had been covered. Consequently, students in 2021 could achieve a top A*/A grade despite not having covered important topics within the curriculum (see Ofqual (2021) for more information).

The work of Hodds (2021) uses a diagnostic test that has remained unchanged for over 30 years, allowing for a fair comparison of mathematical competencies of students on entry. The results of this work were encouraging: students entering Coventry University in 2020-21 were performing at least as well as students entering in 2018-19 and significantly better than those entering in 2019-20, although it was suggested this specific finding may be due to the recent changes in the A level mathematics syllabus impacting the 2019 cohort. Furthermore, students who received their A levels in 2020 and entered in 2020-21 outperformed their colleagues who received their A level results in a year prior to 2020. Similar results had also been seen at the University of Edinburgh (Kinnear and Sangwin, 2020), who require much higher entry tariffs than Coventry University, suggesting that perhaps these promising results were being seen in many UK universities. However, it was unclear that the same results would be seen for the 2021-22 cohort. These students had received much more disruption to their education during the pandemic and had their A level grades assessed in a slightly different way, although still without a formal examination.

This paper therefore sets out to update the findings of Hodds (2021), determining whether students entering Coventry University in 2021-22 were as prepared as students in

2020-21 and those entering pre-pandemic. Furthermore, due to the issues and concerns around grade inflation, a model of predicted grades based on performance in the diagnostic test, amongst other factors, was considered to determine if A level grades were indeed inflated in 2021 as suggested.

3. Methodology

Data from 185 students who had an A level mathematics qualification, were studying either an Engineering or Mathematics course at Coventry University, and starting their degree in September 2021 were analysed for this report. Of these, 138 students entered with an A level qualification in Mathematics from 2021. Of the 47 that entered with an A level qualification prior to 2021, 31 of these students received their A level in 2020 without completing the formal examination (i.e., under the “triple lock” process), and the other 16 received their A levels prior to the pandemic and took the formal examinations. Data from a further 401 students from 2018, 129 students from 2019, and 161 students from 2020, who entered university in the year of receiving their A level, were analysed to determine differences by A level grade and year of entry. Finally, data from a further 1919 students who took the diagnostic test between 2014 and 2021 were also analysed as part of an ordinal logistic regression that was used to predict A level grade based upon performance in the diagnostic test. 2014 was the first year that data was collected on the date that students obtained their A level grades whereas prior to 2014 only the A level grade data was collected. All students who took the test between 2014 and 2021 were included in this data regardless of when they received their A level result.

All students included in this analysis took the same diagnostic test which contains 50 multiple choice questions with five options: a correct answer, three distractors, and one option for “don’t know” on each question. The questions cover a range of topics from arithmetic and algebra, lines and curves, trigonometry, and calculus. All topics are covered either by the A level syllabus or the GCSE syllabus (which is the qualification achieved at the end of compulsory education in England and Wales, usually taken at the age of 16) so students are expected to have prior knowledge of these topics. The questions have remained the same for over 30 years and therefore can be sensibly used to compare the performance of students entering Coventry University with an A level grade in Mathematics. The tests are reviewed on a regular basis and, despite several changes to the A level curriculum, it has always been felt the questions originally set reflect the prerequisite knowledge required for the first semester modules of courses with high-level mathematical content.

The diagnostic test is taken in the first few weeks of study in a scheduled time frame. To account for any enrolment issues, the test is open for a set period and students can take the test at any time within that period. There is also a set time, usually in a lecture or tutorial, where students are invited to take the test on campus in test conditions. The majority of students (over 80% in all courses that took the test in 2021) took the test on campus, with students who could not attend taking the test at home in their own time. The test has a time limit of one hour to complete the 50 questions and students could use scrap paper for working out but no calculators.

Up until 2020, the test was taken using a question booklet and an optical mark reader answer sheet. However, in 2020, due to the pandemic, the test was distributed online for the first time using "Numbas" and the university's online learning platform Moodle as these were the only options available at the time (see Hodds (2021) for a detailed explanation). In 2021, the university had acquired the use of "Wiseflow[1]" which is a dedicated cloud-based, digital assessment platform. Crucially, it uses LaTeX code to render mathematical text and also provides a lockdown browser for taking the test. The diagnostic test questions were uploaded into "Wiseflow" and students either took the test on campus or in their own time at home, as described previously, using the link provided via e-mail. Again, these issues surrounding how the test was taken are considered in section 5.

4. Results

4.1. Comparison of overall results

Firstly, the overall performance of students from each year who entered with an A level qualification and took the diagnostic test in September 2021 was compared. Figure 1 shows the average score for each year of study from 1991 to 2021.

[1] see https://www.uniwise.co.uk/wiseflow for more details

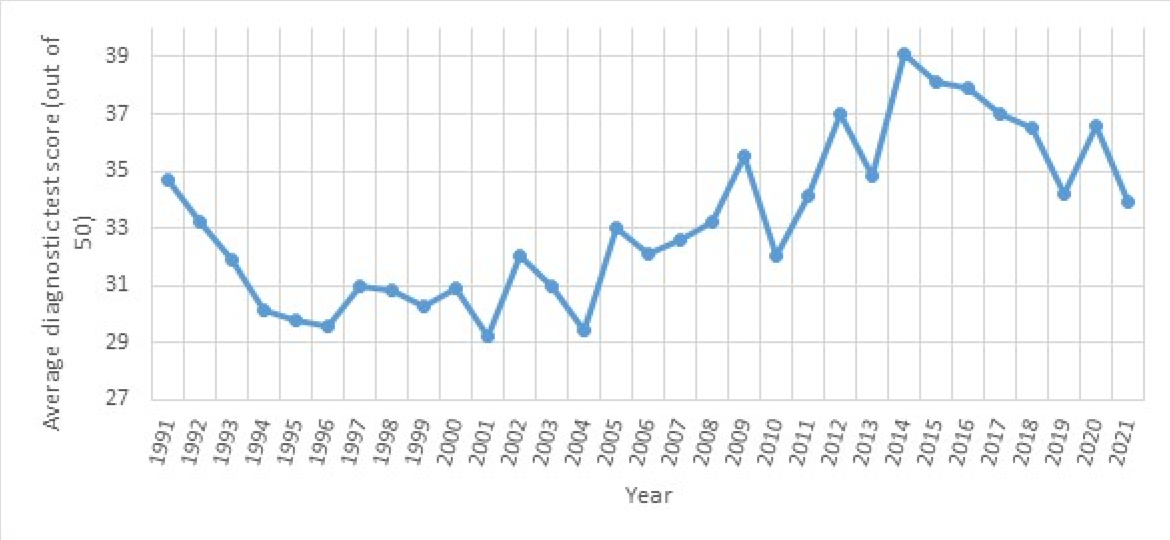

Figure 1: Average diagnostic test score (out of 50) by year

Table 1 below also summarises students' diagnostic test performance for those entering in 2021 compared to those entering in 2018, 2019, and 2020. This shows that the mean score for students entering in 2021 was 2.71 marks lower than students entering in 2020, with this difference being statistically significant ($p = 0.002$). The mean score for students entering in 2021 was also marginally lower when compared to students entering in 2019, but in this case the difference was not statistically significant ($p = 0.391$). It also shows that students entering in 2018 scored on average 2.57 marks higher than those entering in 2021 and this was statistically significant ($p = 0.001$). These results suggest students arriving in 2021 performed worse than the previous 3 years and Figure 1 shows that this performance was the lowest since, and comparable to, the results of a decade earlier.

Year	N	Mean Score (out of 50)	s.d.	Difference to 2021 entry	Levene's Test	t-score	df	p-value
2018	450	36.48	7.83	+2.57	$p < 0.001$	-3.490	633	0.001
2019	159	34.75	8.06	+0.84	$p = 0.002$	-0.859	342	0.391
2020	204	36.62	6.95	+2.71	$p < 0.001$	-3.171	387	0.002
2021	185	33.91	9.81					

Table 1: Average scores (out of 50) by entry year

As with any academic year, the majority students arrive immediately after completing their A levels and some arrive after taking at least a year out of formal education. Clearly, any effect of the pandemic on mathematical competencies would be highest on students who arrived immediately after receiving their A level results in August 2021. Therefore, the average score on the diagnostic test for those students arriving in the 2021-22 academic year and in the year of obtaining their A levels were compared to the average score of those students arriving in 2021-22 but not in the year of their A levels. It was found that students who arrived with A level results from 2021 ($N = 138$, $M = 33.73$, s.d. = 9.86) did not perform significantly worse than those students who arrived with A level results from 2020 only ($N = 31$, $M = 35.13$, s.d. = 10.17), $t(167) = -0.708$, $p = 0.240$. Furthermore, students in 2021 did not perform significantly worse than those who arrived with A level results before 2020 ($N = 47$, $M = 34.43$, s.d. = 9.76), $t(183) = -0.418$, $p = 0.677$, however students with A levels from 2021 did have the lowest average score overall. This is shown in Figure 2 below.

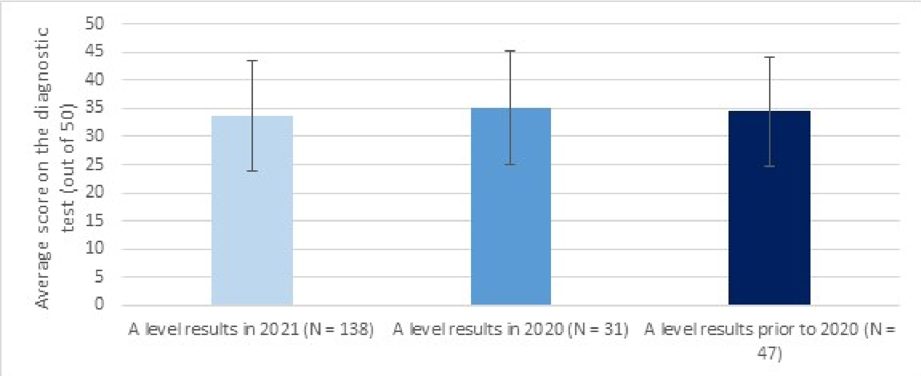

Figure 2: Average score on the diagnostic test (out of 50) for students who took the test in 2021 by when A level qualification was awarded (error bars represent ± 1 s.d.)

These results suggest that those who arrived straight after their A levels in 2021 are not performing significantly worse than those who delayed their arrival by at least a year. The majority of these delayed entrants received their A levels in 2020 (66%) and would have only experienced half a year of disrupted education. Students directly entering in 2021 would have had over a year of disrupted education. One may also expect a decrease in understanding the longer the time away from formal education. Therefore, given that there was no significant difference in performance of students with qualifications from the pandemic and those before, this may provide some further evidence of the longer-term, negative effects on mathematical understanding due to the disruption caused by the pandemic.

4.2. Comparison of average scores by A level grade

For equity of comparison, all data analysed and reported in sections 4.2 and 4.3 only includes students who received their A level in the year that they entered the university. Grades at A level run from level A* (the highest grade) through to grade E and U for ungraded. Table 2 below shows the difference in performance by grade for students who received their A levels in the year of entry (with standard deviations provided in brackets).

Grade	2018	2019	2020	2021
A*/A	41.30 (6.57), N = 75	36.60 (11.68), N = 24	41.61 (5.68), N = 31	35.32 (10.74), N = 34
B	38.53, (6.23), N = 137	36.44 (6.59), N = 41	38.33 (5.48), N = 58	34.28 (7.97), N = 36
C	35.22 (7.04), N = 118	33.19 (6.56), N = 54	35.86 (5.22), N = 49	33.51 (10.40), N = 51
D	30.76 (9.04), N = 50	32.88 (7.08), N = 8	33.32 (6.01), N = 19	30.50 (9.99), N = 16
E	30.76 (7.35), N = 21	19.00 (1.41), N = 2	29.75 (9.64), N = 4	23.00 (0.00), N = 1

Table 2: Average score on the diagnostic test (out of 50) for students entering in each year by A level grade having received their A level in that year of entry (brackets show the standard deviation).

Five, one-way ANOVAs revealed that the differences in performance between the four years considered were significant at the higher grades but not at the lower grades; A*/A: $F(3,162) = 6.127$, $p = 0.001$, B: $F(3,267) = 4.921$, $p = 0.002$, C: $F(3,266) = 1.616$, $p = 0.186$, D: $F(3,89) = 0.550$, $p = 0.649$, E: $F(3,30) = 0.768$, $p = 0.521$. What is also striking is the high standard deviations for each grade in 2021-22 suggesting a much higher spread of results, although in 2019-20 there was an even larger spread of scores at the A*/A grade.

4.3. Comparison of performance on the different sections of the diagnostic test

The diagnostic test is split into seven sections: Basic Arithmetic, Basic Algebra, Lines and Curves, Trigonometry of Triangles, Further Algebra, Trigonometric Functions, and Calculus. To analyse performance on each section of the diagnostic test, seven independent samples t-tests were performed, with a Bonferroni correction, on the results for each A level grade comparing the scores in each section of students who entered in 2021 to those who entered in 2020 to see any impact of the pandemic on the understanding of different topic areas. The results of the analysis are provided in Table 3 below (with the higher average score for each year and section, and significant p-values, highlighted in **bold** for ease of comparison).

Grade and Section		2021	2020	p
A*/A	Basic Arithmetic (7)	**6.43 (1.06)**	6.27 (0.97)	0.737
	Basic Algebra (12)	9.10 (2.77)	**10.68 (1.94)**	0.017
	Lines and Curves (7)	5.18 (2.14)	**5.92 (1.51)**	0.107
	Trigonometry of Triangles (5)	3.41 (1.05)	**3.55 (1.05)**	0.812
	Further Algebra (8)	5.71 (2.41)	**6.28 (1.79)**	0.370
	Trigonometric Functions (6)	3.86 (1.58)	**3.88 (1.43)**	**0.047**
	Calculus (5)	3.14 (1.72)	**3.90 (1.52)**	**0.001**
B	Basic Arithmetic (7)	**6.40 (1.03)**	6.24 (0.85)	0.246

	Basic Algebra (12)	8.42 (2.95)	**10.28 (1.48)**	**0.018**
	Lines and Curves (7)	5.02 (1.79)	**5.85 (1.24)**	0.278
	Trigonometry of Triangles (5)	2.98 (1.27)	**3.32 (1.09)**	0.585
	Further Algebra (8)	4.76 (2.25)	**5.56 (1.79)**	0.069
	Trigonometric Functions (6)	**3.73 (1.47)**	3.60 (1.60)	0.150
	Calculus (5)	2.78 (1.38)	**3.61 (1.50)**	**<0.001**
C	Basic Arithmetic (7)	**6.51 (0.77)**	6.08 (1.09)	0.631
	Basic Algebra (12)	8.15 (3.31)	**9.65 (1.87)**	0.245
	Lines and Curves (7)	4.74 (1.89)	**5.33 (1.49)**	0.153
	Trigonometry of Triangles (5)	3.00 (1.24)	**3.15 (1.21)**	0.940
	Further Algebra (8)	4.47 (2.41)	**4.64 (1.73)**	0.964
	Trigonometric Functions (6)	**3.77 (1.52)**	3.19 (1.49)	0.828
	Calculus (5)	2.65 (1.66)	**3.10 (1.65)**	**0.001**
D/E	Basic Arithmetic (7)	**5.96 (1.34)**	5.58 (1.50)	0.466
	Basic Algebra (12)	7.16 (3.28)	**8.85 (2.55)**	0.225
	Lines and Curves (7)	4.36 (1.93)	**4.55 (1.83)**	0.806
	Trigonometry of Triangles (5)	2.32 (1.28)	**2.76 (1.13)**	0.250
	Further Algebra (8)	3.84 (1.67)	**3.90 (1.80)**	0.157
	Trigonometric Functions (6)	**3.56 (1.37)**	2.66 (1.40)	0.425
	Calculus (5)	2.24 (1.71)	**2.51 (1.69)**	0.062

Table 3: Average score by section of the diagnostic test (with total number of questions in that section in brackets) for each A level grade for 2021 and 2020 (brackets show the standard deviation).

Those students entering in 2021 did better in the Basic Arithmetic section of the test across all grades but there was no statistically significant difference. They also did better on Trigonometric Functions at all grades except A*/A but again there was no statistically significant difference. At grades A*/A, B, and C, students in 2020 did significantly better in the Calculus section, which contains content taught exclusively at A level (i.e., the other sections contain topics that are taught at GCSE for example). This may be explained by students in 2021 not necessarily covering all topics during their A level education due to the disruption. Consequently, they were not assessed on these topics and perhaps would have therefore struggled to answer questions on them in the diagnostic test.

4.4. Using performance on the diagnostic test to predict expected entry grades

From the analysis conducted above it appears that students entering in 2021 have lower mathematical competencies than students entering in previous years. For those entering with an

A level obtained in 2021, their grade was decided by teacher assessment and not summative assessment. As mentioned previously, there was also a fear that A level grades had been inflated in 2021. Therefore, an analysis was conducted to predict the A level grade a student may have received if they had to complete the usual summative assessment, based on their performance on the diagnostic test, and the past performances of students who took the test prior to the pandemic.

An ordinal logistic regression was conducted on the data from all students who took the diagnostic test during the pre-pandemic period between 2014 and 2021 and entered with an A level grade. As discussed previously, 2014 was the first year that data was collected on the date that students obtained their A level grades and prior to this, students were only asked what A level grade they achieved. The assumptions for the use of an ordinal logistic regression were considered and the first three were met: the dependent variable is ordered, at least one of the independent variables are continuous, categorical, or ordered, and there was no multicollinearity seen between the independent variables (significant correlations were all less than 0.8 and the variance inflation factor, VIF, for each variable was significantly less than 10). However, the final assumption of proportional odds between the levels of the dependent variable may not hold as A level grades do not increase proportionally at each grade. This is therefore considered in the discussion and conclusion.

Ordinal logistic regression in this instance provides a prediction of the probability that a student would be given a particular A level grade based on various factors. By calculating the probability for each grade using the model, the most likely A level grade can be predicted[2]. The results of this ordinal logistic regression are provided in Table 4 below.

Parameters		β	Wald χ^2	p	exp (β)
Diagnostic Test Score		0.101	307.495	< 0.001	1.106
A level syllabus code		0.180	4.518	0.034	1.197
Year of Entry code		0.336	4.952	0.026	1.399
Pandemic Code	2021	0.568	10.441	0.001	1.764
	2020	0.336	0.831	0.362	1.154
2020 * Not in year of A level (all other interactions = 0)		-0.781	4.700	0.03	0.458

Table 4: Ordinal Logistic Regression analysis to determine predicted A level grades based on all results between 2014 and 2021 on the diagnostic test

[2] For more information on ordinal logistic regressions and how to interpret them, see Parry (2020), St Andrews Maths Support (n.d.), and UCLA (n.d.)

The dependent variable for this regression was A level grade, with A*/A as the reference category to compare to and coded 6 to 1 (6 = A*/A through to 1 = U). The predictors used were the year of entry code (1 = entered in year of qualification, 0 = entered after year of qualification, $p = 0.026$), and their score on the diagnostic test ($p < 0.001$), both of which were found to be significant predictors. Furthermore, the syllabus that their A level grade came from was also used as a predictor because in 2017 the A level maths curriculum underwent a change where students took exams only at the end of the two years rather than taking modular exams across the two years. Therefore, anyone with an A level from 2019 or later is considered as a student from the post-2017 syllabus. This was also found to be a significant predictor ($p = 0.034$) as a coded variable (1 = pre-2017 syllabus, 0 = post-2017 syllabus). Finally, a fourth predictor variable was included which accounted for whether the student took the diagnostic test pre-pandemic or during (1 = 2021 entry, 2 = 2020 entry, 0 = pre-pandemic entry as the reference category). The 2021 code was a significant predictor ($p = 0.001$) but the 2020 code was not ($p = 0.362$). Interaction terms combining the pandemic code with year of entry, and the pandemic code with A level syllabus were also considered. It was found that only 2020 entry and not entering in the year of qualification was a significant predictor ($p = 0.03$).

These results provide odds ratios ($\exp(\beta)$ column of Table 4) which suggest the likelihood of being at a higher grade for each predictor variable. The odds ratios in Table 4 show that an increase of one mark in the diagnostic test results in the odds of having a higher grade being 1.106 times (or 10.6%) higher. Similarly, having an A level from the pre-2017 syllabus results in the odds of having a higher grade being 1.197 times (or 19.7%) higher than those with an A level from the post-2017 syllabus. Finally, the odds of having a higher grade are 1.399 times (or 39.9%) higher for those entering in the year of obtaining an A level qualification when compared to someone who enters at least a year later. The odds ratios in Table 4 also show that the odds of having a higher grade was 1.76 times (or 76%) higher for a student entering in 2021 compared to a student entering pre-pandemic, all other factors being equal. This is further supported by the data that shows there was a higher proportion of students entering in 2021 with A*/A grades (26%) when compared with 2020 (19%) or pre-pandemic (17%), as shown in Table 5.

A level grade	2021	2020	Pre-Covid
A*/A	26%	19%	17%
B	24%	32%	35%
C	36%	31%	31%
D	12%	13%	12%
E	2%	4%	5%

Table 5: Actual proportions of students taking the diagnostic test by actual A level grade achieved

Although a student entering in 2020 was predicted to be 1.154 times (or 15.4%) more likely to have a higher grade than a student entering pre-pandemic, all other factors being equal, this did not reach significance. Furthermore, the interaction term shows that the odds of having a higher grade were 54.2% (= 1 – 0.458) less for students entering in 2020 and not in the year of qualification than those who entered in 2020 and in the year of qualification. This therefore suggests that the model predicts there was perhaps some inflation of grades during the pandemic, but significantly more so in 2021 than 2020.

An ordinal logistic regression in this scenario helps to determine probabilities of obtaining a particular A level grade or lower by using the predicted beta values and the threshold betas, which are the levels needed to be surpassed for a particular grade to be the suggested outcome. In order to calculate the probability of the particular A level grade only, the probability of the grades below it are subtracted, as the probabilities are cumulative. The formulas for calculating the probabilities for each individual grade are provided in Appendix A for clarity. Figure 3 below shows these probabilities, calculated by the model, of being awarded an A/A* for each cohort (2021, 2020, and pre-pandemic) according to score on the diagnostic test, with all other factors (A level syllabus is post-2017 and students enter in the year of qualification), being equal according to the model.

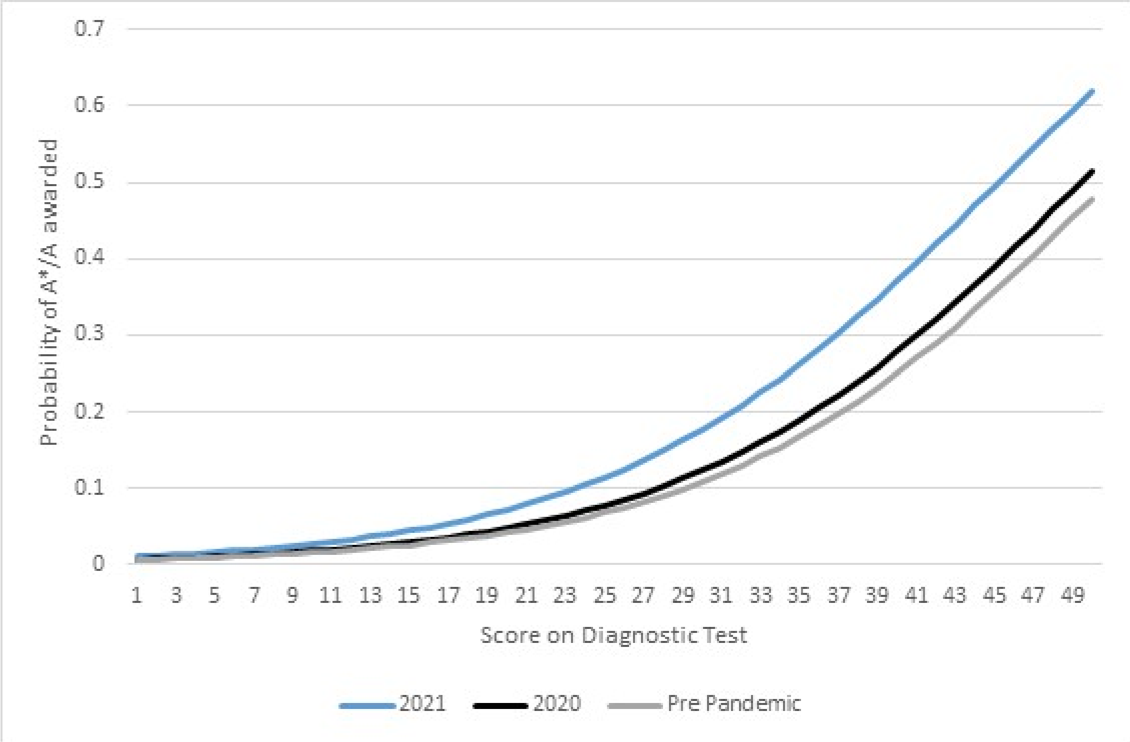

Figure 3: Ordinal logistic regression predicted probability of being awarded an A*/A by year of taking the test, according to diagnostic test score and all other factors being equal

The graph shows a large increase in the predicted probability of being awarded an A*/A in 2021 when compared to other years. For example, there is a 40% chance that a student who scored 41/50 in 2021 has an A*/A grade compared to 27% in 2020 and 25% pre-pandemic. Consequently, this also suggests that in 2021 there is also a 60% chance a student would actually have received a lower grade when scoring 41/50. This is less likely than 2020, where there was a 73% chance, and pre-pandemic, where there was a 75% chance. Hence this suggests despite scoring lower on the diagnostic test, a student in 2021 would be more likely of being awarded an A*/A than a student arriving in 2020 or pre-pandemic.

Figure 4 below shows the same data as Figure 3 but includes data for the students who delayed their arrival by at least a year as separate plots. Students who took their A levels prior to the pandemic, regardless of whether they delayed entry or not, had, according to the model, a lower chance of being awarded an A*/A than those who took their A levels during the pandemic.

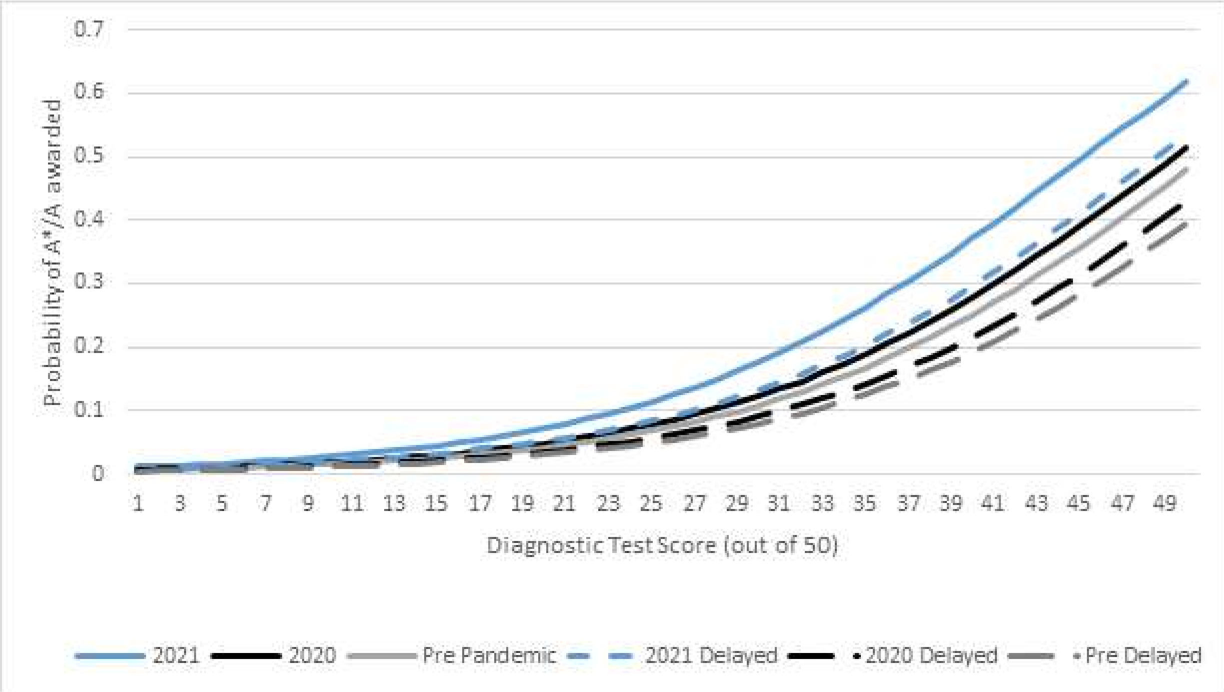

Figure 4: Ordinal logistic regression predicted probability of being awarded an A*/A by year of taking the test, and delayed entry status, according to diagnostic test score and all other factors being equal.

Both Figures 3 and 4 therefore show that the model predicts a higher probability of having been awarded A*/A at far lower scores on the diagnostic test for students entering Coventry University with an A level awarded during the pandemic, compared to pre-pandemic years, and when all other factors are considered equal. Furthermore, this probability is higher in 2021 than 2020 despite a poorer performance overall. At the lower grades however, there is evidence to suggest students in 2021 actually performed better than their grade would suggest, as shown in Figure 5. As the probability of being awarded a lower grade (C/D/E) is lower than the probabilities for 2020 and pre-pandemic at each mark of the diagnostic test, it implies these students in 2021 were performing better than their A level grade would suggest.

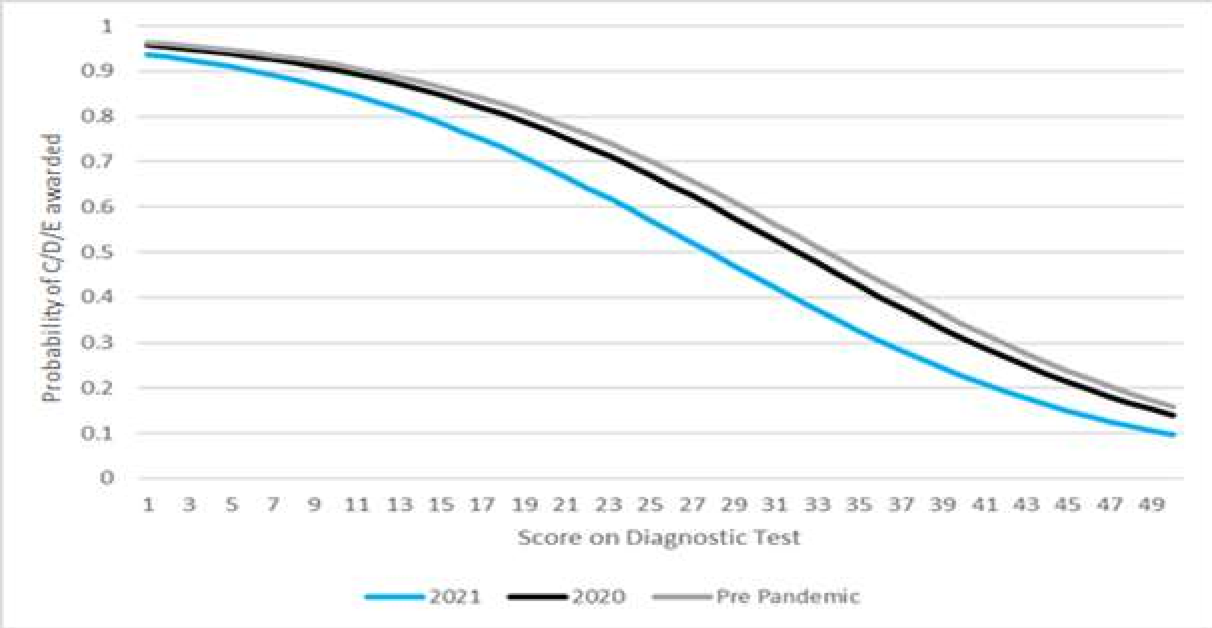

Figure 5: Ordinal logistic regression predicted probability of being awarded a lower grade (C/D/E) by year of taking the test, according to diagnostic test score and all other factors being equal

5. Discussion and Conclusions

This paper has investigated the mathematical entry competencies of students entering one UK university in 2021 with an A level in mathematics. These students will have been impacted the most in terms of their A level learning experience, having had almost two full years of interrupted learning and the majority of it being online. The analysis has shown that students entering in 2021 have a significantly lower level of mathematical competence than students arriving in the majority of the years prior, including 2020 where students also had disruption to their A level learning but for a shorter time period. Furthermore, it appears that many of the top grades in 2021 may not be an accurate reflection of competency, as a large proportion of these students performed significantly worse than their grade would suggest. Indeed, the analysis suggests many of these top grades may indeed be inflated as feared, which is supported by the higher proportion of students arriving in 2021 at Coventry University with an A*/A grade when compared to previous years. Furthermore, the large standard deviations seen at each grade suggest there was a wider range of competency overall than in previous years. Indeed, the findings of this paper support the findings of Golding (2021, p.1) who states that: “Mathematical preparedness, and confidence, for mathematics-intense university courses has also been widely affected, with a bigger range of preparedness and confidence than usual”.

In this paper it has been shown that students entering in 2021 across all grades have a wide range of preparedness but are generally less prepared than in previous years.

The results are also in line with the concerns of many when the A level results were released in August 2021 (e.g., Coughlan, Richardson, and Long, 2021) where there was a 75% increase in the number of A levels being award A*/A across all subjects when compared to 2019 and the last formal assessments. However, the analysis in this paper has also predicted that students at the lower grades arriving at Coventry University in 2021 perhaps performed better than their teacher assessed grade would suggest. As mentioned previously, many teachers felt under pressure to inflate their judgements (Golding, 2021) so perhaps there may have been the need to counter-balance inflated judgements by lowering some results at the C – E grade end of the scale. Alternatively, and indeed perhaps more likely, teacher assessed grades were only against the topics that were covered by that particular group. Consequently, it might be that A level grades appeared inflated because the students with higher grades performed worse on the harder topics in the diagnostic test than they would have been expected to, but these topics might not have been covered and assessed as part of their disrupted A levels. The weaker students however were not expected to do well on these harder topics regardless, so their performance would have perhaps been expected to be at least as good as pre-pandemic. Indeed, this hypothesis is supported by Table 3 where students with A*/A in 2021 did significantly worse in Calculus, which is a purely A level topic, and Trigonometric Functions, when compared to students in 2020. Furthermore, as it cannot be assumed that there are proportional odds between the A level grades in the model, it maybe this is also a reason for seeing the difference between the higher and lower grades.

This paper also set out to be an update to Hodds (2021), which looked at the initial effect on mathematical competencies using data from students arriving in September 2020. The findings of this paper are in contrast to the findings reported in Hodds (2021) which reported that students in 2020 were performing better or at a similar level to pre-pandemic cohorts. Despite this, the work of Golding (2021) perhaps provides a reason for why the 2020-21 cohort may have performed better than expected on the diagnostic test: "Within students' mathematical preparedness, academics expressed greatest confidence in students' basic knowledge, and application in their study area of mathematical facts and of core standard processes, which were on average considered near-adequate. Data handling and mathematical problem solving and reasoning within their study area were typically considered 'weak' to 'adequate', while students' ability to model mathematical situations, to engage with unfamiliar mathematical situations, to reason more abstractly and to communicate mathematically was an area for significant concern" (Golding, 2021, p.271). This suggests that, in 2020, students were perhaps reasonably well prepared for the topics that appear in the diagnostic test (as shown in Hodds (2021)) but not for the higher-level mathematical skills such as problem solving and mathematical reasoning. For students entering in 2021-22 it appears the effects of the pandemic on A level mathematics are perhaps more substantial, impacting even basic mathematical skills but only for students who had two years of interrupted learning. Indeed, it has been reported that students in Year 12 in 2019-20, who would be entering university in 2021, had poor engagement with their studies and the "… high-stakes environment [caused by] the additional challenges created by Covid-19 may have substantial impacts on students' learning and progression" (Redmond, Golding, and Grima, 2020, p.5). Redmond et al. (2020) go on to state that most teachers in their study predicted a significant reduction in attainment and learning outcomes, creating a barrier to confidence and progression within university courses with high mathematical content. The findings of this study support this suggestion and therefore there is perhaps a need to provide a greater level of maths support for these students.

Students' mathematical learning has been affected by the pandemic, predominantly due to having to learn remotely. Students have reported disliking the online learning of mathematics, often finding it challenging, demanding, and providing limited success (Golding, 2021). Furthermore, on arrival at university, staff providing mathematics support services, trying to avail any lack of mathematical competency, have also reported similar findings, suggesting that, on the whole, students prefer face-to-face mathematics support than online (Gilbert et al., 2021). Therefore, it appears that online learning of mathematics during the pandemic has not been as effective as traditional learning, perhaps being one of the reasons why students are less well prepared for the mathematics on their courses.

The work of Kinnear and Sangwin (2020) also shows the wide-ranging preparedness of students across different institutions in the UK, with an update to their work in 2021 also suggesting no change in their students' mathematical competence when compared to pre-pandemic entrants. However, the majority of students in Kinnear and Sangwin (2021) arrive with the minimum requirement of an A in Scottish Higher examinations, which are different to A levels, or a minimum of A level grade B, whereas Coventry University accept students with many lower A level grades. Therefore, straightforward comparisons may not be drawn. Nevertheless, both the data reported in this paper and the data in Kinnear and Sangwin (2021) suggest that there is indeed a larger range of mathematical preparedness and confidence within universities and across the sector in the UK than previously seen. It should be noted though that differences in results regarding attainment within a single country have been reported during the pandemic (e.g., Depping, Lücken, Musekamp, and Thonke, 2021; Schult, Mahler, Fauth, and Lindner, 2021). Indeed, the data reported here only considers students at one UK university and is therefore an important limitation of this work. To confirm these findings it would be useful to see more work published on diagnostic test data during, and since, the pandemic so that comparisons can be drawn and an overall picture of mathematical entrance competency in the UK can be considered.

Another limitation to be considered with this data is comparing the use of the online version(s) of the test to the paper-based version. The data from the paper-based version is the most secure as it was always taken on one day in examination conditions. The data from students in 2020 was provided through the online version utilising "Numbas" and Moodle. This data was open not only to cheating, as students took the test at home due to the lockdown and there was no lockdown browser, but also to students taking breaks (see Hodds (2021) for more details). The data in 2021 was more secure as "Wiseflow" provided a lockdown browser and around 80% of the tests were taken in exam conditions on campus. This still however provides opportunities for some of the results to not truly reflect students' abilities. However, given students did so poorly compared to previous years, it would perhaps be unlikely that they did not take the test seriously and as intended. Nevertheless, it maybe that the results seen in 2020 were perhaps slightly better than they should have been and results in 2021 may therefore seem worse than they should have been, although this is unlikely given the similarity of the predicted proportions of performance in 2020 and pre-Covid-19 shown in Table 2. Furthermore, the data in 2020 matches that of other diagnostic test data work conducted (e.g., Kinnear and Sangwin, 2020).

Despite the limitations, it is clear that the pandemic has severely impacted the learning and understanding of mathematics at all levels. The data reported in this paper shows that those students who experienced two years of disrupted learning are performing at a similar level to those around a decade ago when the university attracted a significantly larger proportion of students with the lowest A level grades. However, we must consider that it is not only students who took A levels during the pandemic that will be affected. Students studying across all years of education around the world have been impacted by lockdown learning methods, with studies starting to report that mathematical understanding has often suffered the worst (e.g., Kuhfeld et al., 2020; Schult et al., 2021). Their subsequent learning of mathematics may therefore be greatly impacted, perhaps causing a snowball effect of reduced understanding. Universities must be prepared for students who have lower mathematical preparedness than seen pre-pandemic and provide greater support to enable them to succeed. With further pressures being announced by the UK Government regarding progression and retention rates (see Department for Education, 2021), the work of mathematics and statistics support centres and the national support networks may become more valuable than ever going forward in finding the best ways of supporting and improving our students' mathematical competencies.

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Appendix A

The formulas below were used to calculate the probabilities of obtaining a particular A level grade according to the year of entry after qualification, syllabus, pandemic/pre-pandemic entry and score on the diagnostic test using data from students who entered Coventry University from 2014 – 2021. The first formulas are for students entering in 2021:

$$P(\text{Grade E or lower}) = \frac{e^{0.423-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{0.423-(0.101\times\text{Diagnostic Sco}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} \tag{1}$$

$$P(\text{Grade D or lower}) = \frac{e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{2.136-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} \tag{2}$$

$$P(\text{Grade C or lower}) = \frac{e^{3.896-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{3.896-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} \tag{3}$$

$$P(\text{Grade B or lower}) = \frac{e^{5.652-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{5.652-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} \tag{4}$$

$$P(\text{Grade A/A* or lower}) = 1 \tag{5}$$

The following formulas are for students who entered in 2020:

$$P(\text{Grade E or lower}) = \frac{e^{0.423-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}}{1+\ e^{0.423-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}} \tag{6}$$

$$P(\text{Grade D or lower}) = \frac{e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}}{1+\ e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}} \tag{7}$$

$$P(\text{Grade C or lower}) = \frac{e^{3.896-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}}{1+\ e^{3.896-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}} \tag{8}$$

$$P(\text{Grade B or lower}) = \frac{e^{5.652-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}}{1+\ e^{5.652-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336)}} \tag{9}$$

$$P(\text{Grade A/A* or lower}) = 1 \tag{10}$$

The following formulas are for students who entered pre-pandemic (2014-19):

$$P(\text{Grade E or lower}) = \frac{e^{0.423-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}}{1+\ e^{0.423-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}} \tag{11}$$

$$P(\text{Grade D or lower}) = \frac{e^{2.136-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}}{1+\ e^{2.136-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}} \tag{12}$$

$$P(\text{Grade C or lower}) = \frac{e^{3.896-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}}{1+\ e^{3.896-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}} \tag{13}$$

$$P(\text{Grade B or lower}) = \frac{e^{5.652-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}}{1+\ e^{5.652-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code})}} \tag{14}$$

$$P(\text{Grade A/A* or lower}) = 1 \tag{15}$$

Finally, the following formulas are for students who entered in 2020 but not in the year of their A level, therefore they include the interaction term:

$$P(\text{Grade E or lower}) = \frac{e^{0.423-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}}{1+\ e^{0.423-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}} \tag{16}$$

$$P(\text{Grade D or lower}) = \frac{e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}}{1+\ e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}} \tag{17}$$

$$P(\text{Grade C or lower}) = \frac{e^{3.896-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}}{1+\ e^{3.896-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}} \tag{18}$$

$$P(\text{Grade B or lower}) = \frac{e^{5.652-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}}{1+\ e^{5.652-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.336\text{-}0.781)}} \tag{19}$$

$$P(\text{Grade A/A* or lower}) = 1 \tag{20}$$

To calculate the probability of an individual grade, simply use the formula above then subtract the probabilities of all the grades below that grade. For example, for a student in 2021:

$$P(\text{Grade E}) = \frac{e^{0.423-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{0.423-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} \tag{21}$$

$$P(\text{Grade D}) = \frac{e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{2.136-(0.101\times\text{Diagnostic Score}+0.336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} - P(\text{Grade E}) \tag{22}$$

$$P(\text{Grade C}) = \frac{e^{3.896-(0.101\times\text{Diagnostic Sco}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{3.896-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} - P(\text{Grade D}) - P(\text{Grade E}) \tag{23}$$

$$P(\text{Grade B}) = \frac{e^{5.652-(0.101\times\text{Diagnostic Score}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}}{1+\ e^{5.652-(0.101\times\text{Diagnostic Sco}\quad .336\times\text{Year of Qualification Code}+0.18\times\text{Syllabus Code}+0.568)}} - P(\text{Grade C}) - P(\text{Grade D}) - P(\text{Grade E}) \tag{24}$$

$$P(\text{Grade A/A*}) = 1 - P(\text{Grade } B) - P(\text{Grade } C) - P(\text{Grade } D) - P(\text{Grade } E) \tag{25}$$

Figures 3 – 5 use equations 21 – 25 and equivalent versions for equations 6 – 15. These were chosen as they use data from students taking the post-2017 A level syllabus and entering in the year of qualification thus representing the biggest majority (89.3%) of students in the data set.