Rewarding Learning

Compendium of approaches taken and formulae used in GCE and GCSE calculation of grades, Summer 2020

A LEVEL PROPOSED GRADING MODEL SUMMER 2020

Introduction

In March 2020, the Education Minister (NI) instructed that the Summer 2020 examination series would be cancelled due to the COVID-19 pandemic and the associated risk to public health.

The Education Minister (NI) has since directed CCEA to *'Calculate grade outcomes based on a combination of teacher professional judgements (including grading and rank ordering by centres) and statistical modelling (enhanced with value added to account for improvements which would have resulted from resits)'.* CCEA Regulation will measure the proposed method outlined in this paper against this directive. The method will also be reviewed in terms of the following factors:

- Accuracy;
- Equality;
- Public acceptability/understandability

To facilitate the Ministerial Directive, CCEA have asked each centre to submit the following information:

- A centre assessment grade (CAG) for each candidate – the judgement submitted to CCEA by the Head of Centre about the grade that each candidate is most likely to have achieved if they had sat their exams and internally assessed components. Subject teachers and relevant heads of department derive this professional judgement from evidence that is held within the centre and which has been reviewed.
- The rank order of candidates within each grade – for example, for all those candidates with a grade C in A level Mathematics, a rank order where 1 is the highest attaining student, and so on. The proposed method is dependent on centres submitting an accurate rank order.

This information will be what teachers believe the candidate would get on the exam or assessment, based on their knowledge of the assessment and all the evidence they have from the candidate's work.

The proposed A level method calculates a grade for each candidate using a z-score method. This allows the likely grade distribution in each centre to be predicted. It then applies this grade distribution to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

The method will:

- Produce predicted centre grade distributions for A level candidates based on previous AS performance;
- Build in enhancement for improvements which would have resulted from resits;
- Grade candidates using the predicted grade distributions and centre rank orders derived from centre assessment grades;
- Assign grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

1. *JCQ – Estimating the missing mark when a candidate is absent from an examination*
2. *Estimating A level marks using z-scores (M. Paulin, March 2020)*

Data to be used for 2020 awarding:

- Candidate [1]AS results;
- Centre assessment grades;
- Centre rank orders.

The method is simple enough so that the precise calculations could be shared with centres and the public if necessary.

1. Comparison with Wales and England

A level qualifications in Wales have the same structure as those in Northern Ireland in that:

- A Level qualifications are unitised;
- AS forms part of the full A level qualification i.e. it is not decoupled. Previous AS performance data will therefore be available for the vast majority of A level candidates;
- AS is weighted at 40% of the full A Level qualification.

Given these similarities, it is likely the approach taken by CCEA in awarding candidates' grades will include many of the same elements used by WJEC in Wales. However, WJEC also offer linear qualifications under the Eduqas brand that are taken by candidates in England. WJEC's approach may differ from that of CCEA due to a desire for consistency in how WJEC's unitised and linear A level qualifications are awarded in summer 2020.

In England, the situation is very different for the following reasons:

- All A level qualifications are linear;
- AS qualifications are stand-alone and therefore decoupled from the full A level. This means that no prior AS performance data is available on which awarding organisations can base their awarding decisions.

Given these fundamental differences, particularly in the lack of AS performance data, it would not be appropriate for CCEA to adopt the same approach to awarding grades as that chosen in England. Furthermore, it is fair to assume that if awarding organisations operating in England had significant AS performance data, then this would be the primary source of data used to estimate grades.

2. CCEA's approach – using z-scores

The fundamental premise in CCEA's approach is that prior AS performance data will form the most reliable basis on which to award A level grades. CCEA research shows that there is a good correlation (correlation coefficient of 0.76) between AS performance and A level performance. The approach will draw on the tried and tested methodology of estimating missing uniform marks in units for which a candidate has been absent. All JCQ awarding bodies employ the same approach, known as the z-score method [1]. Under this procedure the difference between the candidate's estimate and the performance of candidates generally on the unit in question is the same as the average difference between the candidate's performance and the performance of candidates generally on the other units.

If the candidate performed on average slightly better than candidates generally on the other units, then the estimate for the missing mark will be slightly above the general performance on that unit.

[1] Note: Grade A is the highest grade awarded at AS level

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The difference between the performance of the candidate in question and the performance of candidates generally is measured in terms of standard deviations (σ) from the mean (μ).

Under normal circumstances, this procedure would be used in an ad hoc manner for candidates who were absent for a unit. The process uses the means and standard deviations from the unit(s) the candidate has sat along with the mean and standard deviation from the unit(s) the candidate did not sit to estimate a uniform mark for the missed unit. Normal practice is to use AS unit performance to estimate performance in other AS unit(s) and similarly A2 unit performance to estimate performance in other A2 unit(s). However, in Summer 2020, no candidates will have taken any A2 units so the procedure must be modified to allow for this scenario i.e., CCEA will use AS performance to estimate overall A level performance.

Approximately 98% of candidates entered for A2 units in Summer 2020 have uniform marks for all their AS units. For each candidate who is progressing to A2, CCEA intends to use this AS data to calculate a z-score which will then be used to estimate a **total** A level uniform mark.

A significant number of AS entries for Summer 2020 are for candidates who are resitting AS units from 2019. It is a reasonable assumption that candidates who are resitting a unit are doing so in order to improve their performance. An analysis of summer 2019 results shows that there were 19,735 AS unit resits. Of these, 14,952 (75.8%) improved their uniform mark, 634 (3.2%) saw no change and 4,149 (21.0%) got a lower mark than in their first sitting. *CCEA's proposed methodology must take account of the better performance which would result from candidates taking resits*.

3. Individual steps of A Level proposed method for estimating grades

1. Candidates entered for an AS resit in summer 2020 are identified and the average change in uniform marks, if positive, for that unit (based on their original notional grade) is added to their original uniform mark. This step builds in the value added which would have resulted in **any given year** from candidates resitting AS units.
2. Each candidate's total AS uniform marks, including marks adjusted to account for resit improvement, is then calculated.
3. Each candidate is given a z-score for their summer 2019 AS total, $z = \frac{m-\mu}{\sigma}$, using the mean and standard deviation for the distribution of AS totals in that subject in summer 2019.
4. Total A level marks for summer 2019 are calculated for each candidate to get a mean and standard deviation for each subject.
5. Each candidate's A level total is estimated using $m = z * \sigma + \mu$, where μ and σ are the mean and standard deviation for summer 2019 A level totals in the subject.
6. Grades A to U are assigned using standard uniform mark grade boundaries (80%, 70%, … 40%). Candidates with an A are assigned an A* if the difference between their estimated overall mark and their total AS mark is equal to or greater than 90% of marks available at A2 in the subject.
7. A centre grade distribution is generated using the grades calculated using the z-score method.
8. The grade distribution is applied to the centre rank order.

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4. Applying grade distribution to the centre rank order

Centres will submit a rank order and centre assessment grades (CAGs). Once a centre grade distribution has been generated using the method outlined in section 3 above, the predicted distribution will then be applied to the centre rank order. For example, if for a particular centre the model estimates that a centre should be awarded two A* grades, eight A grades, six B grades, two C grades and one D grade, then the top two candidates (with prior AS attainment) from the centre rank order would be awarded A*, the next eight would be awarded A and so on. In effect, CCEA is using its predicted grades to standardise the centre assessment grades. If centres are consistent in estimating their CAGs, then there will be good agreement between the grades issued by CCEA and those estimated by centres.

The method assigns grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

It should be noted that if a centre has been generous in its allocation of the higher grades then candidates who, for example, have been assigned a grade A by the centre might receive a grade B when the CCEA grade distribution is applied to the centre rank order. The opposite is also true i.e. if a centre has underestimated the number of candidates who should achieve the higher grades, then centre grade outcomes may improve when the CCEA grade distribution is applied. Importantly, the centre rank order in all scenarios is paramount and does not change.

5. Test results

CCEA's testing analysed results from multiple subjects (see Appendix 1) using multiple other z-score methods [2], however all of these were discounted in favour of the method outlined in section 3. A brief overview of each tested method is given in Appendix 2 along with the reasons why each was discounted.

All testing used 2018 AS performance data to calculate A level grades which were then compared to actual grades awarded in 2019 for the full cohort and the subset of resitting candidates. *All modelling and comparisons used final grades i.e. grades awarded after all reviews of marking had been completed*.

When the modelled grade outcomes generated using CCEA's proposed method (see section 3) were compared to actual grade outcomes in 2019, it was found that 53.1% of all candidates were awarded the same grade, 22.2% were awarded a lower grade and 24.7% of candidates were awarded a higher grade. In terms of candidates achieving the same grade, this method gave the highest level of correlation. 95.4% of candidates were awarded either the same grade or within one grade.

For the subset of resit candidates, 49% were awarded the same grade, 28% were awarded a lower grade and 23% were awarded a higher grade.

The proposed method also proved reliable in the generation of grade outcomes at A* and A. Outcomes at these grades must be reported annually to the regulatory authorities. The regulatory authorities expect CCEA AO to comply with the principle of 'comparable outcomes' in order to maintain standards year on year and across awarding organisations. This comparable outcomes approach assumes that 'if the group of students (cohort) taking the qualification in one year is of similar ability to the cohort in the previous year then the overall results (outcomes) should be comparable' (Ofqual.blog.gov.uk/2015/08/05).

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Table 1 shows the cumulative % difference between modelled grade outcomes for CCEA's proposed z-score method (for all candidates with AS data from 2018) against actual A level grade outcomes in summer 2019 at grades A* and A. The subjects included have a high resit entry across the majority or all AS units.

Subject	Grade A* cum. difference (compared to actual S2019)	Grade A*/A cum. difference (compared to actual S2019)	Reporting Tolerance (S2019)*
Biology	+2.6 %	-0.3 %	2%
Chemistry	+2.1 %	-0.6 %	2%
Physics	+1.1 %	-1.5%	2%
Geography	+1.3 %	-1.6 %	2%
History	+2.7 %	+2.2 %	2%
English Lit.	-0.8 %	+0.6 %	2%

** Reporting tolerances apply to matched candidate outcomes and are based on matched entry size. The percentage of matched candidates in the above subjects was 85.9% (Biology), 86% (Chemistry), 89% (Physics), 88.4% (Geography), 87.5% (History) and (86.2%) English Literature.*

Table 1

6. Advantages of using the proposed z-score method

CCEA's proposed approach has a number of advantages over the other methods tested.

1. In all other methods, the z-score was used to calculate marks for each individual A2 unit. These marks were then aggregated with each other and the AS unit marks to give an overall A level mark. However, CCEA's modelling shows that there is a degree of error when unit marks are calculated using z-scores. This means that every time a unit mark is calculated and then aggregated, the overall error increases. In the preferred method, the z-score is only used once to calculate a single A level uniform mark therefore limiting the degree of error in the process;
2. The proposed method is much simpler than any other models tested yet gives the highest accuracy in terms of candidates achieving the same grade as those actually awarded. This relative simplicity means that there is significantly less risk of error when applying the model;
3. The simplicity of the proposed method means that it will be more understandable by stakeholders and easier to explain.
4. If CCEA finds that outcomes at subject level fall outside the regulatory reporting tolerances, particularly on the low side, the simplicity of the preferred method makes it relatively straightforward to adjust outcomes.

7. Additional checks

CCEA will identify all candidates whose calculated grade differs by at least two grades (on the low side) compared to the centre assessment grade. In these cases, CCEA will review the reliability of the centre assessment grades as well as candidate performance in units already taken. Based on this review, CCEA might adjust a candidate's grade.

Similarly, CCEA will review centre grade outcomes for the previous 3 years. If any major anomalies are apparent, CCEA will check the data input for that particular centre and rerun the method to ensure that there have been no system or data errors.

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It is envisaged that grade changes based on the above scenarios will only be in exceptional circumstances. Strong protocols will be in place to ensure a fair and consistent approach for all candidates in all centres.

8. Exceptions

There are a number of scenarios which may require a different approach to awarding A level grades:

1. Where candidates have no AS marks in a subject but there are other candidates in that centre entered for A level cash-in who have AS data. In this scenario, the candidate(s) would be slotted into the CCEA rank order at the same position as they appear on the centre rank order. CCEA AO could then award a grade based on the grades of candidates who appear directly above and below the candidate on the CCEA AO rank order.
2. Where **all** candidates in a centre have completed the full A level course (AS and A2) in **one** year and there is therefore no AS data available e.g. Further Mathematics or Mathematics students. In this scenario, the AS approach which uses previous centre performance combined with prior attainment data (mean GCSE) could be used to predict % outcomes for each centre. These outcomes would then be applied to the centre rank order to award grades.
3. Where candidates have completed a qualification in two years but the A2 data (means and standard deviations) stored for previous cohorts is unreliable. This scenario specifically applies to A level Mathematics as the small cohort of 17 year old candidates who took the revised A level units for the first time in summer 19 are likely to be the most able students. Consequently, combining the A level unit results into one mark distribution will give an unusually high mean which when used with the z-score will almost certainly generate inflated outcomes. For Mathematics, the AS approach which draws on previous centre performance combined with prior attainment data (mean GCSE) may be more appropriate in predicting % outcomes for each centre. Alternatively, it may be possible to use scaled uniform mark totals for the legacy specification to estimate a mean and standard deviation for the full A level mark distribution. This could then be used with the z-score to calculate overall A level grades.

The regulatory authorities must approve any alternative methodology used for exceptions.

9. Conclusions

The approach that CCEA proposes to use in awarding A level grades in summer 2020 uses the most reliable data available i.e. previous AS performance, in combination with z-score methodology. The process also takes account of the improvement that would have resulted from candidates resitting units. Extensive testing has been carried out on a range of z-score methods and the proposed approach generates the most accurate overall outcomes. The method may share similarities with the approach used in Wales, giving a level of consistency across jurisdictions where the qualification structure is similar.

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Subjects tested

Grades were estimated for the following subjects:

Code	Title
0342	AL Environmental Tech' Cash-In
0612	AL Software Sys' Dev' Cash-In
0812	AL Sports Science Cash-In
0912	AL Performing Arts Cash-In
0932	AL Journalism Cash-In
1014	AL Biology Cash-In
1114	AL Chemistry Cash-In
1214	AL Physics Cash-In
2656	AL Digital Technology Cash-In
3214	AL Business Studies Cash-In
3314	AL Nutrition & Food Sc Cash-In
3514	AL Art and Design Cash-In
3834	AL History of Art Cash-In
3914	AL Geography Cash-In
4014	AL History Cash-In
4414	AL Economics Cash-In
4834	AL Gov't & Politics Cash-In
5114	AL English Literature Cash-In
5355	AL Moving Image Arts Cash-In
5554	AL Irish Cash-In
5654	AL French Cash-In
5674	AL German Cash-In
5754	AL Spanish Cash-In
7014	AL Music Cash-In
8904	AL Technology & Design Cash-In
4614	AL Religious Studies
8011	AL Life and Health Sciences (SA)
8012	AL Life and Health Science (DA)
9808	AL Health and Social Care (SA)
9814	AL Health and Social Care (DA)
3000	AL Professional Business Services

Revised A level Mathematics (2212) was excluded as they were first awarded in summer 2019, meaning no historical AS and A2 results were available for z-scores. Legacy Mathematics (2211) and Further Mathematics (2331) were also excluded. Applied I.C.T. (SA 9908, DA 9914) was awarded in summer 2019 but has no entries in summer 2020.

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Appendix 2

Overview of CCEA AO methodologies tested but discounted

Method*	Description	Reason why discounted
1	Z-scores were calculated for each candidate based on their AS unit results. An average of these z-scores was calculated for a subject, weighted by the number of uniform marks available in each unit. This was used to estimate missed A2 units.	This was a baseline model that included candidates who **did not** proceed to A level. Modelling also showed positive bias with 32% of candidates achieving a higher grade.
2	Same as method 1 except z-scores were calculated using means and standard deviations for only those candidates who proceeded to A level	Modelling showed that outcomes at subject level were unacceptably low in some subjects eg. Chemistry. Outcomes for resitting candidates were also adversely affected.
3	Same as method 1 except z-scores were calculated using AS results in units candidates **were not** resitting.	This method would exclude candidates who were resitting all AS units meaning a different approach would have to be used for these candidates – this was not acceptable.
4	Z-scores were calculated for all candidates progressing to A2 based on their first AS attempt for all units; A2 unit marks for all candidates were then calculated using these z-scores. For candidates who were resitting, z-scores were calculated using the mean and standard deviation for candidates sitting that unit for the first time who went on to do a resit. This z-score was then applied to the mean and standard deviation for candidates sitting a second time to estimate their resit mark. Candidates' grades were then calculated by aggregating either their actual AS marks (for candidates who were not resitting) or the estimated AS resit mark (for candidates who were resitting) with the calculated A2 unit marks.	This method was initially considered but was rejected due to its high level of complexity. This was judged to bring unnecessary risk to the process of awarding grades.
5	Same method used to estimate AS resit marks as in method 4. Estimated AS resit marks were then used when calculating a z-score for the A2 units.	Level of complexity was too high. Modelling showed that this method significantly overestimated outcomes for the full cohort and the cohort of resitters.
6	Candidate's AS resit mark estimated by simply adding the candidate's original mark to the mean change in uniform marks on resit at full cohort level.	Modelling showed that subject level outcomes for the full cohort and the cohort of resitters was adversely affected in some subjects.
7	Same as method 6 except the resit mark was estimated by simply adding the candidate's original mark to the mean change in uniform marks on resit at centre level	Modelling showed that subject level outcomes for the full cohort and the cohort of resitters were adversely affected in some subjects.

***** *A detailed description of the above methodologies and the modelled outcomes are contained with the CCEA AO paper entitled 'Estimating A level marks using z-scores' (M. Paulin, March 2020).*

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AS LEVEL PROPOSED GRADING MODEL 2020

Introduction

In March 2020, the Education Minister (NI) instructed that the Summer 2020 examination series would be cancelled due to the COVID-19 pandemic and the associated risk to public health.

In Northern Ireland, AS level forms part of the full A level qualification and is weighted at 40% of the total qualification. The 2020 AS grade will not be used for the 2021 A level grade and therefore the 2020 AS is decoupled from the A level.

The Education Minister has instructed CCEA to *'Award AS grades using a combination of teacher professional judgement (including grades and rank ordering by centres) and Mean GCSE scores'.* CCEA Regulation will measure the proposed method outlined in this paper against this directive. The method will also be reviewed in terms of the following factors:

- Accuracy;
- Equality;
- Public acceptability/understandability

To facilitate the Ministerial Directive, CCEA have asked each centre to submit the following information:

- A centre assessment grade (CAG) for each candidate – the judgement submitted to CCEA by the Head of Centre about the grade that each candidate is most likely to have achieved if they had sat their exams and internally assessed components. Subject teachers and relevant heads of department derive this professional judgement from evidence that is held within the centre and which has been reviewed.
- The rank order of candidates within each grade – for example, for all those candidates with a grade C in GCSE Mathematics, a rank order where 1 is the highest attaining student, and so on. The proposed method is dependent on centres submitting an accurate rank order.

This information will be what teachers believe the candidate would get on the exam or assessment, based on their knowledge of the assessment and all the evidence they have from the students' work.

The proposed AS method predicts the likely distribution of grades in each centre based on previous performance of the centre and prior attainment of candidates. It then assigns grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution. The predicted grade distribution created by the method can be tested now by using 2019 AS candidates, 2018/17 Mean GCSE data. The predicted grade distributions can then be compared with grades achieved in 2019. The use of rank orders cannot be tested until June as centre rank orders will not be submitted until then.

The method will

- Produce predicted grade distributions for AS candidates based on centre outcomes for the previous three years and candidates prior attainment (Mean GCSE).

- Grade candidates using the predicted grade distributions and centre rank orders derived from centre assessment grades.
- Assign grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

AS level data available for 2020 awarding:

- Centre previous outcomes.
- Candidate prior attainment based on GCSE Mean.
- Centre rank orders.
- Centre assessment grades.

The method will use previous published outcomes and students GCSE results; therefore, accuracy and equality are integrated. The method is simple and easily explained, for example;
Your centres' predicted performance this year is its performance in the previous three years with an adjustment for the prior attainment (at GCSE) of your students. If students are stronger, the outcomes will go up.

The method is also simple enough so that that the precise calculations can be shared with centres and the public if necessary.

1. Comparison with Wales and England

In Wales the AS qualification structure is identical to that in Northern Ireland in that:

- AS qualifications are unitised;
- AS forms part of the full A level qualification i.e. it is not decoupled;
- AS is weighted at 40% of the full A Level qualification.

The situation is England is somewhat different in that:

- All AS level qualifications are linear;
- AS qualifications are stand-alone and therefore decoupled from the full A level.

However, it is important to note that although the qualification structure is different across jurisdictions, the data available for estimating grades is the same i.e. previous centre outcomes, mean GCSE data, CAGs and centre rank orders. Therefore, the methods used across the three jurisdictions will share similar characteristics.

2. Individual Steps of the AS proposed method for estimating grades

1. Centre prior performance.

For each grade in each centre calculate the cumulative percentage[1] of students awarded the grade or above in the previous year(s). Calculate this using the following formula[2]:

[1] To simplify calculations (i.e. to avoid adding "100" in various places) all calculations are based on proportions (between 0 and 1) rather than percentages (between 0 and 100).
[2] The 'A' in the summation part of the formula represents the top grade A available at AS level.

$$c_{kj} = \frac{\sum_{m=k}^{A} n_{mj}}{n_j}$$

Where
c_{kj} is the calculated cumulative percentage for grade *k* in centre *j*.
n_{mj} is the number of students achieving grade *m* in centre *j*.
n_j is the total number of students in centre *j*.

To ensure progression and allow for improvements in recent years, the data should be the cumulative percentage achieving the final post review of marking (PostROM) grade or above over the previous three years (2017, 2018, 2019). If the centres are new, then use formula in Appendix 1.

2. Calculate predicted performance in each centre for the previous three years based on prior attainment.
Generate the predicted performance for centre j in 2017, 18, 19 (using the existing Mean GCSE prediction matrices reference year 2019, that will also be used to create predictions for 2020). The predicted cumulative percentage at grade k for matched candidates[3] in centre j in the previous three years is denoted p_{kj}. Prediction matrices used will be based on post review of marking (PostROM) data.

3. Calculate predicted performance in each centre for the 2020 based on prior attainment.
Using matched data for centre j in 2020, produce predictions for 2020 based on prior attainment, using the same prediction matrix as the previous step, reference 2019. The predicted cumulative percentage at grade k for matched candidates in centre j in 2020 is denoted q_{kj}.

4. Calculate lowest prior attainment match rate for 2020 and for the prior three years.
Calculate the proportion of students in centre j with matching prior attainment data in the previous three years as r_{j0}. This should be a number between 0 and 1. Calculate the proportion of students with matching prior attainment data in 2020 as r_{j1}. Use the lesser of these two match rates for subsequent calculations. Specifically,

$$r_j = \min(r_{j0}, r_{j1})$$

5. Produce a predicted cumulative percentage of students at grade k or above in each centre
If there is no matching prior attainment data directly, use c_{kj} as the prediction. If there is matching data for all students the prediction will be,

$$c_{kj} + q_{kj} - p_{kj}$$

It will therefore be the prediction based on previous performance (c_{kj}) but adjusted to reflect the extent to which each centre has performed relative to prior attainment predictions in the past.

[3] That is, those with available prior attainment data.

In a proportion of centres, some but not all students have matching prior attainment data. To include both sets of students in the prediction a weighted sum of the two ideas above is used. Specifically:

$$\boldsymbol{Prediction} = \boldsymbol{c_{kj}} + \boldsymbol{r_j}(\boldsymbol{q_{kj}} - \boldsymbol{p_{kj}})$$

Therefore, the centre's historic results from 2017, 18, 19 adjusted according to changes in prior attainment since then. This latter adjustment is only applied to the extent it is supported by matched data.

If the above approach resulted in an undesirable grade distribution at a national level, (e.g., too many students awarded Grade A) then it would be possible to apply an adjustment factor to the formula to control for this.

The final formula for predictions, with adjustment, would become:

$$\boldsymbol{c_{kj}} + \boldsymbol{r_j}(\boldsymbol{q_{kj}} - \boldsymbol{p_{kj}}) - \boldsymbol{A_k}$$

Where A_k is a national adjustment factor (+ or -) to the grade *k* predicted cumulative percentage applied to all centres equally within a given subject.

6. Predicted grade distribution applied to the centre rank order

Centres will submit a rank order and centre assessment grades (CAGs) in June 2020. Once a centre grade distribution has been generated using the above method, the predicted distribution will then be applied to the centre rank order. For example, if for a particular centre the method predicts that 38% should achieve grade A, 34% B, 20% C and 8% D, then the top 38% of candidates from the centre rank order would be awarded A, the next 34% would be awarded B and so on. In effect, CCEA is using its predicted outcomes to standardise the centre assessment grades. If centres are consistent in estimating their CAGs, then there will be good agreement between the grades issued by CCEA and those estimated by centres.

The method assigns grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

It should be noted that if a centre has been generous in its allocation of the higher grades then candidates who, for example, have been assigned a grade A by the centre might receive a grade B when the CCEA grade distribution is applied to the centre rank order. The opposite is also true i.e. if a centre has underestimated the number of candidates who should achieve the higher grades, then centre grade outcomes may improve when the CCEA grade distribution is applied. Importantly, the centre rank order in all scenarios is paramount and does not change.

3. Test Results

The 2020 live data model will use UK prediction matrices based on final post review of marking to predict 2020. This data is only available in late June 2020 therefore the AS testing used 'at time of award data' to predict 2019 grades and compare the prediction to actual 2019 results. There were a number of new subjects in 2019 and these do not have a predicted test grade but will have in the final modelling.

Difference between 2019 CCEA results and 2019 predicted test results

SUBJECT	Grade A	Grade E	2019 ENTRY	TOLERANCE
ART AND DESIGN	4.0	1.5	727	3%
BIOLOGY	0.1	0.4	3882	1%
BUSINESS STUDIES	0.7	-0.4	2122	2%
CHEMISTRY	0.2	-0.1	2642	2%
DIGITAL TECH	0.5	-3.6	1241	2%
ENGLISH LIT	0.1	0	2057	2%
FRENCH	1.6	-0.2	616	3%
GEOGRAPHY	-1	-0.3	2113	2%
G&P	-0.6	-1	1479	2%
HISTORY	1.5	-0.9	2299	2%
FOOD & NUTRITION	2.2	-0.7	803	3%
PHYSICS	2.6	0.3	1819	2%
RS	1.3	-0.1	2297	2%

This testing shows the statistical accuracy of the AS model in producing fair and accurate grade distributions for each subject. The majority of subjects would be within the usual reporting tolerance.

4. Advantages of using the proposed method

There are two distinct advantages of using CCEA's proposed approach.

1. The method is relatively simple and is therefore will be easily understood by stakeholders
2. It uses all the available data on candidates:
    - Three years previous centre performance;
    - Mean GCSE performance;
    - Centre assessment grades;
    - Centre rank orders.

5. Additional checks

CCEA AO will identify all candidates whose calculated grade differs by at least two grades (on the low side) compared to the centre assessment grade. In these cases, CCEA AO will review the reliability of the centre assessment grades. Based on this review, CCEA might adjust a candidate's grade.

Similarly, CCEA will review centre grade outcomes for the previous 3 years. If any major anomalies are apparent, CCEA will check the data input for that particular centre and rerun the model to ensure that there have been no system errors.

It is envisaged that grade changes based on the above scenarios will only be in exceptional circumstances. Strong protocols will be in place to ensure a fair and consistent approach for all candidates in all centres.

6. Exceptions

For very small centres, the proposed method may become less stable. In such cases, it may be more appropriate to utilise the centre assessment grades. A similar approach may also be required with new centres were no previous data is available. Whatever method is used will require regulatory approval.

7. Conclusions

The approach that CCEA AO proposes to use in awarding AS level grades in summer 2020 uses all of the data available. The approach will share similar characteristics with the approaches used in other jurisdictions i.e. England and Wales, giving a level of consistency in how grades will be awarded. Test results show that the method is reliable and generates expected grade outcomes.

Additional Options for new centres to be determined after testing.

The formula can also be written as follows:

$$Prediction = (1 - r_j)c_{kj} + r_j(c_{kj} + q_{kj} - p_{kj})$$

In other words, it is a weighted average of the formula we'd use for centres with all matched candidates and the formula we'd use in the case where we had no matched data.

Some slight optional adjustments

1. Replace c_{kj} with a weighted sum of national and centre performance

Rather than simply read the cumulative percentage at each grade or above from the previous year(s), replace it with

$$c_{kj} = \frac{C_k + \sum_{m=k}^{9} n_{mj}}{1 + n_j}$$

Where C_k is the national cumulative proportion of students achieving grade *k* or above in the previous year(s). In other words, we are imagining that each centre has one more pupil who gets a proportion of each possible grade according to the national proportion in each grade. This slight amendment will bring stability to the c_{kj} values for very small centres whilst hardly altering the predictions for larger centres at all. It also means that if a centre has no previous results then the national cumulative percentage is imputed without needing to be counted as an exception. Finally, it will ensure that all c_{kj} will be greater than 0 and less than 1. This provides some important options when it comes to rounding to predictions to whole numbers of students.

2. Where there is no data from the previous year(s) for a centre set $c_{kj} = p_{kj} = C_k$ and set $r_{j0} = 1$.

The above adjustment means that if there is no available data from the previous year(s) the centre's prediction is:

- q_{kj} in the case of all students having matching prior attainment data,
- C_k in the case of it having no prior attainment data (*and* no previous data),
- and is $C_k + r_{j1}\left(q_{kj} - C_k\right)$ otherwise. This allows the method to make sensible predictions of centre level attainment in all circumstances.

GCSE PROPOSED GRADING MODEL 2020

Introduction

In March 2020, the Education Minister (NI) instructed that the Summer 2020 examination series would be cancelled due to the COVID-19 pandemic and the associated risk to public health.

The Education Minister has instructed CCEA to award GCSE grades based on a combination of:

- *teacher professional judgement (including grades and rank ordering by centres), and*
- *average centre performance models: the model should include average centre performance at subject level over the past three summer series and controls to ensure similar proportions in current series'.*

CCEA Regulation will measure the proposed method outlined in this paper against this directive. The method will also be reviewed in terms of the following factors:

- Accuracy;
- Equality;
- Public acceptability/understandability

To facilitate the Ministerial Directive, CCEA have asked each centre to submit the following information:

- A centre assessment grade (CAG) for each candidate – the judgement submitted to CCEA by the Head of Centre about the grade that each candidate is most likely to have achieved if they had sat their exams and internally assessed components. Subject teachers and relevant heads of department derive this professional judgement from evidence that is held within the centre and which has been reviewed.
- The rank order of candidates within each grade – for example, for all those candidates with a grade C in GCSE Mathematics, a rank order where 1 is the highest attaining student, and so on. The proposed method is dependent on centres submitting an accurate rank order.

This information will be what teachers believe the candidate would get on the exam or assessment, based on their knowledge of the assessment and all the evidence they have from the students' work.

The proposed GCSE method predicts the likely distribution of grades in each centre based on previous performance of the centre. It then assigns grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

The method will:

- Produce predicted grade distributions for GCSE candidates based on centre outcomes for the previous three years.
- Grade candidates using the predicted grade distributions and centre rank orders derived from centre assessment grades.
- Assign grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

GCSE level data available for 2020 awarding:

- Centre previous outcomes.
- Centre rank orders.
- Centre assessment grades.

The method will use previous published GCSE outcomes; therefore, accuracy and equality are integrated. The method is also simple enough so that that the precise calculations can be shared with centres and the public if necessary.

1. Comparison with Wales and England

In Northern Ireland, GCSE students do not have summative prior attainment data at Key Stage 2 or 3, therefore prior attainment data for the 2020 cohort is not available to use when predicting grades. This is also likely to be the case in Wales. In England however, KS2 data is available and is used in conjunction with GCSE outcomes to construct matrices from which annual GCSE predictions are generated. The use of prior KS2 performance data will therefore form an integral part of the method used in England to predict candidates' GCSE grades.

In the absence of KS2 or KS3 data, CCEA's proposed method uses a weighted average of the three years previous centre performance. Centre performance tends not to vary significantly over examination series. In fact, it is on this basis that CCEA annually predicts GCSE outcomes in advance of awarding. This is known as the 'Common Centres' approach and its use at GCSE is a regulatory requirement for both CCEA and WJEC.

2. Individual Steps of the GCSE proposed method for estimating grades

The Minister asked that CCEA should ensure, **as far as it is possible**, that qualifications standards are maintained and the distribution of grades follows a similar pattern to that in previous years. The CCEA proposed method outlined below is designed to do achieve this.

For CCEA, GCSE grading changed in 2019, therefore CCEA has recoded the grades for 2017 and 18 using 2019 subject grade boundaries including the new boundaries for C* and B. The A* grade for 2017 and 2018 was reset using the 'tailored' formula. To ensure standards are maintained (as much as possible), 2019 will be triple weighted in the model and 2018 double weighted. All previous centre outcomes are for results after reviews of marking and appeals have been completed.

For each grade in each centre CCEA will calculate the cumulative percentage of candidates to be awarded the grade or above using the following formula:

$$C_{20} = \frac{3c_{19} + 2c_{18} + c_{17} \ + T_{19}}{3n_{19} + 2n_{18} + n_{17} + 1}$$

Where

C_{20} is the cumulative proportion of candidates in the subject in the centre expected to be awarded the grade (or better) in the June 2020 series.

c_{19} is the cumulative number of candidates from the centre who achieved the grade (or better) in the subject in the June 2019 series.

c_{18} is the cumulative number of candidates from the centre who achieved the grade (or better) in the subject in the June 2018 series.

c_{17} is the cumulative number of candidates from the centre who achieved the grade (or better) in the subject in the June 2017 series.

T_{19} is the cumulative proportion of the national (CCEA total) cohort who achieved the grade (or better) in the subject in the June 2019 series.

n_{19} is the number of results issued to the centre in the June 2019 series.

n_{18} is the number of results issued to the centre in the June 2018 series.

n_{17} is the number of results issued to the centre in the June 2017 series.

The aim of this model is to determine the cumulative number of candidates who are expected to be awarded a specific grade (or better) for each centre in a specified subject. The model will be applied to each centre for each subject at all grades (A*-G).

Step 1: The number of candidates who achieved the grade (or better) in 2017, 2018 and 2019 within a centre are totalled and added to the national (CCEA total) cohort who achieved that grade or better in 2019. Taking grade C as an example, the number of candidates include those who achieved grade C, B, A and A*. This creates a cumulative total for grade C. The cumulative grade C total for each of the three years (2017, 2018 and 2019) are added together. *In order to account for smaller centres, and standardise outcomes, the national (total) cohort who achieved cumulative grade C in 2019 is also added to the three-year centre level total.*

Step 2: Add the total number of results issued (all grades) to the centre for the last three years (2017, 2018 and 2019) plus 1 (to stabilise and account for smaller centres). It should be noted that in both step 1 and 2, 2019 data will be weighted by 3 (e.g. cumulative grade C total multiplied by 3, total centre grades multiplied by 3) and 2018 is weighted by 2. There is no need for weighting in 2017. *This weighting allows the model to account for progression over the past three years and to prioritise 2019 as the current GCSE standard.*

Step 3: To determine the cumulative number of candidates to be awarded grade C (or better) the value from step 1 (3 year centre-level outcomes plus national cohort) is divided by step 2 (total number of centre results for last 3 years).

The formula will be applied to each subject in each centre and provides a prediction of the centre's grade distribution based on a weighted average of the previous 3 years, giving more weight to more recent years.

Step 4: The centres grade distribution is then applied to the centre rank order. Centres will submit a rank order and centre assessment grades (CAGs) in June 2020. Once a centre grade distribution has been generated using the above method, the predicted distribution will then be applied to the centre rank order. For example, if for a particular centre the method predicts that 10% should achieve A*, 28% should achieve grade A, 34% B, 13% C*, 7% C and 8% D, then the top 10% of candidates from the centre rank order would be awarded A*, the next 28% would be awarded A and so on. In effect, CCEA is using its predicted outcomes to standardise the centre assessment grades. If

centres are consistent in estimating their CAGs, then there will be good agreement between the grades issued by CCEA and those estimated by centres.

The method assigns grades to candidates within each centre to retain their original rank order and to match the predicted grade distribution.

It should be noted that if a centre has been generous in its allocation of the higher grades then candidates who, for example, have been assigned a grade A by the centre might receive a grade B when the CCEA grade distribution is applied to the centre rank order. The opposite is also true i.e. if a centre has underestimated the number of candidates who should achieve the higher grades, then centre grade outcomes may improve when the CCEA grade distribution is applied. Importantly, the centre rank order in all scenarios is paramount and does not change.

If when the grade distribution is applied to the centre rank order, this does not result in a whole number of candidates receiving a grade, then CCEA will always round up. For example if the model predicts 9.3 candidates should be awarded grade B then 10 candidates would be awarded the grade.

3. Test Results

To ascertain which weighting would prove most accurate at predicting centres' grade distributions, the method was tested using various weightings starting with none (baseline). The 3,2,1 weighting shown in the formula in section 2 proved the most successful in accurately predicting candidates' grades.

In order to show that the GCSE model provides accurate grade distributions, a comparison of the grades predicted by the model and the 2019 actual results was conducted. The subject-level grade distributions as a percentage (proportion*100 = percent) predicted by the GCSE model were compared to the 2019 outcomes after reviews of marking and appeals had been completed.

The test data shows that the differences between the subject-level model predicted outcomes and the 2019 outcomes are very small. Results indicate that in the majority of grades (92.7%), the difference between the model predicted outcomes and 2019 outcomes is two percentage points or less. The largest difference in favour of the model predicted outcome is in Journalism at grade D (6.9 percentage points). The largest difference in favour of the 2019 outcome is in Mathematics at grade B (5.3 percentage points). It should be noted that there were only 8 grades out of 438 possible grades which showed a difference of more than 3 percentage points in favour of 2019 outcomes (Agriculture and Land Use grades C* and C; Irish grade A*; Leisure and Tourism grades B, C* and F; Mathematics grades B and C*).

N.B. A comprehensive report on all testing of the GCSE method has been completed and is available for review[1]**.**

4. Advantages of using the proposed method

1. It uses a range of data on candidates:
    - Three years previous centre performance;

[1] *GCSE 2020 Statistical Modelling Report, CCEA Research and Statistics, May 2020.*

- National cohort outcomes;
- Centre assessment grades;
- Centre rank orders.

2. It regrades outcomes in 2017 and 2018 to align with the new GCSE grading scale.
3. The weighting allows the model to account for progression over the past three years and to prioritise 2019 as the current GCSE standard.
4. The national outcome at a particular grade has been incorporated to account for smaller centres and standardise outcomes.
5. The method is relatively simple and is therefore will be easily understood by stakeholders.

5. Additional checks

CCEA will identify all candidates whose calculated grade differs by at least two grades (on the low side) compared to the centre assessment grade. In these cases, CCEA will review the reliability of the centre assessment grades. Based on this review, CCEA might adjust a candidate's grade.

Similarly, CCEA will review centre grade outcomes for the previous 3 years. If any major anomalies are apparent, CCEA will check the data input for that particular centre and rerun the model to ensure that there have been no system errors.

It is envisaged that grade changes based on the above scenarios will only be in exceptional circumstances. Strong protocols will be in place to ensure a fair and consistent approach for all candidates in all centres.

6. Exceptions

For very small centres, the proposed method may become less stable. In such cases, it may be more appropriate to utilise the centre assessment grades. A similar approach may also be required with new centres were no previous data is available. Whatever method is used will require regulatory approval.

Summary of A Level /AS qualification formulae used

Candidates entered to resit a unit in summer 2020 have their resit mark estimated as:

$$m_{u,resit} = m_u + \mu_{u,g}$$

where u is the unit, m_u is the candidate's original uniform mark in the unit, g is their original notional grade in the unit and $\mu_{u,g}$ is the mean change in uniform marks for candidates resitting unit u with original notional grade g.

For each candidate in the centre with AS units, a z-score is calculated:

$$z = \frac{m_s - \mu_s}{\sigma_s}$$

where m_s is the total uniform mark in the candidate's AS units including estimated resit marks, μ_s is the mean AS total uniform mark for all candidates in the subject and σ_s is the standard deviation for AS total uniform marks in the subject.

A level marks are estimated using:

$$m_a = \mu_a + z * \sigma_a$$

where μ_a is the mean total uniform mark in the subject in summer 2019 and σ_a is the standard deviation.

Grade boundaries are applied to the set of A level marks estimated for the centre to produce a grade distribution, which is applied to the centre assessed rank order.

Summer 2020 AS level

1. Centre prior performance.

For each grade in each centre calculate the cumulative percentage of students awarded the grade or above in the previous year(s). Calculate this using the following formula[1]:

$$c_{kj} = \frac{\sum_{m=k}^{A} n_{mj}}{n_j}$$

Where

c_{kj} is the calculated cumulative percentage for grade *k* in centre *j*.

n_{mj} is the number of students achieving grade *m* in centre *j*.

n_j is the total number of students in centre *j*.

2. Calculate predicted performance in each centre for the previous three years based on prior attainment.

Generate the predicted performance for centre *j* in 2017, 18, 19 (using the existing Mean GCSE prediction matrices that will also be used to create predictions for 2020). The predicted cumulative

[1] The 'A' in the summation part of the formula represents the top grade A available at AS level.

percentage at grade k for matched candidates[2] in centre j in the previous three years is denoted p_{kj}. Prediction matrices used will be based on post review of marking (PostROM) data.

3. Calculate predicted performance in each centre for the 2020 based on prior attainment.
Using matched data for centre j in 2020, produce predictions for 2020 based on prior attainment, using the same prediction matrix as the previous step. The predicted cumulative percentage at grade k for matched candidates in centre j in 2020 is denoted q_{kj}.

4. Calculate lowest prior attainment match rate for 2020 and for the prior three years.
Calculate the proportion of students in centre j with matching prior attainment data in the previous three years as r_{j0}. This should be a number between 0 and 1. Calculate the proportion of students with matching prior attainment data in 2020 as r_{j1}. Use the lesser of these two match rates for subsequent calculations. Specifically,

$$r_j = \min(r_{j0}, r_{j1})$$

5. Produce a predicted cumulative percentage of students at grade k or above in each centre
If there is no matching prior attainment data directly, use c_{kj} as the prediction. If there is matching data for all students, the prediction will be,

$$c_{kj} + q_{kj} - p_{kj}$$

In a proportion of centres, some but not all students have matching prior attainment data. To include both sets of students in the prediction a weighted sum of the two ideas above is used. Specifically:

$$\boldsymbol{c_{kj} + r_j(q_{kj} - p_{kj})}$$

Therefore, the centre's historic results from 2017, 18, 19, adjusted according to changes in prior attainment since then. This latter adjustment is only applied to the extent it is supported by matched data.
If the above approach resulted in an undesirable grade distribution at a national level, then it would be possible to apply an adjustment factor to the formula to control for this.

The final formula for centre predicted grade distribution.

$$\boldsymbol{c_{kj} + r_j(q_{kj} - p_{kj}) - A_k}$$

Centre predicted grade distribution applied to the centre assessed rank order.

[2] That is, those with available prior attainment data.

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