GL Assessment®

GL Education®

TECHNICAL REPORT –
UK & IRELAND EDITION

CAT4®

COGNITIVE ABILITIES TEST

Contents

CAT4 UK EDITION

Test reliability

The reliability of a test is a measure of the consistency of a student's test scores over repeated testing, assuming conditions remain the same – that is, there was no fatigue, learning effect or lack of motivation. Tests with poor reliability might result in very different scores for a student across two test administrations.

The reliability of the test was estimated using the Cronbach's Alpha formula which produces values ranging from 0 to 1. Values above 0.80 are considered to be very good. The reliability values for the various *CAT4* batteries are given in the table below, and all show that the tests are very reliable. These are based on students who took part in the UK standardisation.

	***CAT4* reliability**				
***CAT4* level**	**Verbal Reasoning Battery**	**Quantitative Reasoning Battery**	**Nonverbal Reasoning Battery**	**Spatial Ability Battery**	**Overall *CAT4***
Level X	0.93	0.91	0.87	0.83	0.95
Level Y	0.89	0.88	0.89	0.78	0.94
Pre-A	0.82	0.81	0.78	0.67	0.90
A	0.91	0.91	0.90	0.87	0.97
B	0.89	0.90	0.90	0.88	0.96
C	0.86	0.91	0.87	0.85	0.96
D	0.90	0.91	0.89	0.86	0.96
E	0.89	0.88	0.86	0.88	0.96
F	0.89	0.87	0.85	0.88	0.96
G	0.90	0.84	0.85	0.86	0.95
Average	**0.89**	**0.88**	**0.87**	**0.84**	**0.95**

For interpreting the score of an individual student, the standard error of measurement (*SEM*) is a more useful statistic than a reliability coefficient. It indicates how large, on average, the fluctuations in standard scores may be. The *SEM* for the Verbal Reasoning Battery is 5.0, which indicates that there is a 68% chance that the student's true verbal SAS will be in the range +/- 5.0. For example, for an average-performing student with a verbal SAS of 100, there is a 68% chance that his or her true verbal score is in a range from 95 to 105.

	***CAT4* Standard error of measurement (*SEM*)**				
***CAT4* level**	**Verbal Reasoning Battery**	**Quantitative Reasoning Battery**	**Nonverbal Reasoning Battery**	**Spatial Ability Battery**	**Overall *CAT4***
Average	5 .0	5.2	5.4	6.0	3.4

However, most tests show the 90% chance or confidence bands. For values around the average, the 90% confidence band is as follows:

	CAT4 90% confidence band				
***CAT4* level**	**Verbal Reasoning Battery**	**Quantitative Reasoning Battery**	**Nonverbal Reasoning Battery**	**Spatial Ability Battery**	**Overall *CAT4***
Average	+/- 8	+/- 9	+/- 9	+/- 10	+/- 6

For example, for an average-performing student with a verbal SAS of 100, there is a 90% chance that the true verbal score is in a range from 92 to 108.

Test re-test reliability

A study of 3,883 students who took Level D and subsequently took Level F two years later showed the correlation for the mean *CAT4* SAS between the two time points was high at 0.88. The correlations for the overall mean *CAT4* SAS and the four batteries are shown in the table below:

	Correlation between Level D and Level F SAS
Mean *CAT4*	0.88
Verbal	0.80
Quantitative	0.75
Nonverbal	0.71
Spatial	0.74

The results showed a high level of consistency and: 62% of students had mean *CAT4* scores within +/- 5 SAS points; 90% of students had mean *CAT4* scores within +/- 10 *SAS* points.

Cognitive Abilities Test and National Test indicators

There has always been a significant and positive correlation between a student's scores in reasoning tests and their school performance, as measured by national tests or public examinations. The link may be assumed to exist because much school activity is concerned with the application of reasoning abilities in the initial learning of curriculum content, and then building on and recombining existing knowledge as learning progresses.

The indicators that feature in reports for the Cognitive Abilities Test are derived by tracking the progress of large and representative samples of students over time. Through this process, we can determine the actual relationship between *CAT4* scores and students' subsequent

attainment in national tests and examinations.

Through statistical analysis of the matched datasets, we are able to provide indicated or typical outcomes for each student based on the students' *CAT4* scores. These indicators can also be aggregated to provide indicated outcomes for the cohort and school or college as a whole. These indicators are updated regularly to keep them in line with national trends of performance in national tests and examinations.

Key Stage 2 National Test indicators: England

The KS2 indicators are derived from an analysis of the relationship between *CAT4* scores from Level A to Level C and KS2 test results at age 11 from a large and nationally representative sample of around 24,000 students taking the KS2 SATS in 2019. This relationship between *CAT4* scores and KS2 SATS is also used to estimate the retrospective KS2 indicators. These indicators are updated regularly as we get new data.

Correlations of *CAT4* and KS2 scaled scores

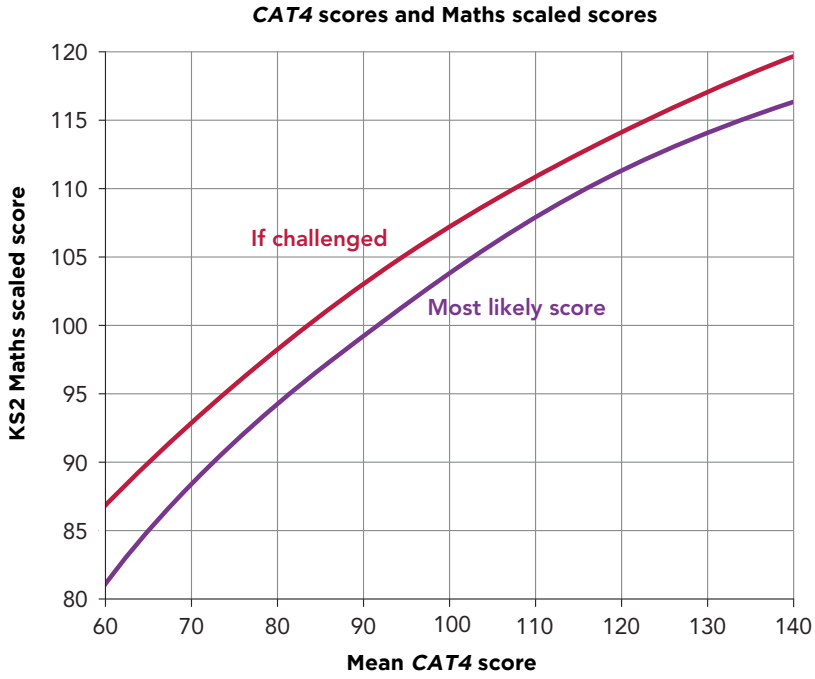
There is a strong relationship between *CAT4* scores and Key Stage 2 outcomes. The strength of the relationship between two variables can be measured by a statistic called the correlation coefficient. A value of zero indicates no relationship between the two measures, whereas a value of one indicates a perfect positive relationship. The table below

KS2 SATS scaled scores	Mean *CAT4* score	Verbal SAS	Quantitative SAS	Nonverbal SAS	Spatial SAS
Mathematics	0.70	0.62	0.67	0.60	0.56
Reading	0.67	0.70	0.62	0.54	0.48
Grammar, Punctuation and Spelling	0.66	0.67	0.62	0.54	0.48

shows the correlation coefficients between *CAT4* standard age scores (SAS) and students' subsequent KS2 scaled score outcomes.

The correlations are all highly significant. The Mathematics outcomes tend to have their highest correlation with the mean *CAT4* SAS. The *CAT4* Verbal Reasoning score gives a slightly higher or similar correlation than the mean *CAT4* score for English Reading, and Grammar, Punctuation and Spelling.

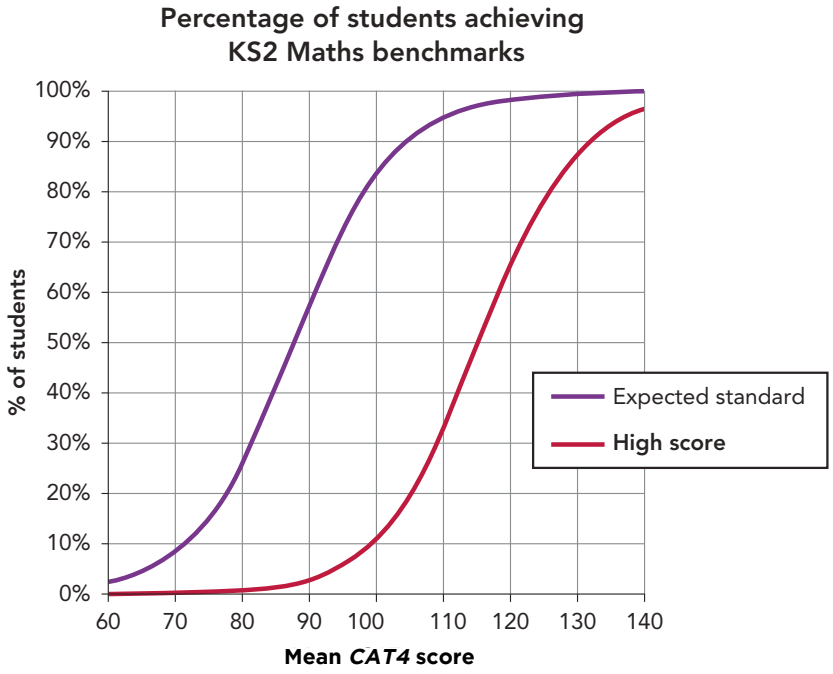
The graph below illustrates the relationship between the mean *CAT4* score and the KS2 Mathematics scaled scores. It shows the most likely scaled score and the score if the student is challenged. We can see that the scaled scores increase as the *CAT4* scores increase.



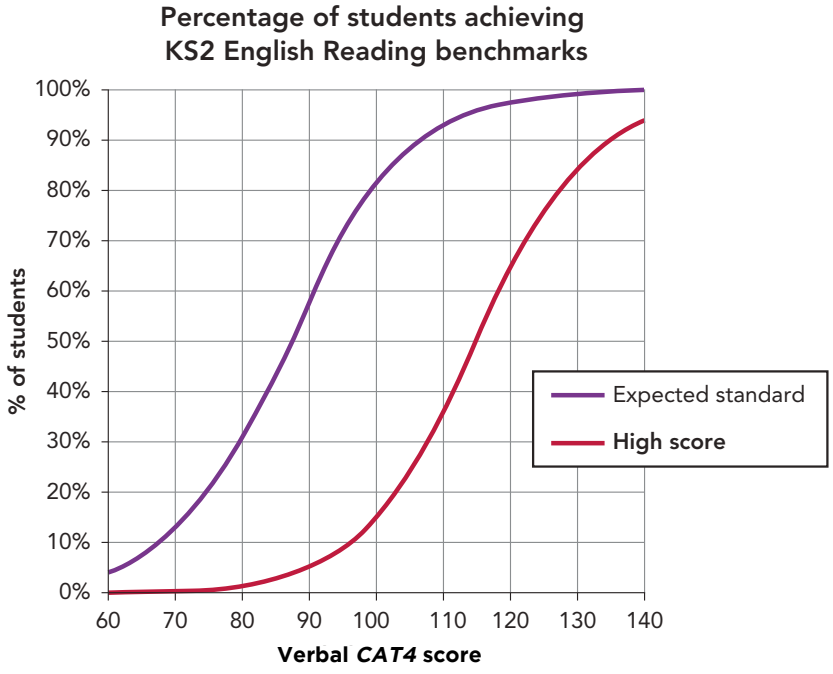
For example, a student with a mean *CAT4* score of 90, the 'most likely' Mathematics scaled score is 99 and the 'if challenged' threshold is 103. Not all students with a mean *CAT4* score of 90 will get a Mathematics scaled score of 99. The 'most likely' score is an average, so around half of the students with mean *CAT4* scores of 90 will obtain a Mathematics scaled score below 99; 25% of the students will obtain a Mathematics scaled score of between 99 and 102; and 25% of the students will obtain an 'if challenged' score of 103 or above.

Likelihood of Key Stage 2 indicated standard

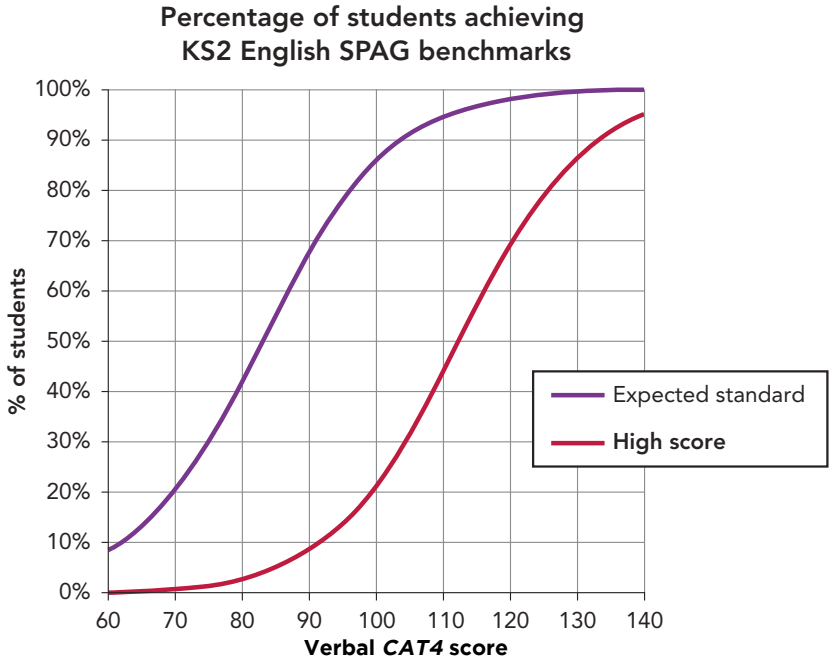
The graph below illustrates the proportion of students achieving a scaled score of 100 (the government's expected standard) or the high score of 110 for Mathematics for each mean *CAT4* score. We can see that the higher the mean *CAT4* score, the greater the proportion of students who achieve the government's benchmark or above. For example, 58% of students with a mean *CAT4* score of 90 obtained the expected standard of 100 or above in Mathematics; in contrast, about 95% of students with a mean *CAT4* score of 110 achieved this.



The chart below illustrates the relationship between the Verbal *CAT4* score and the KS2 English Reading benchmarks.



The chart below illustrates the relationship between the Verbal *CAT4* score and the KS2 English Spelling, and Grammar (*SPAG*) benchmarks.



KS2 indicators for groups of students

The table below illustrates how the group/class indicators have been calculated for a fictitious group of five students and shows the probability of obtaining different KS2 Mathematics benchmarks.

			Probability of students reaching	
	Mean *CAT4* score	**Most likely scaled score achieved in Mathematics**	**Expected standard = 100**	**High score = 110**
Student 1	85	97	41%	2%
Student 2	95	102	73%	6%
Student 3	106	106	92%	23%
Student 4	109	108	95%	31%
Student 5	111	108	96%	37%
		Average	80%	20%
		Number of students achieving:	4	1

The individual student indicators do not show any of these five students likely to obtain a high scaled score benchmark of 110 or more. However, some students have a high chance of achieving this, e.g. student 5 has a 37% chance of obtaining a high score of 110 or more. Overall for this group of five students we expect 20% (i.e. one out of the five students) to achieve the high score. As an illustration, if your group has 10 students all with mean *CAT4* scores of 106, the most likely outcome for each of these 10 students individually is a scaled score of 106. However, it is likely that 23% of these students (i.e. two out of the 10 students) will achieve the high score.

The group level indicators are the average of the probabilities for all students in the group. Our research has shown that this method provides the most accurate set of group level indicators. However, group indicators are extremely sensitive to variations in the number of students in the group, and may be very unstable for groups of less than 30 students. Group indicators should only ever be taken as a rough guide to the possible future performance of a class.

Key Stage 2 National Test indicators: Wales

The *CAT4* KS2 reports for Wales show estimates of the Literacy and Numeracy National Tests age-standardised scores as well as estimates of teacher assessment levels.

The table below shows the correlations between *CAT4* and the Year 6 National Tests and teacher assessments. This is based on a study of around 2,500 students who completed *CAT4* and the National Tests in Wales.

Welsh test	Mean *CAT4* score	Verbal SAS
Literacy	0.68	0.70
Numeracy (Procedural)	0.70	0.60
Numeracy (Reasoning)	0.64	0.54
English teacher assessment	0.66	0.67
Maths teacher assessment	0.69	0.62
Science teacher assessment	0.65	0.63
Welsh 2nd subject teacher assessment	0.54	0.55

The correlations are all highly significant. The Mathematics and Science outcomes tend to have their highest correlation with the mean *CAT4* SAS. The *CAT4* Verbal Reasoning score alone gives a slightly higher correlation than the mean *CAT4* score for Literacy, English and Welsh 2nd subject.

GCSE indicators

The GCSE indicators are derived from an analysis of the relationship between *CAT4* scores from Level D and above and GCSE examination results at age 16 for a large and nationally representative sample of around 91,000 students in 2019. These indicators are updated regularly as we get new data.

Correlations of *CAT4* and GCSE grades

As already stated, the strength of the relationship between two variables can be measured by a statistic called the correlation coefficient. A value of zero indicates no relationship between the two measures, whereas a value of one indicates a perfect positive relationship. The table below shows the correlation coefficients between *CAT4* standard age scores and pupils' subsequent GCSE outcomes.

	Mean *CAT4* score	Verbal SAS	Quantitative SAS	Nonverbal SAS	Spatial SAS
Attainment 8*	0.72	0.67	0.64	0.61	0.57
Art and Design	0.48	0.44	0.38	0.41	0.42
Biology	0.62	0.57	0.53	0.49	0.47
Business Studies	0.56	0.45	0.52	0.49	0.40
Chemistry	0.57	0.50	0.50	0.45	0.43
Citizenship	0.51	0.52	0.45	0.41	0.35
Computer Studies	0.65	0.60	0.56	0.53	0.51
Design and Technology	0.55	0.47	0.51	0.45	0.46
Drama	0.55	0.55	0.45	0.47	0.42
English Language	0.62	0.62	0.53	0.51	0.46
English Literature	0.58	0.57	0.50	0.48	0.43
Food and Nutrition	0.61	0.59	0.53	0.51	0.47
French	0.53	0.54	0.45	0.43	0.38
Geography	0.68	0.65	0.59	0.56	0.52
German	0.53	0.54	0.45	0.42	0.38
History	0.60	0.59	0.52	0.48	0.43
ICT	0.52	0.43	0.49	0.46	0.38
Maths	0.78	0.66	0.72	0.66	0.63
Media Studies	0.50	0.41	0.48	0.42	0.38
Music	0.56	0.55	0.50	0.44	0.45
Physical Education	0.60	0.56	0.52	0.49	0.46
Physics	0.60	0.52	0.52	0.47	0.46
Religious Education	0.53	0.52	0.46	0.44	0.37
Science Combined	0.66	0.59	0.56	0.55	0.50
Sociology	0.48	0.39	0.48	0.40	0.34
Spanish	0.45	0.44	0.38	0.37	0.35
Statistics	0.72	0.60	0.60	0.67	0.57

*Attainment 8 score is used in England

The correlations are all highly significant. Most GCSE outcomes tend to have their highest correlation with mean *CAT4* score. The exceptions are English Language and English Literature where the *CAT4* Verbal Reasoning score gives a slightly higher correlation than mean *CAT4* score.

Likelihood of GCSE indicated grades

The example below illustrates the probabilities of achieving the various GCSE 9-1 grades in Mathematics (U is ungraded) for a student with a mean *CAT4* score of 100. The indicators are not precise: they indicate the outcomes expected for students with a particular *CAT4* score making average progress in a typical secondary school.

Student name	**Mean *CAT4* score**	**Mathematics GCSE grades – probabilities**									**Most likely grade achieved**
		U/1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
John Sims	100	2%	4%	11%	34%	30%	11%	5%	2%	0%	4.9

The 'most likely grade achieved' is reported to one decimal place. In this case the student is expected to be on the top end of grade 4 as he has a 52% chance of achieving grade 4 or below and a 48% chance of achieving grade 5 or above, so the expectation is that the student is near the grade 4/5 boundary.

The example below illustrates the probabilities of achieving the various GCSE A*-G grades in History (U is ungraded) for a student with a mean *CAT4* score of 100.

Student name	**Mean *CAT4* score**	**History GCSE grades – probabilities most likely**									**Most likely grade achieved**
		U	G	F	E	D	C	B	A	A*	
John Sims	100	2%	2%	5%	11%	18%	26%	22%	11%	3%	C

The 'most likely grade achieved' is grade C with the student having a 64% chance of achieving grade C or below and a 34% chance of achieving grade B or above.

GCSE grade indicators for groups of students

The table below illustrates how the group/class indicators have been calculated for a fictitious class with five students and shows the most likely grade achieved and the probabilities associated with getting different Mathematics 9-1 grades. The group indicator is an average of the individual student outcomes and probabilities. A similar method is used for subjects using the A*-G grades.

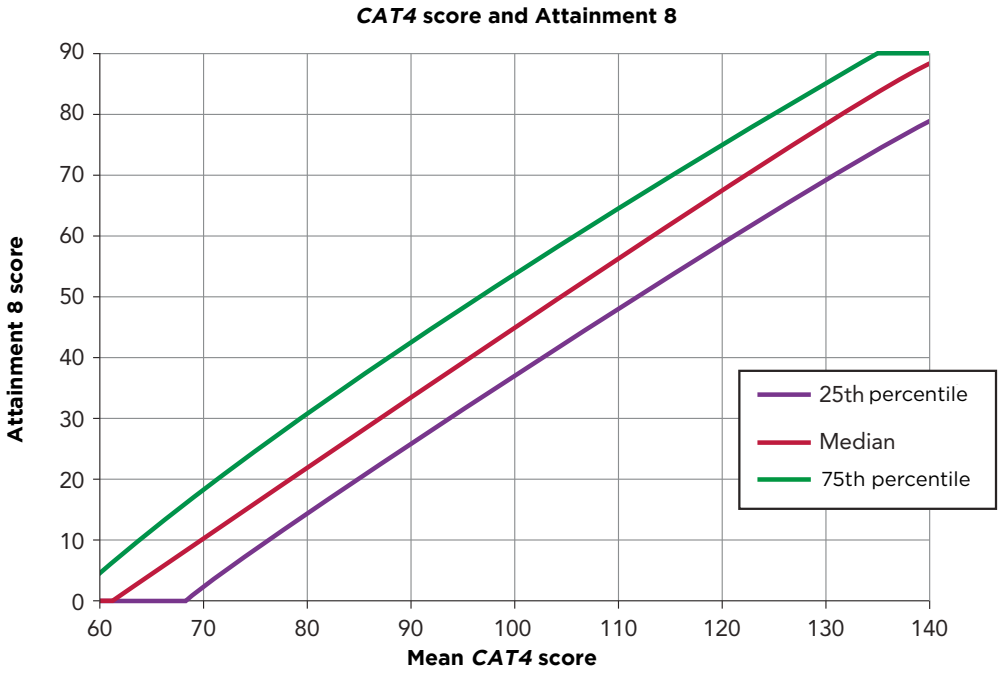
Using individual student grade estimates to provide information about the overall class or group grade outcomes will in most cases lead to underestimating the number of students likely to get both the higher and lower GCSE grades.

Student	Mean *CAT4* score	Attainment 8 score	Mathematics GCSE grades – probabilities									Most likely grade achieved
			U/1	2	3	4	5	6	7	8	9	
1	70	11	78%	14%	5%	2%	0%	0%	0%	0%	0%	1
2	85	29	21%	26%	27%	20%	5%	1%	0%	0%	0%	2.8
3	100	46	2%	4%	11%	34%	30%	11%	5%	2%	0%	4.9
4	115	63	0%	0%	1%	6%	17%	23%	28%	18%	6%	6.9
5	140	79	0%	0%	0%	0%	0%	1%	3%	13%	83%	9
Group indicator (average)		46	20%	9%	9%	12%	11%	7%	7%	7%	18%	4.9

The group level indicators are the average of the probabilities for all students in the group. Our research has shown that this method provides the most accurate set of group level indicators. However, group indicators are extremely sensitive to variations in the number of students in the group, and may be very unstable for groups of less than 30 students. Group indicators should only ever be taken as a rough guide to the possible future performance of a class.

CAT4 and GCSE Attainment 8

The graph below illustrates the relationship between *CAT4* score and the Attainment 8 score.



For example, for a student with a mean *CAT4* score of 90, the most likely Attainment 8 is 42 and the 'if challenged' score is 49. Not all students with a mean *CAT4* score of 90 will get an Attainment 8 score of 35.

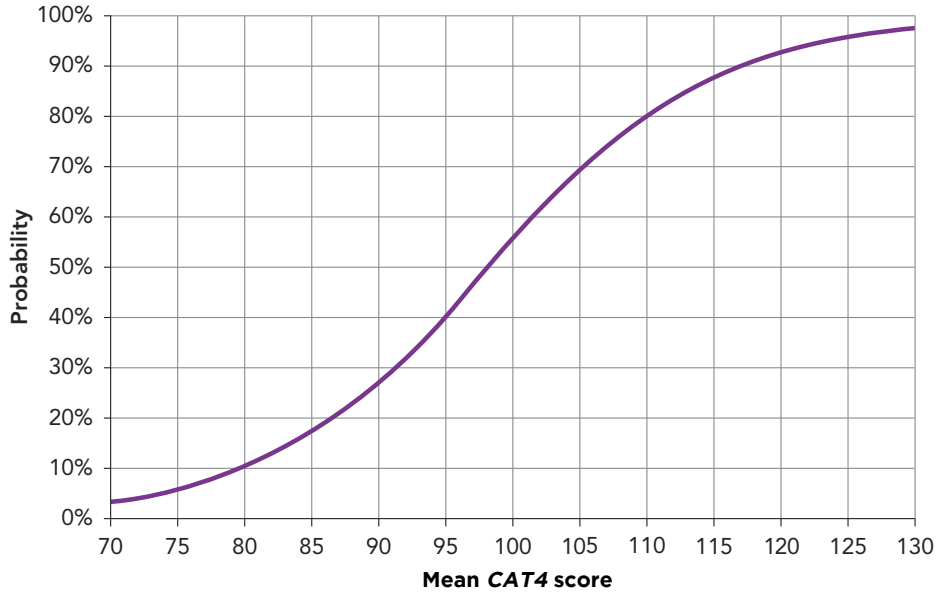
Around half the students will get an Attainment 8 score below 35, with around 25% of the students obtaining an Attainment 8 score of less than 26 – the bottom 25th percentile. Around 25% of students will obtain the 'if challenged' score of 43 and above.

CAT4 and GCSE grades A*-G

Wales is retaining the current A*-G grading system; but in Northern Ireland the GCSE grading system is currently the same as for England, using the mixture of A*-G and 9-1 grades. A new structure based on a revised A*-G grading system was implemented in Northern Ireland in summer 2019. The new A* aligns closely to grade 9, and a new C* grade is equivalent to grade 5.

The graph below illustrates the proportion of students achieving five+ GCSE grades 9-4 (A*-C) including English and Mathematics for each mean *CAT4* score. We can see that the higher the mean *CAT4* score, the greater the proportion of students who achieve five or more A* to C grades. For example, only 17% of students with a mean *CAT4* score of 85 obtain five+ 9-4 (A*-C) grades; in contrast, about 89% of students with a mean *CAT4* score of 115 achieve five+ 9-4 (A*-C) grades.

Probability of five or more GCSEs at grades A*–C including English and Mathematics



Setting targets

The above confirms the need for suitably cautious interpretation when using the indicators with staff and parents, and particularly if sharing them with individual students. In the latter context, we would advise that school staff follow the established best practice of schools, using the results for mentoring and target-setting purposes by:

- stressing to students that the indicators are a statistical prediction, not a prophecy of their actual Key Stage or GCSE results;
- emphasising to students the range of outcomes that could be achieved;
- emphasising the importance of the students' motivation and effort in determining the grade they obtain, identifying any areas in which the student requires greater support from the teacher;
- not using the indicators to label students as actual or potential 'failures';
- setting the indicators in the context of all other known relevant factors and other assessment information, thus making sure targets are reasonable.

CAT4 trialling

Pre-trials

Small-scale trials were conducted in autumn 2009 to check some of the new questions being developed for the *CAT4* Spatial Ability Battery. Three versions of the new spatial test were created and were trialled with approximately 850 students in Years 4, 6, 8 and 9. Results from this study were used to develop further spatial questions for the main trials.

Main trials

The main trials of all the questions in all four batteries of *CAT4* were carried out in autumn 2010.

The numbers of students taking part in the trials were as follows:

Trial sample	
Year	**Number of students**
4	2,028
6	1,870
8	2,179
10	2,114
Total	8,191

For the trials, 24 test booklets were created, that is six test booklets for each year group. All students took Verbal Classification and Figure Recognition plus two of the remaining six test types, so that all items were taken by at least 300 students. Some of the questions were duplicated in booklets across year groups.

The data from the trials were analysed to provide information on the difficulty level of each question, its ability to discriminate between high and low scorers, and the extent to which it proved equally difficult for both sexes, once each sex's general level of performance was taken into account. This information was then used to select and order the sequences of questions for the final standardisation version of *CAT4*.

CAT4 UK standardisation: levels Pre-A to G

The standardisation of *CAT4* took place between September and December 2011 in England, Wales, Scotland and Northern Ireland. A national database of schools was created and schools were grouped into 10 categories – by country (Wales, Scotland and Northern Ireland) and, for England, further grouped into independent or grammar, plus five categories of school intake based on the proportion of students taking free school meals.

Schools were selected by stratified random sampling procedures within these groupings. As this was a national sample, many schools taking part in the standardisation had never used *CAT4* before. For the standardisation, schools were asked to do one pre-selected *CAT4* test level and were given an option to do other levels. Schools were free to choose between the paper and digital version of the test. Primary schools were asked to test all students in the year group but secondary schools had the option either to test two randomly selected teaching groups if they tested by paper, or to test the whole year group if they chose the digital option.

The numbers of students taking part in the standardisation were as follows:

	Standardisation sample		
Country	**Primary**	**Secondary**	**Total**
England	4,663	13,085	17,748
Wales	269	2,169	2,438
Scotland	259	2,439	2,698
Northern Ireland	179	1,645	1,824
Total	5,370	19,338	24,708

These numbers were compared with the national population:

	Standardisation sample			National population
Country	**Primary**	**Secondary**	**Total**	
England	87%	68%	72%	83%
Wales	5%	11%	10%	5%
Scotland	5%	13%	11%	8%
Northern Ireland	3%	9%	7%	3%
Total	100%	100%	100%	100%

Note: Totals may not add up to 100% due to rounding

The primary school sample is slightly over-represented by students from England and under-represented by students from Scotland. The secondary school sample is over-represented by students from Wales, Scotland and Northern Ireland and under-represented by students from England. The standardisation results were therefore weighted to account for sample bias.

The numbers of students doing the paper and digital editions are given below:

	Number of students in standardisation sample, by delivery method		
Delivery mode	**Primary**	**Secondary**	**Total**
Digital	1,123 (21%)	13,412 (69%)	14,535 (59%)
Paper	4,247 (79%)	5,926 (31%)	10,173 (41%)
Total	5,370	19,338	24,708

CAT4 UK standardisation: levels X and Y

Pre-trials

CAT4 Levels X and Y were developed after the main *CAT4* Levels A-G were published. Small-scale trials were conducted in Autumn 2009 to check some of the new spatial questions being developed for the *CAT4*. Three versions of the spatial tests were created and were trialled with around 850 students in Years 4, 6, 8 and 9. Results from this study informed the development of further spatial questions for trialling.

Main trials

The main trials of the *CAT4* Levels X and Y questions were carried out in Autumn 2013. Approximately 1200 students in Years 2 and 3 took part in the trials.

Four test booklets were created - two test booklets for each year group. Around 300 pupils took each booklet, with the parallel booklets of each year group alternated within a class. All the questions used in *CAT4* Levels X and Y were used in the trialling with some of the questions duplicated in booklets across the two different year groups.

The data from the trials were analysed to provide information on the difficulty level of each question, its ability to discriminate between high and low scorers and the extent to which it proved equally difficult for both sexes, once overall score was taken into account. This information was then used to select and order the sequences of questions for the final standardisation version. Two versions of the test were created: Form X for 7 year-olds (Year 2 in England and Wales or equivalent) and Form Y for 8 year-olds (Year 3 in England and Wales or equivalent).

Standardisation

The standardisation of *CAT4* Levels X and Y took place between May and June 2014 in England, Wales, Scotland and Northern Ireland. A national database of schools was created and schools were grouped into nine categories by country and within England. This was further grouped into 'Independent' plus five categories of maintained sector schools based on the proportion of students taking free school meals.

Schools were selected by stratified random sampling procedures within

these groupings. As this was a national sample, many schools taking part in the standardisation had never used *CAT4* before. Around 1900 students completed Form X and around 1100 students completed Form Y. The standardisation results were weighted to account for sample response bias.

The mean *CAT4* Levels X and Y standard age scores (SAS) for males and females for Levels X and Y are in the tables below.

Level X

Gender		Nonverbal SAS	Verbal SAS	Quantitative SAS	Spatial SAS	Mean *CAT4* score
Females	Mean	102.4	102.4	100.1	100.5	101.5
	N	944	941	941	941	945
	Std. Deviation	14.9	15.0	14.0	14.8	11.4
Males	Mean	98.6	98.6	100.3	99.3	99.2
	N	981	966	967	962	984
	Std. Deviation	14.6	14.8	16.9	15.0	12.0
Total including unknown	Mean	100.5	100.5	100.2	100.0	100.4
	N	1931	1913	1914	1909	1934
	Std. Deviation	14.8	15.0	15.5	14.9	11.8

Level Y

Gender		Nonverbal SAS	Verbal SAS	Quantitative SAS	Spatial SAS	Mean *CAT4* score
Females	Mean	102.8	103.2	100.4	100.6	101.8
	N	533	533	538	538	539
	Std. Deviation	14.8	14.8	14.8	14.2	11.9
Males	Mean	98.4	98.1	100.8	99.6	99.3
	N	550	550	548	548	550
	Std. Deviation	14.4	14.8	17.1	15.1	12.1
Total including unknown	Mean	100.5	100.6	100.6	100.1	100.6
	N	1082	1083	1086	1086	1088
	Std. Deviation	14.7	15.0	16.0	14.6	12.1

Overall, female mean *CAT4* scores are around 2 SAS points higher than for males for both Levels X and Y. In particular, the mean Verbal and Nonverbal scores are around 4 SAS points for females.

Note that the mean *CAT4* score is not a Standard Age Score but an average of the nonverbal, verbal, quantitative and spatial SAS. The standard deviation for the mean *CAT4* score is around 12, lower than the 15 that is expected for an SAS. This does not indicate the sample was unrepresentative in its spread of ability: rather, that the scores for the four components are correlated, so the spread narrows as scores are averaged.

CAT4 and teacher assessment levels

There is a significant and positive correlation between student's *CAT4* scores and their school performance, as measured by national tests or public examinations. The link may be assumed to exist because a lot of school activity is concerned with the application of reasoning abilities in the initial learning of curriculum content, and then building on and recombining existing knowledge as learning progresses.

During the standardisation, teachers in England and Wales were asked to provide information on students' current teacher assessment (TA) levels in English, Maths and Science for Level X.

The strength of a relationship between two measures can be expressed with a statistic termed a correlation coefficient. This coefficient goes from 0, indicating no relationship to 1 indicating a perfect relationship.

The table below shows the correlations between the *CAT4* standard age scores (SAS) and the TA levels. The mean *CAT4* score is the average of the verbal, quantitative, spatial and non-verbal reasoning SAS scores. The correlation coefficients are all highly significant. The figures in bold are the highest correlations for each test outcome. The mean of the scores on all three batteries gives the highest correlations for Maths and Science. For English, the verbal battery gives a slightly higher correlation than the mean *CAT4* score. Teachers reported sub-levels for English and Maths but reported whole levels for Science. The correlations with Science are slightly lower because the Science TA levels are reported as whole levels and hence do not discriminate as well.

Level X	**Correlation**		
	English level	**Maths level**	**Science level**
Nonverbal SAS	0.41	0.39	0.37
Verbal SAS	**0.65**	0.57	0.52
Quantitative SAS	0.47	0.48	0.40
Spatial SAS	0.42	0.43	0.43
Mean CAT4 score	0.63	**0.61**	**0.55**

Note: Figures in bold are the highest correlations for each outcome.

Evaluating differences between *CAT4* scores

Evaluating a difference between two scores, whether scores on two different tests or scores on the same test on two occasions, has to be a three-stage process.

Statistical significance of differences

First, it needs to be decided if the difference is large enough to be considered as 'real' rather than just a result of having imprecisely measured the two scores. This depends upon the test reliability of each of the two scores and, hence, the 'noise' around each one.

The measurement error when calculating a difference between two scores is evaluated using a coefficient called the standard error of measurement difference (SEM_{diff}).

The SEM_{diff} for *CAT4* scores is approximately seven standard score points. Consequently, if two scores are more than seven SAS points apart, it is 68% likely that they are real, and if they are 11 points apart, the likelihood is 90% that the difference is a real one.

Rarity of differences

Second, if the difference is 'real' or statistically significant, then the **unusualness** or **rarity** of the difference has to be evaluated. A significant difference can sometimes be very common. For example, if you use a millimetre ruler to measure a boy's height when he is seven and then again when he is eight, the difference between these two heights can be measured very accurately to within two millimetres. Therefore 'real' or statistically significant differences will be very common in a sample of boys because the difference between the heights is likely to be substantially greater than two millimetres in almost all cases.

The spread of difference in scores can be determined either directly from the data or by a formula that takes into account the spread of scores on each test and the correlation between the two sets of scores. If the sample size is large enough, the two methods will produce very similar results; this was the case for the standardisation of *CAT4*. The formula used is:

$$SEM_{diff} = \sqrt{(SD_1^2 + SD_2^2 - 2r_{12}\, SD_1 SD_2)}$$

where SD_1 and SD_2 are the standard deviations of the scores on each test and r_{12} is the correlation between the two tests.

When looking at differences between a child's scores on the same battery on two occasions (e.g. Verbal in Year 7 and Verbal in Year 8) the table below can be used[1]. For example, a score increase of 11 SAS points or more will occur with between 10% and 15% of children, but a decrease of 17 or more points will occur with only the most extreme 5%.

Difference in SAS scores from first to second occasion	Percentage of students obtaining this extent and direction of difference
Increases by >16	5%
Increases by >12	10%
Increases by >9	15%
Decreases by >9	15%
Decreases by >12	10%
Decreases by >16	5%

When looking at score differences between different batteries (e.g. Quantitative and Nonverbal), this table should be used instead[2]. The SAS score differences are larger in this situation because the two measures are of different underlying mental processes and so tend to be less highly correlated than two scores on the same test.

Difference in SAS scores from Battery 1 to Battery 2	Percentage of students obtaining this extent and direction of difference
Higher by >19	5%
Higher by >15	10%
Higher by >12	15%
Lower by >12	15%
Lower by >15	10%
Lower by >19	5%

[1] The figures in the table have assumed a mean correlation of 0.8 between the two occasions.

[2] The figures in the table have assumed a mean correlation of 0.7 between pairs of batteries.

Practical significance of differences

Finally, it needs to be remembered that a difference between two batteries which occurs commonly in the general population is not necessarily insignificant. It can indicate a real, albeit common, difference between the development of the cognitive abilities underlying the two battery scores, with implications for the ways in which the student concerned is likely to progress academically. Such differences need to be interpreted in the light of all that is known of a student's background and educational record. For example, students who have a background of poor socio-economic and educational opportunities who gain higher scores for Nonverbal Reasoning than for Verbal Reasoning may not have any real difference between their abilities to reason with words and with shapes. Instead, they may not have had the chance to acquire the basic reading and word knowledge needed to perform well on the verbal tasks. On the other hand, if they have good socio-economic and educational backgrounds, then the score difference may suggest that there is a genuine difference in abilities to think with words and with shapes.

Gender differences

The table below shows the mean SAS scores and standard deviation for each of the *CAT4* batteries and for primary and secondary schools. The results are based on 2,578 females and 2,792 males from primary schools; 9,471 females and 9,867 males from secondary schools.

School type	Gender		Verbal Reasoning SAS	Quantitative Reasoning SAS	Nonverbal Reasoning SAS	Spatial Reasoning SAS	Mean *CAT4* SAS
Primary	Female	Mean	100.8	99.3	100.1	99.4	99.9
		Std. Deviation	14.4	13.9	14.6	14.5	12.3
	Male	Mean	99.3	100.9	99.9	100.8	100.2
		Std. deviation	15.4	15.9	15.3	15.3	13.4
	Total	Mean	100.0	100.1	100.0	100.1	100.1
		Std. deviation	14.9	15.0	15.0	14.9	12.9
Secondary	Female	Mean	100.5	99.1	100.5	100.4	100.1
		Std. deviation	14.4	13.4	14.2	14.2	12.1
	Male	Mean	99.5	101.3	99.7	99.8	100.1
		Std. deviation	15.5	16.1	15.6	15.4	13.6
	Total	Mean	100.0	100.1	100.1	100.1	100.1
		Std. deviation	15.0	14.8	14.9	14.8	12.8

Verbal Reasoning scores in primary schools are on average around 1.5 SAS points higher for females than for males. In contrast, Spatial and Quantitative Reasoning scores are around 1.5 SAS points higher for males than for females. There is not much of a gender difference for Nonverbal reasoning.

In secondary schools the Quantitative Reasoning scores are on average around two SAS points lower for females than for males. Average gender score differences for the other *CAT4* batteries are smaller – all within one SAS point.

The spread of scores as measured by the standard deviation is in general greater for males than for females. Therefore you are more likely to get proportionately more males than females having the extreme low or high SAS scores.

Verbal-Spatial profile

The table below shows the proportion of males and females within the verbal-spatial profile for primary and secondary schools.

	Primary			Secondary		
Verbal-Spatial Profile	Female	Male	Total	Female	Male	Total
Extreme spatial bias	1%	2%	1%	1%	2%	2%
Moderate spatial bias	3%	6%	5%	3%	6%	5%
Mild spatial bias	9%	11%	10%	9%	14%	11%
No bias	68%	67%	68%	66%	63%	65%
Mild verbal bias	13%	9%	11%	13%	10%	11%
Moderate verbal bias	5%	3%	4%	5%	4%	5%
Extreme verbal bias	1%	1%	1%	2%	1%	2%
	100%	100%	100%	100%	100%	100%

Note: Totals may not add up to 100% due to rounding

A total of 19% of females in primary schools have a verbal bias (mild, moderate and extreme categories) compared to 13% of males. In contrast, 19% of males in primary schools have a spatial bias compared with 13% of females.

A total of 20% of females in secondary schools have a verbal bias compared to 15% of males. In contrast, 22% of males in secondary schools have a spatial bias compared with 13% of females.

The gender difference among those with an extreme bias to spatial thinking are more striking. Overall, 2.3% of males show this profile, compared with only 0.8% of females. The bias is less differentiated by gender for those with an extreme bias to verbal thinking, with overall 1.8% of females and 1.3% of males being this category.

Paper-digital comparison study

Two studies were conducted to see if there was a difference in the way students scored between the paper and digital editions of *CAT4*.

- The overall numbers of students doing the digital and paper versions in the standardisation sample were large. This allowed a study to be undertaken looking at the relative difference in scores between those students doing paper and digital editions during the *CAT4* standardisation.
- The second study, also in autumn 2011, looked at the results of an equivalence study conducted in three year groups. Around 1,300 students in this study did both the paper and digital versions of the *CAT4* Nonverbal Battery for Levels A, B and E. To reduce practice effects, around half the students completed the paper edition first followed by the digital while the other half took the digital edition first followed by the paper.

The results of both studies have shown small differences in scores, with students completing the paper edition scoring slightly higher on average than on the digital edition. For example, the Nonverbal Reasoning Battery Level E paper raw score is, on average, half a mark higher than for the digital edition and around one mark higher for Level B.

The normative scores have therefore been adjusted to take into account any differences in the way students respond digitally or on paper.

CAT4 IRISH EDITION

CAT4 Irish standardisation

Irish age-based norms for the *CAT4* were derived from the administration of four levels of the tests (D to G) to students in random samples of primary and second-level schools nationwide in 2012. The Irish version of the tests has the same content as the UK edition and is aimed at the following students:

Test level	Suitable for	Age range
Level D	5th and 6th classes	10:06-12:11
Level E	End 6th/First Year	11:06-13:11
Level F	Second/Third Year	12:06-15:11
Level G	Fourth/Fifth Year	14:06-17:00+

The numbers of students used in the Irish standardisations were as follows:

Test level	Number of students
Level D	1,733
Level E	1,818
Level F	1,678
Level G	1,387
Total	6,617

Test reliability

The reliability of a test is a measure of the consistency of a student's test scores over repeated testing, assuming conditions remain the same – that is, there was no fatigue, learning effect or lack of motivation. Tests with poor reliability might result in very different scores for a student across two test administrations.

The test reliabilities of the Irish version are high and are similar to the UK edition.

	***CAT4* reliability**				
Test level	**Verbal Reasoning Battery**	**Quantitative Reasoning Battery**	**Nonverbal Reasoning Battery**	**Spatial Ability Battery**	**Overall *CAT4***
Level D	0.89	0.90	0.88	0.87	0.96
Level E	0.89	0.88	0.86	0.87	0.95
Level F	0.90	0.87	0.84	0.88	0.95
Level G	0.91	0.86	0.83	0.88	0.95
Average D-G	**0.90**	**0.88**	**0.85**	**0.87**	**0.95**

For interpreting the score of an individual student, the standard error of measurement (*SEM*) is a more useful statistic than a reliability coefficient. It indicates how large, on average, the fluctuations in standard scores may be. The *SEM* for the Verbal Reasoning Battery is 4.8, which indicates that there is a 68% chance that the student's true verbal SAS will be in the range +/- 4.8. For example, for an average-performing student with a verbal SAS of 100, there is a 68% chance that his or her true verbal score is in a range from 95 to 105.

	***CAT4* standard error of measurement (*SEM*)**				
***CAT4* level**	**Verbal Reasoning Battery**	**Quantitative Reasoning Battery**	**Nonverbal Reasoning Battery**	**Spatial Ability Battery**	**Overall *CAT4***
Average D-G	4.8	5.3	5.8	5.3	3.0

However, most tests show the 90% chance or confidence bands. For values around the average, the 90% confidence band is as follows:

	***CAT4* 90% confidence band**				
***CAT4* level**	**Verbal Reasoning Battery**	**Quantitative Reasoning Battery**	**Nonverbal Reasoning Battery**	**Spatial Ability Battery**	**Overall *CAT4***
Average D-G	+/- 8	+/- 9	+/- 9	+/- 9	+/- 5

For example, for an average-performing student with a verbal SAS of 100, there is a 90% chance that the true verbal score is in a range from 92 to 108.

Gender differences

The table below shows the average SAS scores for all the students who took part in the Irish standardisation, by gender.

Gender		**Verbal Reasoning SAS**	**Quantitative Reasoning SAS**	**Nonverbal Reasoning SAS**	**Spatial Reasoning SAS**	**Mean *CAT4* SAS**
Female	Mean	100.4	98.9	100.6	99.5	99.8
	Number of students	3,750	3,745	3,750	3,715	3,766
Male	Mean	99.6	101.9	99.6	101.1	100.4
	Number of students	2,714	2,700	2,719	2,676	2,737
Total	Mean	100.0	100.1	100.2	100.2	100.1
	Number of students	6,574	6,556	6,578	6,499	6,617

Males were on average around three SAS points higher and around 1.5 SAS points higher for Spatial. Females were around one SAS point higher than for males the Verbal and Nonverbal Batteries.

Irish Leaving Certificate indicators

Results were collected from 870 students who completed *CAT4* and the Leaving Certificate. Subject grades were obtained as either Ordinary (O) or Higher (H) level. The equivalence between the Ordinary and Higher grades as set out in https://www.cao.ie/index.php?page=scoring&s=lcepointsgrid was used to combine results from the two levels to a common scale. For example, Higher 6 grade is equivalent to Ordinary 2 grade and both of these have 46 points.

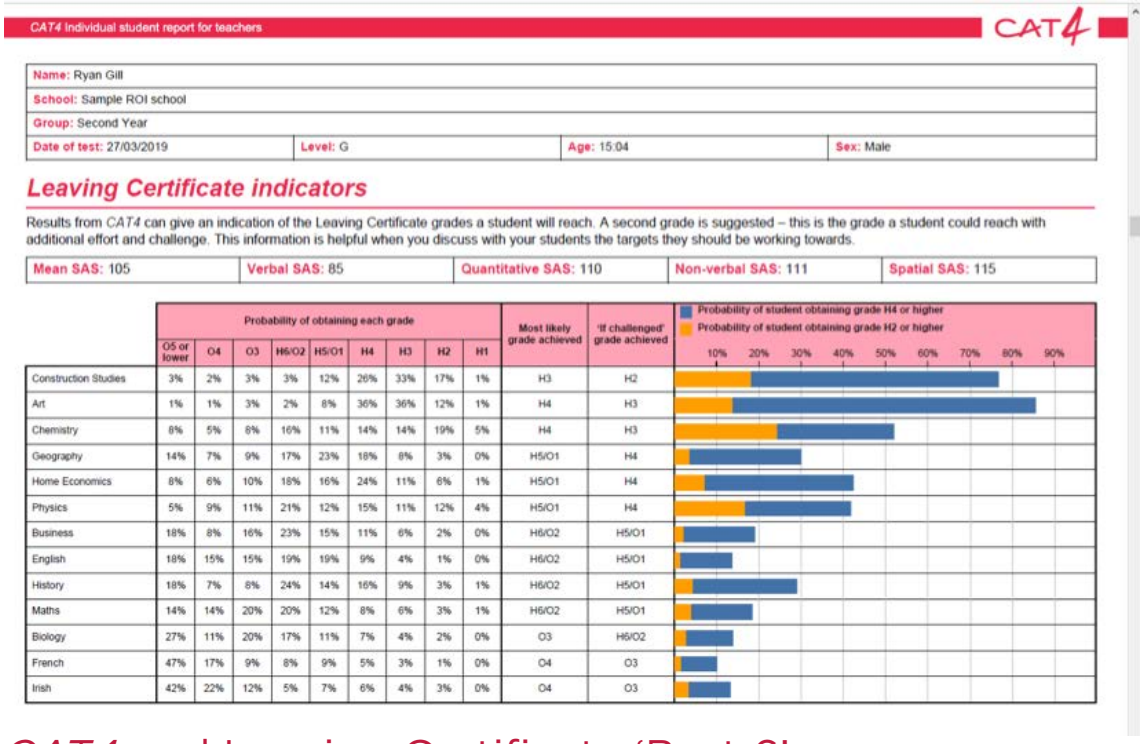
The strength of the relationship between two variables can be measured by a statistic called the correlation coefficient. A value of zero indicates no relationship between the two measures, whereas a value of one indicates a perfect positive relationship. The correlations between *CAT4* scores and Leaving Certificate subjects grades are shown below. These show that the overall mean *CAT4* SAS has a moderate to strong association with the subject grades.

	Mean *CAT4* score	Verbal SAS	Quantitative SAS	Nonverbal SAS	Spatial SAS
Art	0.55	0.52	0.42	0.48	0.47
Biology	0.60	0.63	0.43	0.48	0.44
Business	0.50	0.60	0.42	0.30	0.30
Chemistry	0.52	0.50	0.48	0.40	0.29
Construction Studies	0.52	0.44	0.31	0.40	0.45
English	0.58	0.67	0.42	0.43	0.35
French	0.54	0.59	0.39	0.41	0.35
Geography	0.60	0.63	0.42	0.43	0.45
History	0.46	0.52	0.35	0.30	0.33
Home Economics	0.43	0.54	0.42	0.32	0.20
Irish	0.40	0.46	0.29	0.31	0.23
Maths	0.65	0.57	0.53	0.53	0.47
Physics	0.53	0.50	0.46	0.44	0.38

The Leaving Certificate indicators for each subject are derived from the statistical relationship between *CAT4* scores and Leaving Certificate subject grades or points scores. Indicators are calculated from the mean *CAT4* Standard Age Score (*SAS*) for Maths, Physics, Chemistry, Art and Construction Studies and are based on verbal SAS for the other subjects.

Likelihood of Leaving Certificate grades

The example below shows the grades most likely to be achieved by one student. The most likely grade for Construction Studies is H3 but this student has an 18% chance of obtaining a grade higher than H3, a 26% chance of obtaining grade H4 and a 23% chance of obtaining a grade below H4. The indicators are not precise: they indicate the outcomes expected for students with a particular *CAT4* score making average progress in a typical school. They come with a margin of error which reflects the differences in progress that may be made by different students. This is reflected in the probabilities of obtaining each grade.



CAT4 Individual student report for teachers

CAT4

Name: Ryan Gill			
School: Sample ROI school			
Group: Second Year			
Date of test: 27/03/2019	**Level:** G	**Age:** 15:04	**Sex:** Male

Leaving Certificate indicators

Results from *CAT4* can give an indication of the Leaving Certificate grades a student will reach. A second grade is suggested – this is the grade a student could reach with additional effort and challenge. This information is helpful when you discuss with your students the targets they should be working towards.

Mean SAS: 105	Verbal SAS: 85	Quantitative SAS: 110	Non-verbal SAS: 111	Spatial SAS: 115

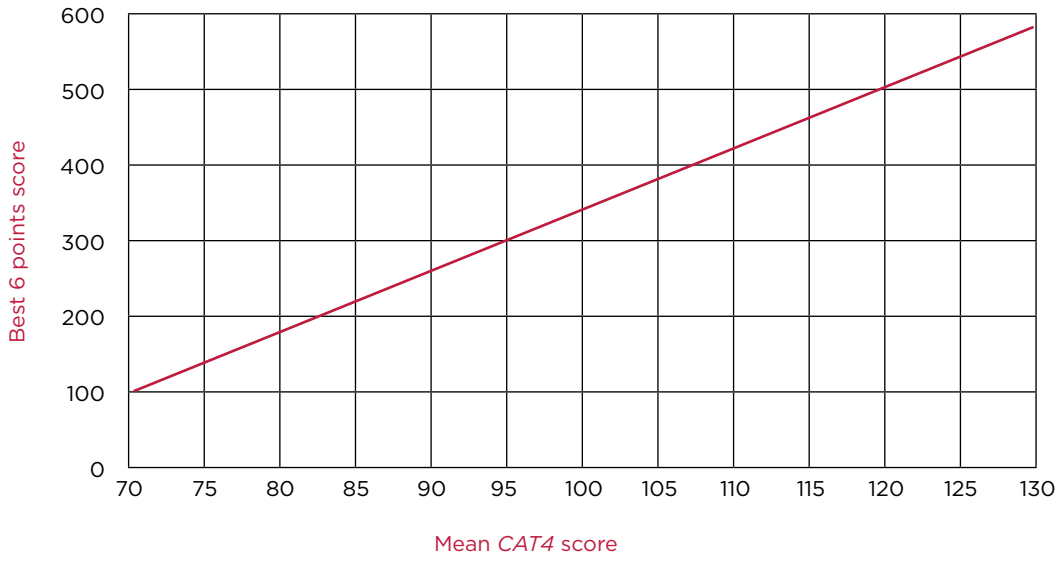
	Probability of obtaining each grade									Most likely grade achieved	'If challenged' grade achieved
	O5 or lower	O4	O3	H6/O2	H5/O1	H4	H3	H2	H1		
Construction Studies	3%	2%	3%	3%	12%	26%	33%	17%	1%	H3	H2
Art	1%	1%	3%	2%	8%	36%	36%	12%	1%	H4	H3
Chemistry	8%	5%	8%	16%	11%	14%	14%	19%	5%	H4	H3
Geography	14%	7%	9%	17%	23%	18%	8%	3%	0%	H5/O1	H4
Home Economics	8%	6%	10%	18%	16%	24%	11%	6%	1%	H5/O1	H4
Physics	5%	9%	11%	21%	12%	15%	11%	12%	4%	H5/O1	H4
Business	18%	8%	16%	23%	15%	11%	6%	2%	0%	H6/O2	H5/O1
English	18%	15%	15%	19%	19%	9%	4%	1%	0%	H6/O2	H5/O1
History	18%	7%	8%	24%	14%	16%	9%	3%	1%	H6/O2	H5/O1
Maths	14%	14%	20%	20%	12%	8%	6%	3%	1%	H6/O2	H5/O1
Biology	27%	11%	20%	17%	11%	7%	4%	2%	0%	O3	H6/O2
French	47%	17%	9%	8%	9%	5%	3%	1%	0%	O4	O3
Irish	42%	22%	12%	5%	7%	6%	4%	3%	0%	O4	O3

Probability of student obtaining grade H4 or higher
Probability of student obtaining grade H2 or higher
10% 20% 30% 40% 50% 60% 70% 80% 90%

CAT4 and Leaving Certificate 'Best 6' score

A summary 'Best 6' indicator based on the total points score for Maths and the best of five other subjects was calculated for each student. The correlation between the 'Best 6' points score and the mean *CAT4* score was 0.61 and the relationship is displayed graphically below.

Relationship between Best 6 points score and mean *CAT4* score



Leaving Certificate indicators for groups of students

The table below shows how the group/class indicators have been calculated for a fictitious class with five students and shows the most likely grade achieved and the probabilities associated with getting different Mathematics grades. The group indicator is an average of the individual student outcomes and probabilities.

Calculating group indicators for Mathematics for a fictitious class of five students

Student	Mean *CAT4* score	'Best 6' score	Leaving Certificate grades – probabilities									Most likely grade achieved
			<=O5	O4	O3	H6/ O2	H5/ O1	H4	H3	H2	H1	
1	70	99	95%	3%	1%	0%	0%	0%	0%	0%	0%	O5
2	85	217	72%	14%	8%	4%	1%	1%	0%	0%	0%	O5
3	100	337	25%	20%	21%	16%	8%	5%	3%	2%	0%	O3
4	115	457	4%	5%	10%	17%	16%	17%	17%	11%	3%	H5/O1
5	140	600	0%	0%	0%	1%	2%	3%	10%	36%	47%	H2
Group indicator (average)		342	39%	8%	8%	8%	6%	5%	6%	10%	10%	