Evidence for Excellence in Education

Report

Additional Analysis of Wales' Performance in PISA 2012

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Additional Analysis of Wales' Performance in PISA 2012

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1 Analysis 1: performance and background characteristics

Basic descriptive analysis of PISA 2012 performance in Wales looking at a number of school and pupil level factors.

1.1 Performance by gender

Table 1: PISA 2012 performance by gender and subject

Subject	Mean score boys	Mean score girls	Score difference (B-G)
Mathematics	474	464	**10**
Reading	465	494	**-28**
Science	496	486	**10**

Note: bold indicates a score difference that is statistically significant

In the PISA 2012, Wales had a statistically significant difference in performance in all three subjects by gender. In mathematics and science, boys outperformed girls, a score difference of ten points was seen for both subjects. However, for reading, girls performed significantly better than boys, a score difference of 28 points.[1]

1.2 Performance by free school meal eligibility (FSM)

Table 2: PISA 2012 performance by free school meal eligibility (FSM) and subject

Subject	Mean score FSM	Mean score non-FSM	Score difference (FSM – non-FSM)
Mathematics	426	474	**-48**
Reading	437	485	**-48**
Science	444	497	**-53**

Note: bold indicates a score difference that is statistically significant

Learners who are eligible for free school meals (FSM) performed significantly worse in all three subjects than learners who are not eligible for FSM. The biggest score difference was seen in science, where the mean scores of learners eligible for FSM scored was on average of 53 score points lower. For mathematics and reading the score difference between these

[1] Please note, that scores differ to results originally published in the PISA 2012 National Report for Wales, because data had to be rescaled. Scores presented here are based on the corrected scale scores. The original report can be downloaded here: http://www.nfer.ac.uk/publications/PQUK02/PQUK02_home.cfm

two groups of learners was an average of 48 score points. The size of the score differences is equivalent to more than one full-year of education (OECD, 2013).

1.3 Performance by ethnicity

Figure 1: PISA 2012 performance by ethnicity and subject

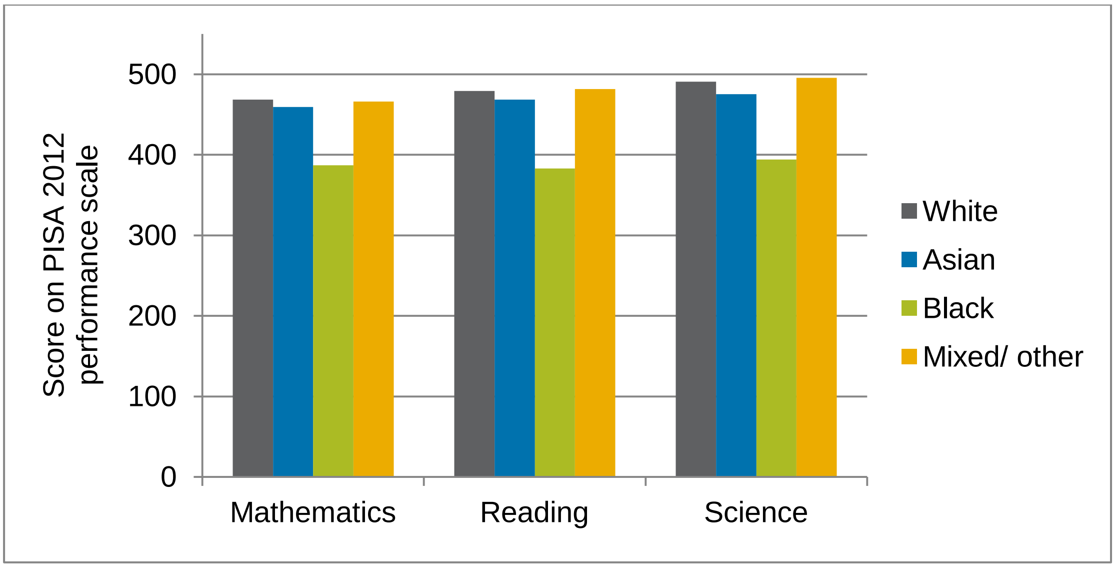


Table 3: PISA 2012 performance by ethnicity and subject

Subject	White	Asian		Black		Mixed/other	
	Mean score	Mean score	Score difference*	Mean score	Score difference*	Mean score	Score difference*
Mathematics	469	459	-9	387	**-81**	466	-2
Reading	479	469	-11	383	**-96**	482	2
Science	491	475	-16	394	**-97**	496	5

*This is the difference between the average score for this specific ethnic group and the average score of learners categorised as white in the National Pupil Data (NPD).

Note: bold indicates a score difference that is statistically significant

For this analysis the average scores for each of the ethnic groups (Asian, black and mixed/other) are compared with the average score obtained by the learners in a reference category – the reference category for ethnicity is 'white'. This analysis will enable us to explore whether the learners in these three ethnic groups have scores that are significantly different to learners categorised as white in the National Pupil Data (NPD).

In PISA 2012, Asian learners and learners of mixed/other ethnicity had comparable performance in mathematics, reading and science to white learners. The differences in average performance between these ethnic groups were small and not statistically significant. However, black learners had significantly lower scores on average in all three subjects. The biggest score difference was seen in science, where this group of learners performed on average 97 score points lower than white learners. For mathematics and reading score differences between these two groups of learners were 81 and 96 score points, respectively. However, the number of learners in this group is very small (n=11) and therefore these findings, although significant, should be interpreted with caution.

1.4 Performance by special educational needs (SEN) status

Figure 2: PISA 2012 performance score by special educational needs (SEN) status and subject

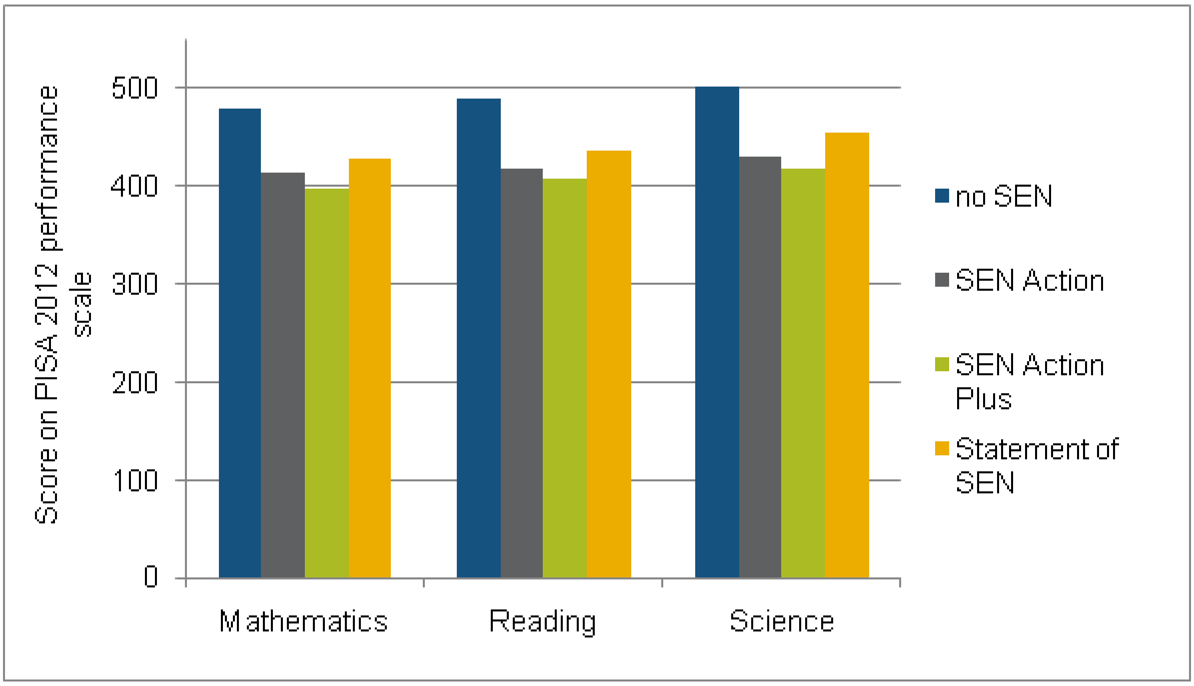


Table 4: PISA 2012 performance by special educational needs (SEN) status and subject

Subject	No SEN	SEN Action		SEN Action Plus		Statement of SEN	
	Mean score	Mean score	Score difference*	Mean score	Score difference*	Mean score	Score difference*
Mathematics	478	414	**-64**	397	**-81**	429	**-50**
Reading	490	417	**-73**	407	**-83**	437	**-53**
Science	501	430	**-72**	417	**-84**	455	**-47**

*This is the difference between the average score for learners with this specific level of SEN and the average score of learners without any SEN.

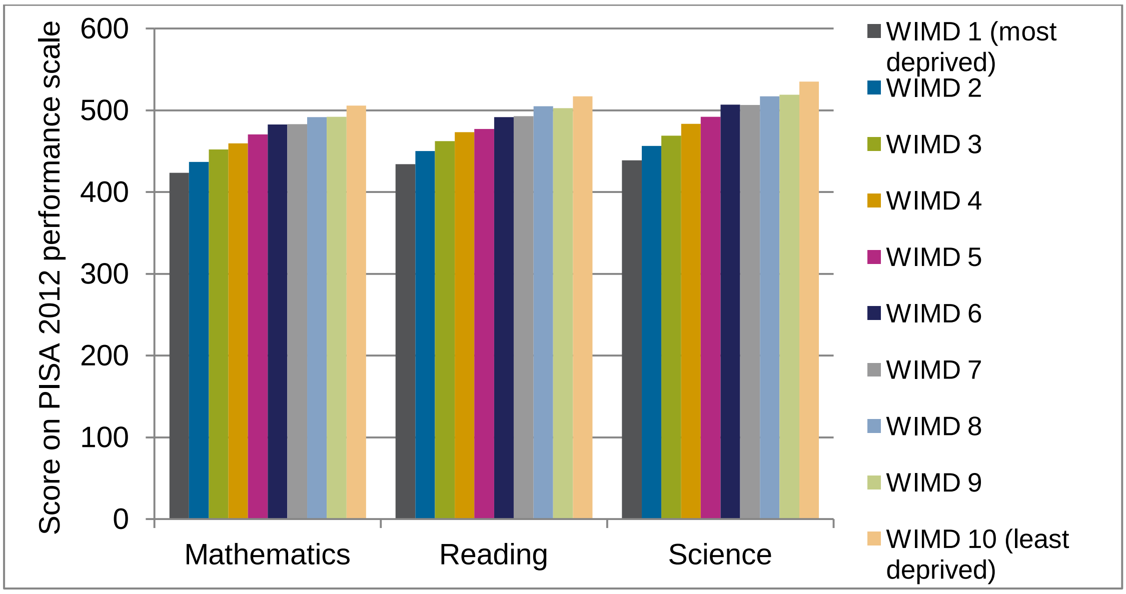
Note: bold indicates a score difference that is statistically significant

The average scores for learners in each of the Special Educational Needs (SEN) categories (SEN Action, SEN Action Plus and Statement of SEN) are compared with the average score obtained by the learners in the reference category – the reference category for SEN is 'no SEN'. This analysis will enable us to explore whether the learners in these SEN categories have scores that are significantly different to learners without SEN.

On average, learners with SEN had significantly lower PISA scores compared with learners without SEN, this was the case for all three subjects. The biggest score difference for all three subjects was seen for learners with SEN Action Plus status, who on average scored more than 80 points lower than learners without SEN. Learners with SEN Action status scored on average 64 points lower than learners without SEN learners in mathematics, with a score difference of 73 in reading and 72 in science. Learners with statement of SEN had higher mean scores than learners in the other SEN categories (Action and Action Plus). It is possible that, as these learners have had their needs externally assessed, they are receiving more targeted help which enables them to overcome the impact of their needs on their attainment than learners in the other two categories. However, the number of pupils in this group is relatively small and therefore these findings should be interpreted with caution. The score difference between learners with statements of SEN and learners with no SEN are still statistically significant.

1.5 Performance by the Welsh Index of Multiple Deprivation (WIMD)

Figure 3: PISA 2012 performance by decentiles of the Welsh Index of Multiple Deprivation (WIMD) and subject



WIMD is a measure of multiple deprivation that is both an area-based measure and a measure of relative deprivation (Welsh Government, 2011). It is used to give a deprivation rank for each of the small areas in Wales. One area has a higher deprivation rank than another if the proportion of people living there who are classed as deprived is higher. In this analysis the average scores for the WIMD categories 2 -10 were compared with the average score obtained by the learners in the reference category – the reference category for WIMD is 'WIMD 1' (the most deprived group). This analysis will enable us to explore whether the learners in WIMD categories 2-10 have scores that are significantly different to learners in WIMD 1.

Learners living in most deprived areas (WIMD 1) performed significantly worse in mathematics, reading and science than learners in less deprived areas (WIMD 2-10). The biggest score differences, between learners living in areas ranked as the most deprived (WIMD1) and those in less severely deprived areas, were seen in science. In general as the degree of deprivation increases (i.e. the lower the WIMD rank number) the PISA mean scores decrease, this was the case for all three subjects. For example, if we take mathematics, learners in the 5th WIMD decentile (WIMD 5) outperformed learners in WIMD 1 by on average 47 score points in mathematics, and for learners in the 10th WIMD decentile (WIMD 10) the score difference is 82 score. These differences translate into more than one and two full-years of education, respectively (OECD, 2013).

Table 5: PISA 2012 performance by decentiles of the Welsh Index of Multiple Deprivation (WIMD) and subject

Subject	WIMD 1	WIMD 2		WIMD 3		WIMD 4		WIMD 5		WIMD 6		WIMD 7		WIMD 8		WIMD 9		WIMD 10	
	Mean score	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*
Mathematics	424	437	13	452	**29**	460	**36**	470	**47**	483	**59**	483	**59**	491	**68**	492	**68**	506	**82**
Reading	434	450	**16**	462	**28**	473	**39**	477	**43**	492	**58**	493	**59**	505	**71**	503	**69**	517	**83**
Science	439	457	**18**	469	**30**	483	**45**	492	**53**	507	**68**	507	**68**	517	**78**	519	**80**	535	**96**

*This is the difference between the average score for pupils in this WIMD decentile and the average score of learners in WIMD 1 (the most deprived).

Note: bold indicates a score difference that is statistically significant

1.6 Performance by medium of instruction

Table 6: PISA 2012 performance by medium of instruction and subject

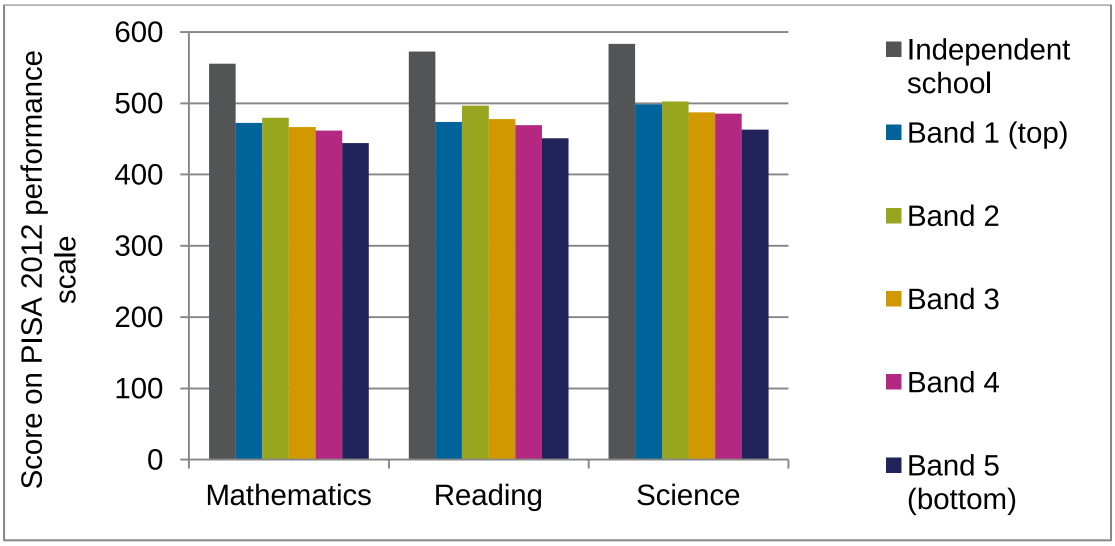
Subject	Mean score Welsh medium	Mean score English medium	Score difference (W-E)
Mathematics	477	467	**10**
Reading	478	480	-2
Science	486	492	-6

Note: bold indicates a score difference that is statistically significant

In reading and science, the performance of learners attending Welsh medium and English medium schools is comparable, that is, score differences are not statistically significant. However, in mathematics, learners attending Welsh medium schools outperform those in English medium schools by 10 score points. This difference is statistically significant.

1.7 Performance by GCSE performance band

Figure 4: PISA 2012 performance by GCSE performance band and subject



In this analysis the average scores for the learners in schools in performance bands 1, 3, 4 and 5 and independent schools were compared with the average score obtained by the learners in the reference category – the reference category for GCSE performance banding is Band 2 (this is the band with the highest number of secondary schools in 2013). This analysis will enable us to explore whether the learners in in schools in performance bands 1, 3, 4 and 5 and independent schools have scores that are significantly different to learners in schools categorised as Band 2.

Learners in independent schools had the highest PISA performance scores in all three subjects. They outperformed learners in schools that are categorised as Band 2 on average by 81 score points in science and 76 score points in both mathematics and reading.

Learners in Band 2 schools had the highest mean scores for all three subjects. However, when compared with learners in Band 1 and Band 3 schools these score differences were only significant for reading (a score difference of 23 and 19 points respectively). The finding for Band 1 schools may seem counter intuitive, as it may be expected that on average earners in schools with a higher banding would outperform those from schools with a lower banding. However, this finding should be interpreted with caution as the number of schools in Band 1 is relatively small (only 20 secondary schools in Wales were categorised as Band 1 in 2013).

Caveat: Performance bands are derived from school effectiveness measures. Effectiveness measures are essentially independent of performance levels. While it is worthwhile comparing effectiveness measures with performance levels within the same assessment, inferences should be drawn with caution when comparing effectiveness measures of one assessment with performance levels of another assessment.

Table 7: PISA 2012 performance by GCSE performance band and subject

Subject	Independent schools		Band 1		Band 2	Band 3		Band 4		Band 5	
	Mean score	Score diff*	Mean score	Score diff*	Mean score	Mean score	Score diff*	Mean score	Score diff*	Mean score	Score diff*
Mathematics	555	**76**	472	-7	480	467	-13	462	**-18**	444	**-36**
Reading	572	**76**	474	**-23**	497	478	**-19**	469	**-28**	451	**-46**
Science	584	**81**	499	-4	503	487	-15	486	**-17**	463	**-40**

*This is the difference between the average score for learners in this performance band and the average score of learners in performance band 2 (the performance band with the most schools in 2013).

Note: bold indicates a score difference that is statistically significant

2 Analysis 2: PISA 2012 and GCSE outcomes

***Analysis**: Multilevel models to explore the associations between the performance in PISA assessments and GCSE.*

2.1 Associations between performance in PISA 2012 and GCSE

Table 1 shows how closely performance in each of PISA's three subject domains (mathematics, science and reading) is related to performance in the corresponding GCSE subjects. The relationship is expressed through a correlation coefficient. A correlation coefficient describes the strength of a relationship between two variables. It ranges from +1 to -1. A correlation coefficient of +1 would suggest that two variables have a perfect linear relationship, where an increase in one variable is accompanied by an identical increase in another variable. A correlation coefficient of 0 would indicate that two indicators are not at all related and a correlation coefficient of -1 would indicate that two variables have a perfect linear relationship but in an opposite direction, as one goes down the other goes up.

The association between achievement in the PISA mathematics assessment and in the mathematics GCSE is strong (0.69), indicating that performance in both assessments is closely related.

The association between achievement in the PISA science assessment and achievement in the science GCSE is less strong. However, a correlation coefficient of 0.52 indicates that the two assessments are still quite closely related.

For the comparison of performance in reading, the achievement of learners who took the PISA test in Welsh was correlated with their Welsh first language GCSE scores, and the achievement of learners who took the PISA test in English was correlated with their English language GCSE scores. When both languages are analysed together, the association between achievement in the PISA reading assessment and English/Welsh first language GCSE is strong (0.67). Looking at achievement in the English-medium PISA reading assessment and achievement in the English language GCSE separately, a strong association (0.68) is also observed, indicating that performance in both types of assessments is closely related. The strength of the association is slightly weaker for learners who took the PISA test in Welsh and the Welsh first Language GCSE (0.61).

Table 8: Association of performance in PISA with performance in GCSE by subject

PISA and GCSE subject	Correlation coefficient
Mathematics	0.69
Science	0.52
English/Welsh first language combined	0.67
English language	0.68
Welsh first Language	0.61

2.2 Associations between GCSE performance and learner and school characteristics

For each subject domain we investigated associations between performance in PISA and GCSE taking account of differences between learners and schools, for example free school meals (FSM) eligibility and language of instruction.

Figure 5: Learner and school characteristics included in the analysis

School characteristics (National Pupil Data)

- Language medium
- Band
- Consortium
- Proportion of FSM

Learner characteristics (National Pupil Data)

- Gender
- FSM eligibility
- Special educational needs (SEN)
- English as an additional language (EAL)
- Ethnicity
- English or Welsh speaker (for reading)

Learner characteristics (PISA)

- PISA's index of economic, social and cultural status (ESCS)
- parents' occupational prestige and level of education, family wealth (e.g. whether the learner has his/her own room)
  - cultural possessions (e.g. works of art) and the number of books in the home

Note: National Pupil Data is information sourced from the National Pupil Database; PISA is information sourced from the PISA 2012 data.

It is important to recognise that it is not only learner characteristics relate to individual achievement. In addition, the characteristics of the school (e.g. Welsh- or English-medium) that the learner attends can also be associated with achievement. It is therefore important that the analysis includes both individual and school characteristics. Additionally, learners with different social background characteristics are not evenly distributed across schools. Learners with similar background characteristics tend to attend the same schools, creating a specific social background context in each school. Both the characteristics of the school and the composition of individual learner characteristics within a school create a unique context for the school, which is different for each school.

Multilevel models are used to evaluate the relationship between individual characteristics and school characteristics and GCSE achievement within the same analysis. This approach allows us to describe the combined impact of individual and school characteristics on learners' academic achievement, and to evaluate how much of the difference in achievement between learners is explained by individual and school characteristics.

2.2.1 Characteristics associated with achievement in GCSE mathematics

As noted above, achievement in GCSE mathematics is strongly related to achievement in PISA, that is, learners with high scores in PISA tend to also have high GCSE scores and vice versa. Despite this strong association some learners still have lower GCSE scores. Eligibility for FSM, level of ESCS and whether or not a learner has SEN are additionally significantly associated with GCSE mathematics scores. This means that, for two learners with similar PISA mathematics scores, a learner that is eligible for FSM or has SEN will achieve a lower score in his or her mathematics GCSE. In contrast, a learner with a higher ESCS score will achieve a higher score in his or her mathematics GCSE. Gender, EAL and ethnicity are not significantly associated with GSCE scores in mathematics when we account for PISA scores.

At the school level, there are significant associations between medium of instruction and mathematics GCSE scores and between school band and mathematics GCSE scores. This means that if we look at a group of learners with similar scores in the PISA mathematics assessment and similar individual learner characteristics, those in a Welsh-medium school will, on average, have higher mathematics GCSE scores, but those attending schools categorised in the middle-lowest and lowest bands (Band 4 and 5) will, on average, have lower GCSE scores in mathematics.

2.2.2 Characteristics associated with achievement in GCSE science

Achievement in science GCSE is significantly related to achievement in the PISA science assessment, that is , learners with high scores in the PISA test also tend to have high GCSE scores and vice versa. But, despite the strong association between achievement in the science GCSE and PISA science, some learners will do less well in their science GCSE. Boys, those eligible for FSM, and those with SEN do on average do less well in their science GCSE, even though they have similar PISA scores as other groups of learners. Learners with similar PISA science scores but with a higher ESCS score, and those of Asian and Black ethnicity, do, on average, achieve higher in their science GCSE. Neither EAL nor ethnicity are significantly associated with science GSCE scores when we account for PISA scores.

At the school level, as is the case for mathematics, there are significant associations between medium of instruction and science GCSE scores and between school band and science GCSE scores. This means that if we look at a group of learners with similar scores in the PISA science assessment and similar individual learner characteristics, those in a

Welsh-medium school will, on average, have higher science GCSE scores, but those attending schools categorised in the middle-lowest band (Band 4) will, on average, have lower GCSE scores in mathematics.

2.2.3 Characteristics associated with achievement in GCSE reading

Achievement in English/Welsh language GCSE is significantly related to achievement in the PISA reading assessment¸ that is, learners with high PISA scores also tend to have high GCSE scores and vice versa. As is the case for mathematics and science, despite the strong association between achievement in PISA and English/Welsh language GCSE, some learners will do less well in their language GCSE. The analysis suggests that boys, those eligible for FSM and those with SEN will, on average, do less well in their English/Welsh language GCSE than other groups of learners with similar PISA scores. However, learners with a higher ESCS score and those of Asian ethnicity will, on average, do better in their English/Welsh language GCSE examination, despite achieving similar PISA reading scores. Accounting for all of these learner characteristics, Welsh speakers – learners who took the PISA test in Welsh and took a Welsh First Language GCSE – do, on average, do better in their language GCSE than learners taking the English-medium assessments.

At the school level, there are significant associations between English/Welsh language GCSE scores and school band, consortium and the proportion of learners eligible for FSM in a school. This means that if we look at a group learners with similar PISA reading scores and similar individual learner characteristics, those in more socially deprived schools (Band 5 schools and with higher proportions of FSM eligible learners) will, on average, have lower English/Welsh language GCSE scores than learners attending less socially deprived schools. In terms of the consortium, the analysis suggests that learners attending schools in North Wales (GwE) will, on average, have lower English/Welsh language GCSE scores than learners attending schools in the Central South.

2.3 Proportions of variance explained by PISA scores, learner and school characteristics

Another way to express the closeness of an association between variables is to describe the amount of variance in one variable that can be explained by the other, that is, to what extent one variable is 'responsible' for the differences in the other variable. Proportions of explained variance are simply another means of describing the strength of the association, the more variance explained the stronger the association.

Given that achievement in mathematics, science and language GCSEs is closely related to performance in PISA, it is not surprising to find that a substantial amount of the variation in GCSE scores can be explained by differences in PISA scores.

Table 2 and Figure 2 summarise the amount of variance in GCSE mathematics, science and reading scores explained by PISA scores, learner characteristics and school characteristics. The proportion of variance explained by these variables differs between the three subjects.

For mathematics and reading, PISA scores explain 47.3 per cent and 45.1 per cent of variance respectively in the corresponding GCSE subject scores. In mathematics, characteristics of the individual learners explain an additional 2.7 per cent and school characteristics an additional 1.2 per cent of variation in mathematics GCSE scores. However, in reading, learner characteristics explain more of the variation in English/Welsh language GCSE scores, accounting for an additional 7.5 per cent of variance. This finding supports existing research evidence, which indicates that reading achievement is more strongly related to learners' social background characteristics than is the case for achievement in other subjects (OECD, 2010a, 2013a). School characteristics explain an additional 1.3 per cent of variance in English/Welsh language GCSE scores after accounting for differences in PISA reading scores and learner characteristics.

Table 9: Proportions of variance in GCSE scores explained by PISA scores, learner characteristics and school characteristics

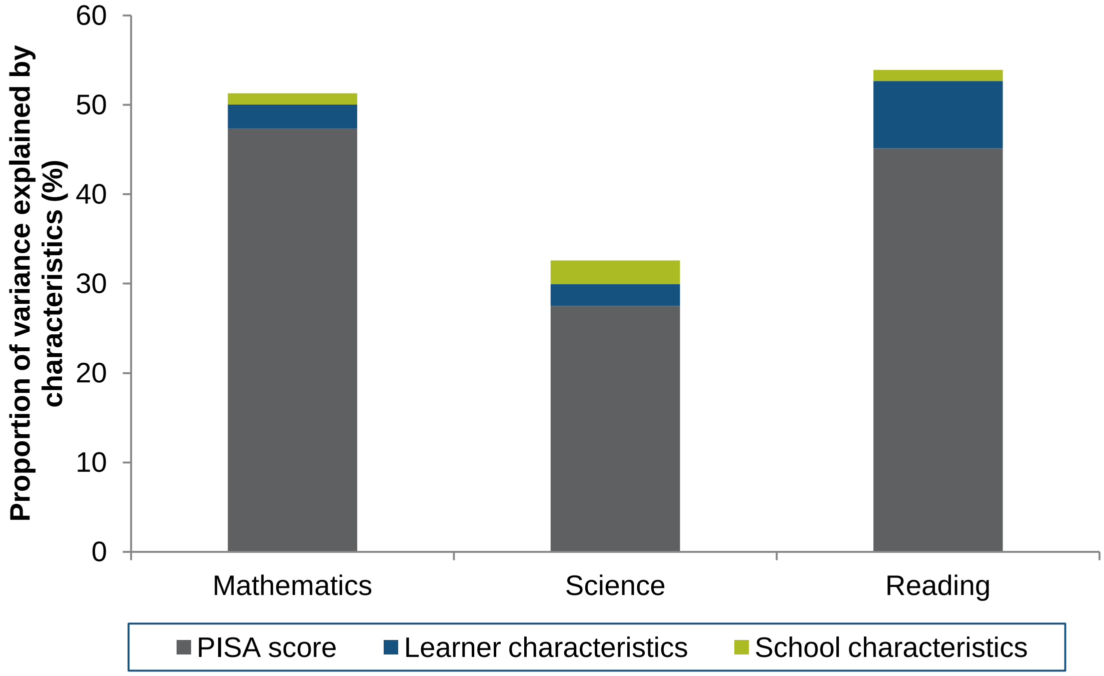
Characteristics	Mathematics	Science	Reading
PISA score	47.3	27.5	45.1
Learner characteristics	2.7	2.4	7.5
School characteristics	1.2	2.6	1.3
Total amount of variance explained	51.3	32.6	53.9

Notes: Values in this table are rounded.

In contrast to mathematics and reading, achievement in the PISA science assessment explains a substantially lower amount of the variation in science GCSE scores (only 27.5 per cent). This suggests that there is less overlap between the assessments, in terms of the knowledge they require learners to apply, than is the case for mathematics and reading. In science, learner and school characteristics explain an additional 2.4 and 2.6 per cent of the variation in science GCSE scores between learners.

Our analysis indicates that differences between schools are more strongly related to differences in science GCSE scores than is the case for mathematics and reading. This suggests that school characteristics other than those accounted for in this analysis, such as curriculum content coverage or subject-specific teaching of science, could potentially further explain differences in science GCSE scores.

Figure 6: Proportion of variance in GCSE scores explained by PISA scores, learner characteristics and school characteristics



Note: Although the amount of variance explained by learner and school characteristics seems quite small, it should be kept in mind that the PISA scores themselves are also dependent on characteristics of the learner (OECD, 2013a). As such the associations between learner characteristics and achievement are already 'captured' in the PISA scores.

3 Analysis 3: measures of deprivation

Analysis to understand the relationship between eligibility for free school meals (FSM), the Welsh Index of Multiple Deprivation (WIMD) and the PISA 2012 index of economic, social and cultural status (ESCS).

Researchers have extensively investigated the relationship of social background characteristics and academic achievement (Sirin, 2005). Their studies have shown that differences in academic achievement related to social background emerge early in life and have lasting consequences for an individual's educational and labour opportunities later in life (Alexander *et al*., 2007; Caro *et a*l., 2014).

Different indicators of social background may differ in strength of their relationship with academic achievement, i.e. the indicators explain variation in academic achievement across learners of different social backgrounds to varying degrees. For example, information about family income may explain more variation in achievement than information about the number of books in the home. This is mainly due to the fact that different indicators capture different aspects of social background, such as economic deprivation (wealth) or the value a family attributes to education and educational resources (number of books in the home).

The objective of Analysis 3 is to understand the relationship between the social background indicators, described below, and also evaluate how well each of these indicators explain differences in learners' performance in PISA 2012.

Indicator 1: Free School Meal eligibility (FSM)

FSM is a binary indicator of whether a learners' family has claimed eligibility for free school meals. The indicator primarily captures the economic circumstances of the learners' family (Hobbs and Vignoles, 2007).

Indicator 2: Welsh Index of Multiple Deprivation (WIMD)

WIMD is a measure of multiple deprivation that is both an area-based measure and a measure of relative deprivation (Welsh Government, 2011). It is used to give a deprivation rank for each of the small areas in Wales. One area has a higher deprivation rank (lower number) than another if the proportion of people living there who are classed as deprived is higher. WIMD is currently made up of eight domains (or types) of deprivation:

- income
- employment
- health
- education
- geographical access to services
- community safety

- physical environment
- housing.

A WIMD rank can be allocated to individuals based on where they live, however, it is important to keep in mind that as the index is an area-based measure and it is impossible to know whether individuals themselves suffer from multiple deprivation.

Indicator 3: PISA 2012 index of economic, social and cultural status (ESCS)

ESCS is an index score that combines a variety of family background characteristics (OECD, 2014). It includes information on parents' occupational prestige and parents' level of education, family wealth (e.g. whether the learner has his/her own room), educational resources at home (e.g. a desk), cultural possessions (e.g. works of art) and the number of books in the home. The index aims to capture different dimensions of social background such as economic deprivation and the value a family attributes to education and educational resources.

Table 7 shows how closely the three different indicators are related to each other. A correlation coefficient describes the strength of a relationship between two variables. It ranges from +1 to -1. A correlation coefficient of +1 would suggest that two indicators have a perfect linear relationship and capture exactly the same information. A correlation coefficient of 0 would indicate that two indicators are not at all related and capture entirely different information. A correlation coefficient of -1 would indicate that two indicators have a perfect linear relationship but in an opposite direction, as one goes down the other goes up.

We see that WIMD and ESCS have the strongest relationship with each other, i.e. capture some similar aspects of social background. This relationship is less strong for FSM and WIMD as well as for FSM and ESCS, indicating that different information about a learner's social background is captured with these different indicators.

Table 10: Correlations of FSM, WIMD and ESCS (standard errors in brackets)

Subject	FSM		WIMD		ESCS	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
FSM	-	-	0.24	(0.01)	0.29	(0.02)
WIMD	0.24	(0.01)	-	-	0.40	(0.02)
ESCS	0.29	(0.02)	0.40	(0.02)	-	-

Learners with different social background characteristics are not evenly distributed across schools. Rather learners with similar background characteristics tend to attend the same schools. This creates a specific context within a school that is composed of the social background characteristics of its learners. This context can be described as a unique characteristic of the school and is different for each school.

To evaluate both, the relationship of individual and school characteristics with academic achievement within the same analysis, multilevel models are run. This approach allows us to describe the combined impact of individual social background characteristics and the average social background of the school (also known as the compositional effect) on learners' academic achievement. In this way, we can evaluate how much of the difference in achievement between learners is explained by FSM, WIMD, ESCS and their school averages

Figure 7: Proportion of total variance in achievement explained by social background indicators in each subject

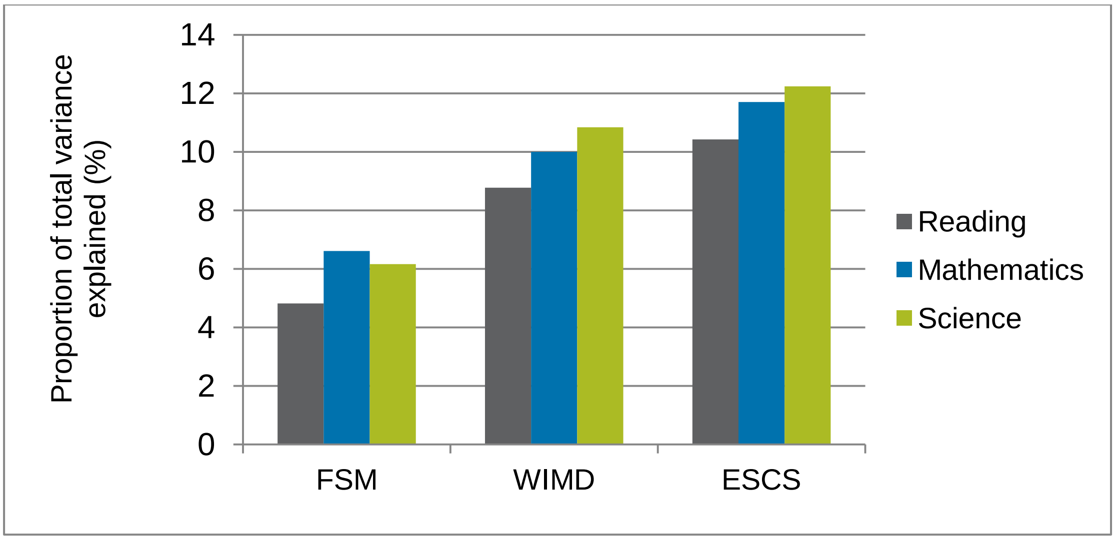


Table 11: Proportion of total variance in PISA 2012 performance explained by social background indicator and subject

Subject	FSM	WIMD	ESCS
Mathematics	6.6	10.0	11.7
Reading	4.8	8.8	10.4
Science	6.2	10.8	12.2

Across all subjects the ESCS explains more variance in PISA 2012 performance than the WIMD or FSM. This means that the ESCS is the strongest predictor of differences in performance between learners in Wales. ESCS explains 10.4 per cent of variance in reading performance, 11.7 per cent in mathematics and 12.2 per cent in science. In comparison, WIMD explains 8.8 per cent of variance in reading performance, ten per cent in mathematics and 10.8 per cent in science. The lowest percentage of performance variance is explained by FSM with only 4.8 percent in reading, 6.6 per cent in mathematics and 6.2 per cent in science.

4 Analysis 4: learner attitudes, beliefs and behaviours

Analysis: *Multilevel models to explore the associations between learner attitudes, beliefs and behaviours and performance in mathematics GCSE.*

> *How students think and feel about themselves shapes their behaviour, especially when facing challenging circumstances (Bandura, 1977). (...) Mathematics self-beliefs have an impact on learning and performance on several levels: cognitive, motivational, affective and decision-making. They determine how well students motivate themselves and persevere in the face of difficulties, they influence students' emotional life, and they affect the choices students make about coursework, additional classes, and even educational and career paths (Bandura, 1997; Wigfield and Eccles, 2000).*
>
> **OECD, 2013b, p. 88**

To explore the association between learner attitudes, beliefs and behaviours and mathematics GCSE scores, data from the PISA 2012 *Student Questionnaire* was included in the multilevel models (OECD, 2014). The analysis focused on the following scales:

- mathematics self-efficacy
- mathematics self-concept
- mathematics anxiety
- motivation to learn mathematics (intrinsic and instrumental)
- mathematics work ethic
- mathematics behaviour.

The questions that formed each of these scales are provided below:

Mathematics self-efficacy
Question: How confident do you feel about having to do the following mathematics tasks? • Using a train timetable to work out how long it would take to get from one place to another. • Calculating how much cheaper a TV would be after a 30% discount. • Calculating how many square metres of tiles you need to cover a floor. • Understanding graphs presented in newspapers. • Solving an equation like 3x+5=17. • Finding the actual distance between two places on a map with a 1:10,000 scale. • Solving an equation like 2(x+3)=(x+3)(x-3). • Calculating the petrol consumption rate of a car. ***Answer categories***: "very confident", "confident", "not very confident", "not at all confident".

Mathematics self-concept

Question: Thinking about studying mathematics, to what extent do you agree with the following statements?

- I am just not good at mathematics.
- I get good marks in mathematics.
- I learn mathematics quickly.
- I have always believed that mathematics is one of my best subjects.
- In my mathematics class, I understand even the most difficult work.

Answer categories: “strongly agree”, “agree”, “disagree”, “strongly disagree”.

Mathematics anxiety

Question: Thinking about studying mathematics, to what extent do you agree with the following statements?

- I often worry that it will be difficult for me in mathematics classes.
- I get very tense when I have to do mathematics homework.
- I get very nervous doing mathematics problems.
- I feel helpless when doing a mathematics problem.
- I worry that I will get poor marks in mathematics.

Answer categories: “strongly agree”, “agree”, “disagree”, “strongly disagree”.

Intrinsic motivation to learn mathematics

Question: Thinking about your views on mathematics, to what extent do you agree with the following statements?

- I enjoy reading about mathematics.
- I look forward to my mathematics lessons.
- I do mathematics because I enjoy it.
- I am interested in the things I learn in mathematics.

Answer categories: “strongly agree”, “agree”, “disagree”, “strongly disagree”.

Instrumental motivation to learn mathematics

Question: Thinking about your views on mathematics, to what extent do you agree with the following statements?

- Making an effort in mathematics is worth it because it will help me in the work that I want to do later on.
- I do mathematics because I enjoy it.
- Learning mathematics is worthwhile for me because it will improve my career chances.
- Mathematics is an important subject for me because I need it for what I want to study later on.
- I will learn many things in mathematics that will help me get a job.

Answer categories: “strongly agree”, “agree”, “disagree”, “strongly disagree”.

Mathematics work ethic

Question: Thinking about your views on mathematics, to what extent do you agree with the following statements?

- I finish my homework in time for mathematics lessons.
- I work hard on my mathematics homework.
- I am prepared for my mathematics exams.
- I study hard for mathematics tests.
- I keep studying until I understand mathematics material.
- I pay attention in mathematics lessons.
- I listen in mathematics lessons.
- I avoid distractions when I am studying mathematics.
- I keep my mathematics work well organised.

Answer categories: "strongly agree", "agree", "disagree", "strongly disagree".

Mathematics behaviour

Question: How often do you do the following things at school and outside of school?

- I talk about mathematics problems with my friends.
- I help my friends with mathematics.
- I do mathematics as an extracurricular activity.
- I take part in mathematics competitions.
- I do mathematics more than 2 hours a day outside of school.
- I play chess.
- I program computers
- I participate in a mathematics club.

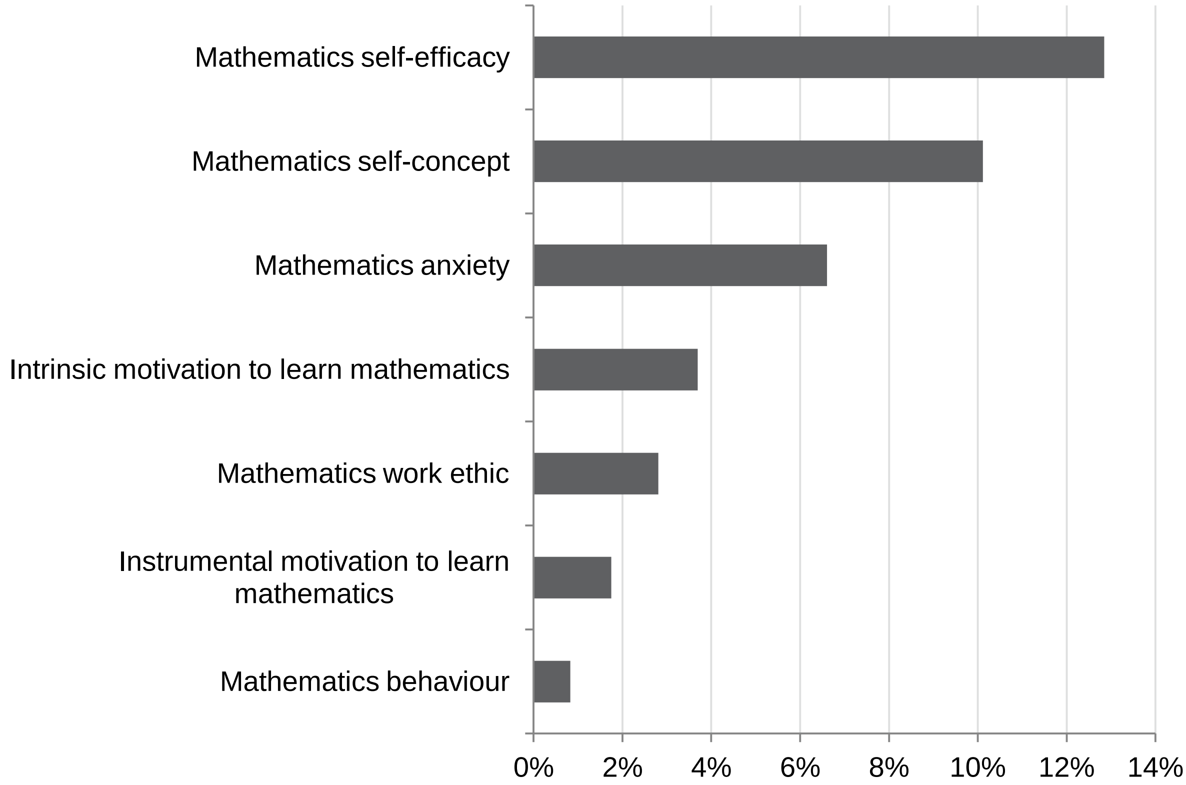
Answer categories: "always or almost always", "often", "sometimes", "never or rarely".

We used multilevel models to investigate the relationship between learner attitudes, self-beliefs and behaviours and mathematics GCSE scores. These models enable us to explore the association between these factors and mathematics GCSE scores, independent of learner and school characteristics, for example learners' FSM eligibility or the banding of the school they attend.

All associations between learner attitudes (intrinsic and instrumental motivation to learn mathematics), self-beliefs (mathematics self-efficacy, self-concept and anxiety) and learner behaviours (mathematics work ethic, mathematics behaviour) are significantly associated with mathematics GCSE scores (after accounting for other learner and school characteristics). For example, if we take two learners with similar individual characteristics who attend schools with similar characteristics, the learner with higher intrinsic motivation has a higher score in his/her mathematics GCSE. All but one of the associations are positive, the exception is mathematics anxiety, where higher levels of anxiety are associated with lower scores in mathematics.

Figure 3 and Table 3 show the proportion of variance in mathematics GCSE scores that can be explained by learners' attitudes, self-beliefs and behaviours. They show the independent contribution of each of these factors in explaining the variance in mathematics GCSE scores. These proportions are in addition to the variation explained by other learner and school characteristics (as described in section 1.2).

Figure 8: Proportion of variance in GCSE mathematics scores explained by learner attitudes, self-beliefs and behaviours



Note: conditional on learner and school characteristics (20% of variance)

Table 12: Proportion of variance in GCSE mathematics scores explained by learner attitudes, self-beliefs and behaviours

Attitudes, behaviour and self-beliefs	Proportion of variance explained (%)
Mathematics self-efficacy	12.8
Mathematics self-concept	10.1
Mathematics anxiety	6.6
Intrinsic motivation to learn mathematics	3.7
Mathematics work ethic	2.8
Instrumental motivation to learn mathematics	1.7
Mathematics behaviour	0.8

Note: conditional on learner and school characteristics (20% of variance)

Learners' self-efficacy and their mathematics self-concept are most closely related to mathematics GCSE scores and explain 12.8 per cent and 10.1 per cent respectively of differences in mathematics GCSE scores. This means that if we take two learners with similar individual characteristics attending two schools with similar characteristics, the learner with a higher self-concept and self-efficacy will have better mathematics GCSE scores. Self-efficacy is described as a learner's belief that they can produce the desired effects through their actions. This belief is seen as a powerful incentive to act or persevere when faced with difficulties (Bandura, 1977).

> *While better performance in mathematics leads to higher levels of self-efficacy, students who have low levels of mathematics self-efficacy are at a high risk of underperforming in mathematics, despite their abilities (Bandura, 1997; Schunk and Pajares, 2009). If students do not believe in their ability to accomplish particular tasks, they will not exert the effort needed to complete the tasks successfully, and a lack of self-efficacy becomes a self-fulfilling prophecy.*
>
> **OECD, 2013b, p.89**

Given these definitions it is perhaps unsurprising that of all the learner attitudes, self-beliefs and behaviours investigated, self-efficacy was the one most closely associated with mathematics GCSE scores.

Learners' anxiety about mathematics can explain 6.6 per cent of differences in mathematics GCSE scores, even when other individual and school characteristics are similar. Mathematics work ethic and the learner's intrinsic motivation to learn mathematics explain slightly less variance (2.8 per cent and 3.7 per cent respectively). The learner attitudes, self-beliefs and behaviours that are most loosely associated with mathematics GCSE scores are mathematics behaviour and the instrumental motivation to learn mathematics as they only explain 0.8 per cent and 1.7 per cent of variance, respectively.

5 Analysis 5: PISA sub-domains and GCSE outcomes

Analysis: *Multilevel models to look at the association between PISA mathematics sub-domains and GCSE outcomes.*

Mathematical literacy in PISA 2012 is assessed in relation to four content categories (change and relationships, quantity, space and shape and uncertainty and data) and three process categories (formulating, employing and interpreting). In this section the associations between mathematics GCSE scores and scores in the PISA 2012 content and process categories are investigated.

5.1 PISA mathematics content categories

As shown in Table 4, there is a strong relationship between mathematics GCSE scores and all four of the PISA 2012 mathematical content categories, ranging from 0.63 for space and shape, to 0.66 for uncertainty and data, to 0.67 for change and relationships and quantity. As is the case for overall PISA mathematics scores, learners who do well in the different content categories in PISA also tend to do well in their mathematics GCSE. Figure 4 describes the PISA 2012 mathematics content categories.

Table 13: Associations of performance in PISA content categories with performance in mathematics GCSE

PISA content category	Correlation coefficient
Change and relationships	0.67
Quantity	0.67
Space and shape	0.63
Uncertainty and data	0.66

We used multilevel models to evaluate the relationship between learner characteristics and school characteristics and mathematics GCSE scores. The results are very similar to the overall mathematics analysis (Section 1). Despite the strong association between scores in the PISA content categories and GCSE scores, learners with certain characteristics still have lower mathematics GCSE scores. This means that if you take two learners with similar PISA scores in the four content categories, those who are eligible for FSM, those with SEN and those who attend middle-lowest and lowest Band schools (Band 4 and 5) will, on average, have lower mathematics GCSE scores. Conversely, learners with higher ESCS scores will, on average, have higher GCSE scores.

Figure 9: Description of PISA 2012 mathematics content categories

PISA mathematics content categories

Quantitiy

Quantity incorporates the quantification of attributes of objects, relationships, situations, and entities in the world, understanding various representations of those quantifications, and judging interpretations and arguments based on quantity. It involves understanding measurements, counts, magnitudes, units, indicators, relative size, and numerical trends and patterns, and employing number sense, multiple representations of numbers, mental calculation, estimation, and assessment of reasonableness of results.

Uncertainty and data

Uncertainty and data covers two closely related sets of issues: how to identify and summarise the messages that are embedded in sets of data presented in many ways, and how to appreciate the likely impact of the variability that is inherent in many real processes. Uncertainty is part of scientific predictions, poll results, weather forecasts, and economic models; variation occurs in manufacturing processes, test scores, and survey findings; and chance is part of many recreational activities that individuals enjoy. Probability and statistics, taught as part of mathematics, address these issues.

Change and relationship

Change and relationships focuses on the multitude of temporary and permanent relationships among objects and circumstances, where changes occur within systems of interrelated objects or in circumstances where the elements influence one another. Some of these changes occur over time; some are related to changes in other objects or quantities. Being more literate in this content category involves understanding fundamental types of change and recognising when change occurs so that suitable mathematical models can be employed to describe and predict change.

Space and shape

Space and shape encompasses a wide range of phenomena that are encountered everywhere: patterns, properties of objects, positions and orientations, representations of objects, decoding and encoding of visual information, navigation, and dynamic interaction with real shapes and their representations. Geometry is essential to *space and shape*, but the category extends beyond traditional geometry in content, meaning and method, drawing on elements of other mathematical areas, such as spatial visualisation, measurement and algebra. Mathematical literacy in *space and shape* involves understanding perspective, creating and reading maps, transforming shapes with and without technology, interpreting views of three-dimensional scenes from various perspectives, and constructing representations of shapes.

Source: OECD (2013a).

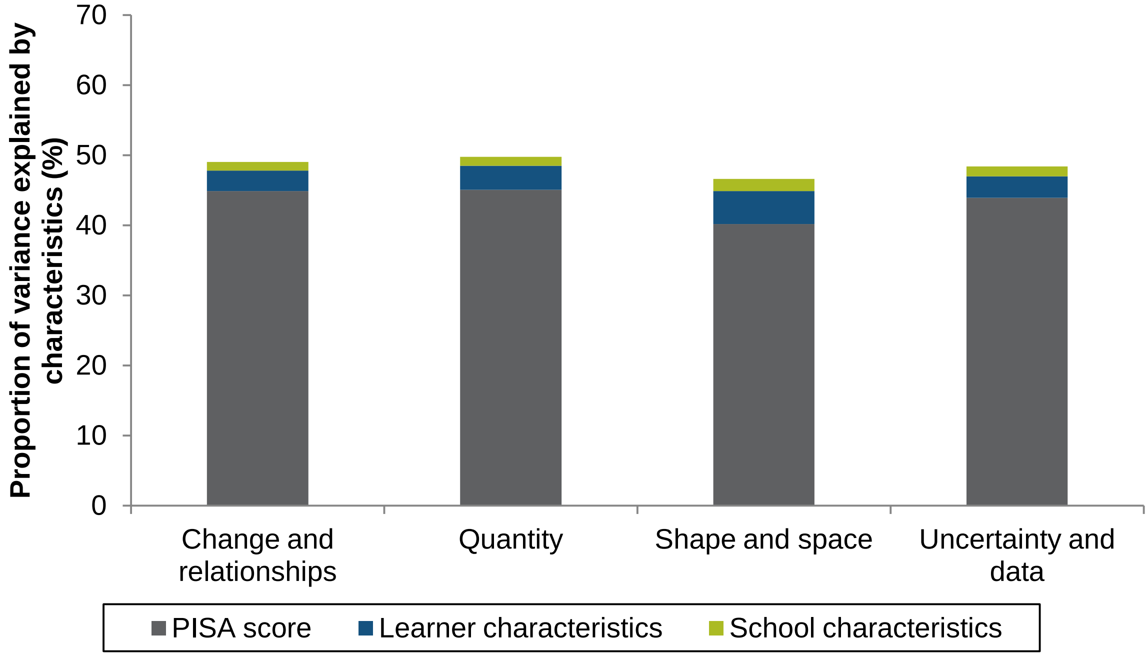
Given that there is a strong relationship between each of the four content categories and mathematics GCSE scores, it is unsurprising that a large proportion of the variation in GCSE scores can to be explained by differences in achievement in the content categories. The amount of variance explained differs only slightly across the four content categories and is very similar to the amount of variance explained by the overall PISA mathematics score (47.3 per cent; section 1.3). Only space and shape explains slightly less of the variation in mathematics GCSE scores: 40.2 per cent compared to 44.9 per cent for change and relationships, 45.1 per cent (quantity) and 43.9 per cent (uncertainty and data). As is the case for overall mathematics achievement in PISA, learner and school characteristics additionally explain small amounts of variance in mathematics GCSE scores. These vary slightly between models, accounting for different levels of achievement across the four content categories (shown in Table 5 and Figure 5).

Table 14: Proportion of variance in mathematics GCSE scores explained by learner characteristics and school characteristics by content category

Characteristics	Change and relationships	Quantity	Space and shape	Uncertainty and data
PISA score	44.9	45.1	40.2	43.9
Learner characteristics	2.9	3.4	4.7	3.0
School characteristics	1.3	1.2	1.7	1.4
Total amount of variance explained	49.0	49.8	46.6	48.4

Notes: Values in this table are rounded.

Figure 10: Proportion of variance in mathematics GCSE scores explained by learner characteristics and school characteristics by content category



Note: Although the amount of variance explained by learner and school characteristics seems quite small, it should be kept in mind that the PISA scores themselves are also dependent on characteristics of the learner (OECD, 2013a). As such, the associations between learner characteristics and achievement are already 'captured' in the PISA scores.

5.2 PISA mathematics process categories

The PISA items are also classified according to the main mathematical processes that a learner needs to use to solve the problem he or she is presented with. The three process categories are:

- 'employing' mathematical concepts, facts, procedures and reasoning
- 'formulating' situations mathematically
- 'interpreting', applying and evaluating mathematical outcomes.

There is a strong relationship between mathematics GCSE scores and all three of the PISA 2012 mathematical process categories (as shown in Table 6). This means that learners who do well in formulating situations mathematically; employing mathematical concepts, facts, procedures and reasoning; or in interpreting, applying and evaluating mathematical outcomes will, on average, also do well in their mathematics GCSE.

Table 15: Associations of performance in PISA process categories with performance in mathematics GCSE

Process category	Correlation coefficient
Employing	0.67
Formulating	0.66
Interpreting	0.65

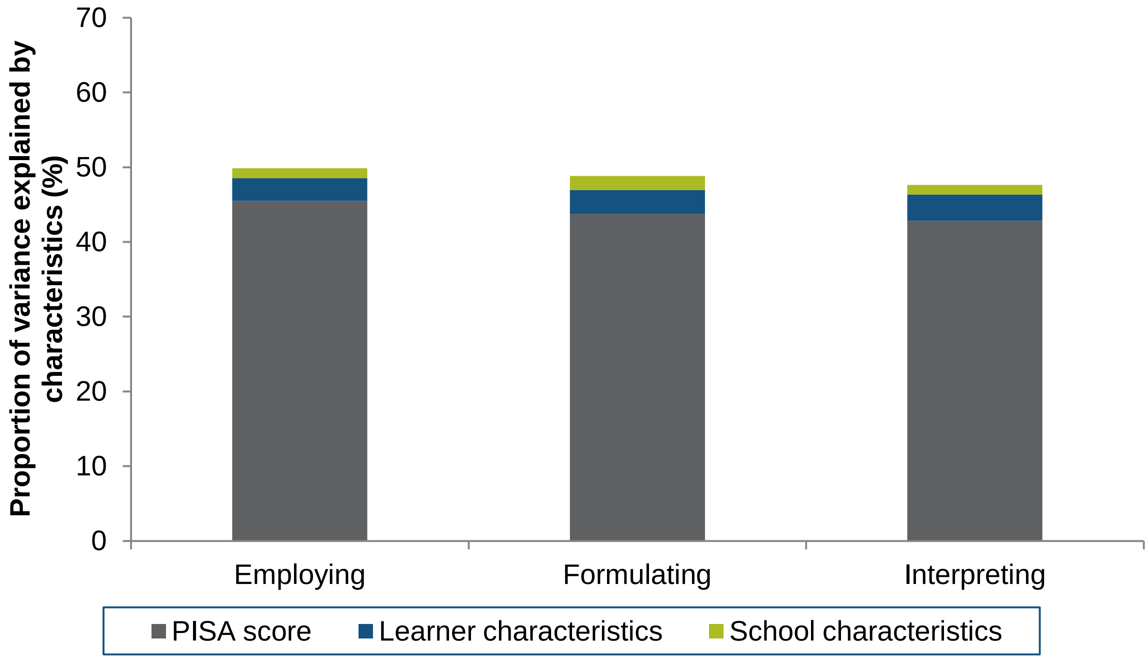
We used multilevel models to evaluate the relationship between learner characteristics and school characteristics and mathematics GCSE scores. The results are very similar to the overall mathematics analysis (see section 1). Despite the strong association between PISA scores in the process categories and mathematics GCSE scores, learners with some characteristics will still have lower mathematics GCSE scores. This means, for two learners with similar PISA scores in the process categories, those eligible for FSM, those with SEN and those in middle-lowest and lowest Band schools (Band 4 and 5) will, on average, have lower mathematics GCSE scores. Those with higher ESCS scores on average have higher GCSE scores.

Given that there is a strong relationship between each of the three process categories and mathematics GCSE scores, it is unsurprising that a large proportion of the variation in GCSE scores can to be explained by differences in the process categories scores. The amount of variance explained by each of the categories is very similar (shown in Table 7 and Figure 6). The process category employing explains the largest amount of variance in mathematics GCSE achievement (45.5 per cent), followed by formulating (43.7 per cent) and interpreting (42.8 per cent).

Table 16: Proportion of variance in mathematics GCSE scores explained by learner characteristics and school characteristics by process category

Factors	Employing	Formulating	Interpreting
PISA score	45.5	43.7	42.8
Learner characteristics	3.0	3.2	3.5
School characteristics	1.3	1.9	1.3
Total amount of variance explained	49.9	48.8	47.6

Figure 11: Proportion of variance in mathematics GCSE scores explained by learner characteristics and school characteristics by process category



Note: Although the amount of variance explained by learner and school characteristics seems quite small, it should be kept in mind, that the PISA scores themselves are also dependent on characteristics of the learner (OECD, 2013a). As such, the associations between learner characteristics and achievement are already ‘captured’ in the PISA scores.

6 Analysis 6: low performers in PISA 2012

***Analysis**: Multilevel logistics models to identify the likelihood of being a low performer in a specific subject if a learner is already a low performer in one of the other subjects.*

This section explores the likelihood of learners who are low performers in one PISA subject being a low performer in another, for example if a learner is a low performer in science is he or she more likely to be a low performer in mathematics? We also examine the associations between learner characteristics, school characteristics and the likelihood to be a low performer.

PISA defines ability in terms of proficiency levels of which there are six. The proficiency levels describe the types of skills learners are likely to demonstrate and the tasks that they are able to complete (OECD, 2014). Test questions that focus on simple tasks and involve familiar contexts where all relevant information is present are categorised at lower levels. Questions that are more demanding, that require learners to develop and work with models for complex situations, identifying constraints and specifying assumptions, are categorised at higher levels. For this analysis, learners were categorised as low performers if they achieved PISA level 1 or failed to achieve PISA level 1. Figure 7 gives an overview of what learners at proficiency level 1 are typically able to do.

Figure 12: Typical abilities of learners at PISA proficiency level 1

Mathematics	Science	Reading
• answer questions that involve familiar contexts where all relevant information is present • identify information and carry out routine procedures according to direct instructions in explicit situations • perform actions that are almost always obvious and follow immediately from the given stimuli.	• students have such a limited scientific knowledge that it can only be applied to a few, familiar situations • they can present scientific explanations that are obvious and that follow explicitly from given evidence.	• locate one or more independent pieces of explicitly stated information, where the required information in the text is prominent and there is little, if any, competing information • recognise the main theme or author's purpose in a text about a familiar topic • make a simple connection between information in the text and common, everyday knowledge.

Sources: OECD (2014, 2010, 2007)

6.1 Low performance in PISA mathematics

Twenty-eight per cent of learners in Wales are categorised as low performers in PISA mathematics. Learners who are low performers in science are almost 28 times more likely to also be low performers in mathematics, compared to average or high[2] performers in science. Similarly, low performers in reading are almost 20 times more likely to also be low performers in mathematics. Low performance in mathematics is consequently more closely associated with low performance in science than it is with reading. Our analysis also shows that learners are much less likely to be low performing in mathematics when they are categorised as average or high performing in at least one of the other two subjects. For example, if we take two learners who have low achievement in science, the learner with average or high achievement in reading is less likely to be a low performer in mathematics compared with the learner who is also a low achiever in reading.

This analysis also explored whether other learner characteristics or school characteristics increase or decrease the likelihood of being a low performer in mathematics. Table 8 below and Figure A1 in the Appendix summarise the findings.

A number of characteristics are associated with the likelihood of a learner being a low performer in the PISA mathematics assessment. If all other learner and school characteristics are equal the following groups of learners are significantly less likely to be low performers in mathematics:

- boys
- learners with higher ESCS scores.

In contrast, a learner with SEN is twice as likely to be a low performer in mathematics as a learner without SEN. This increased likelihood is statistically significant. In terms of school characteristics, learners in schools with higher proportions of learners with eligibility for FSM are significantly more likely to be low performers in mathematics, even after accounting for other learner and school characteristics.

6.2 Low performance in PISA science

Twenty-two per cent of learners in Wales are categorised as low performers in PISA science. As noted above, learners who are low performers in mathematics are 28 times more likely to also be low performers in science compared to average or high performers in mathematics. Low performers in reading are 22 times more likely to be low performers in science. Consequently, low performance in science is more closely associated with low performance in mathematics than with low performance in reading. As is the case for mathematics, our analysis also shows that learners are much less likely to be low performing in science when they are average or high performing in at least one of the other two subjects.

[2] Learners are categorised as average or high performers if they are not low performers. In terms of PISA proficiency levels this means learners who achieve above proficiency level 1.

Table 17: Characteristics associated with the likelihood of being a low performer in PISA

Characteristics	Mathematics	Science	Reading
PISA Science low performer	+		+
PISA Reading low performer	+	+	
PISA Mathematics low performer		+	+
Learner characteristics			
Male	–	–	+
Eligible for FSM	+	+	+
ESCS	–	–	–
Special educational needs	+	+	+
English as an additional language	–	–	+
Asian ethnicity	+	+	–
Black ethnicity	+	+	–
Mixed or other ethnicity	+	–	–
Welsh speaker (reading only)			+
School characteristics			
Welsh Medium school	–	+	+
Band 1 - highest	–	–	+
Band 3 – middle	–	–	+
Band 4 - middle-lowest	+	–	+
Band 5 – lowest	–	+	+
GwE (North Wales)	+	–	+
ERW (South West and Mid Wales)	–	–	–
EAS (South East Wales)	–	+	–
Proportion FSM (school)	+	+	+

Note: Cells in blue indicate statistically significant associations.

As is the case for mathematics, a number of characteristics are associated with the likelihood of a learner being a lower performer in the PISA science assessment. If all other learner and school characteristics are equal, boys are significantly less likely to be low performers in science than girls. Mirroring the findings for mathematics, a learner with SEN is twice as likely to be a low performer in science as a learner without SEN (all other learner and school characteristics being equal). This is a statistically significant increase. In addition, learners in Welsh medium schools are significantly more likely to be low performers in science than those in English medium schools (if all other learner and school characteristics are equal). Results are summarised in Table 8 and Figure A2 in the Appendix.

6.3 Low performance in PISA reading

Twenty-four per cent of learners in Wales are categorised as low performers in PISA reading. Learners are 22 times more likely to be low performing in reading when they are also low performing in science and 20 times more likely to be low performing in reading when they are low performing in mathematics. As was the case for the other subjects, learners are much less likely to be low performing in reading when they are average or high performing in at least one other subject.

As in the other subjects, there are a number of characteristics associated with the likelihood of being a low performer in the PISA reading assessment. If all other learner and school characteristics are equal, learners with higher ESCS scores are significantly less likely to be low performers in science than learners with lower ESCS scores.

In contrast, if all other learner and school characteristics are equal the following groups of learners are significantly more likely to be low performers in reading:

- boys
- learners with SEN.

No characteristic of the schools that learners attend is significantly related to the likelihood of being a low performer in reading after accounting for other differences in characteristics between learners and schools. Table 8 above and Figure A3 in the Appendix summarise the results.

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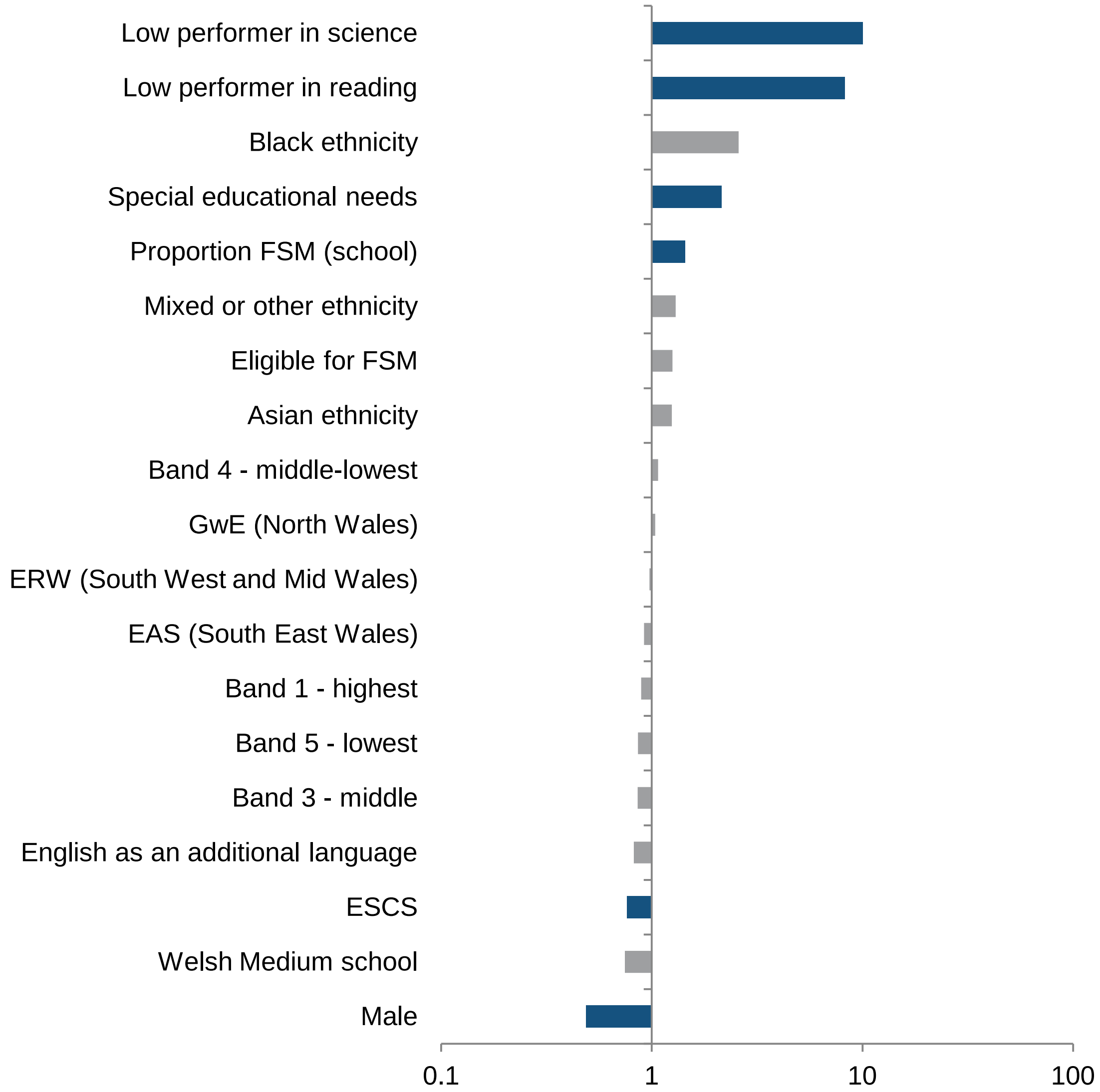
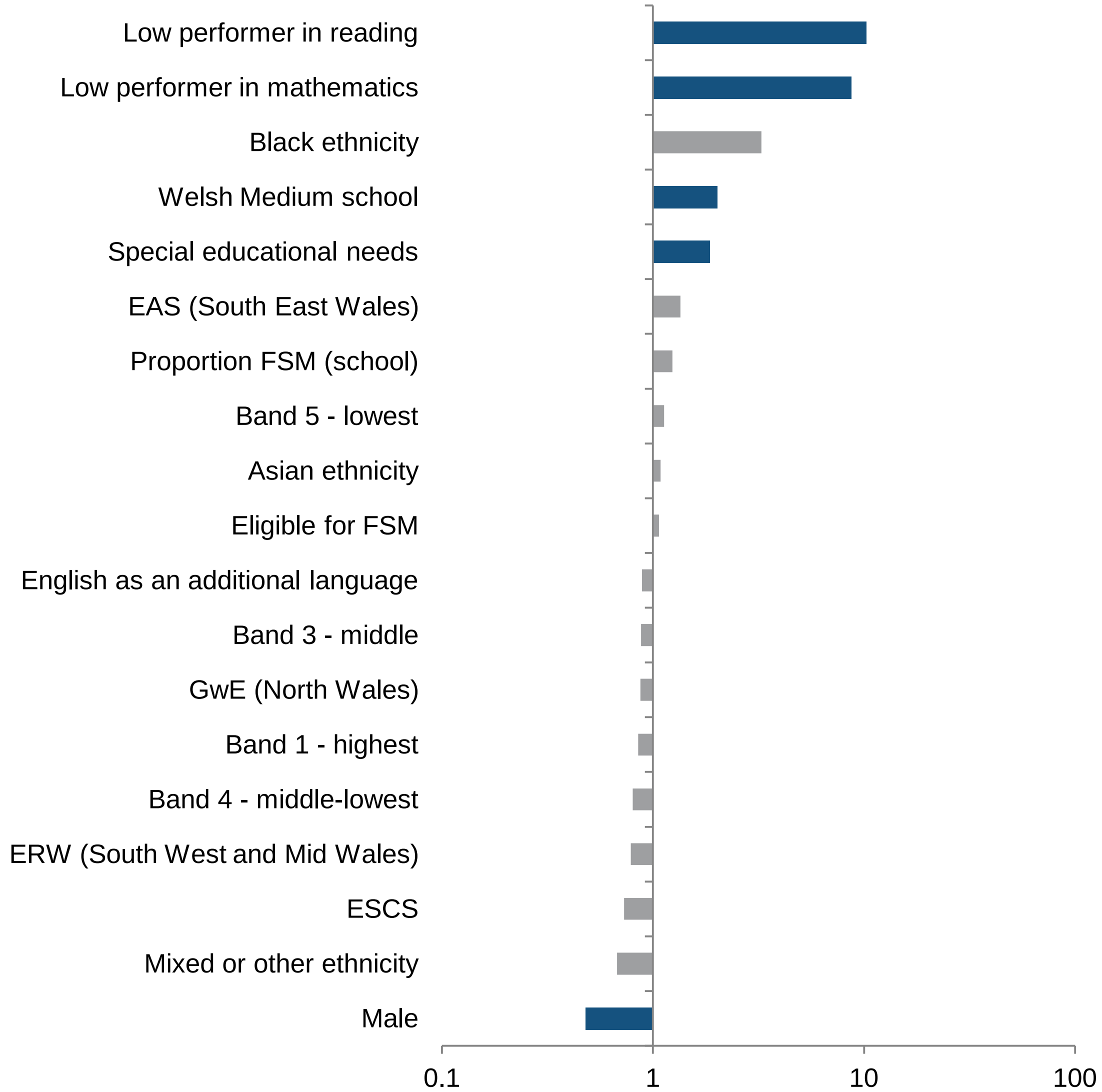
Appendix A

Figure A1: Characteristics associated with the likelihood (odds ratio) of being a low performer in mathematics



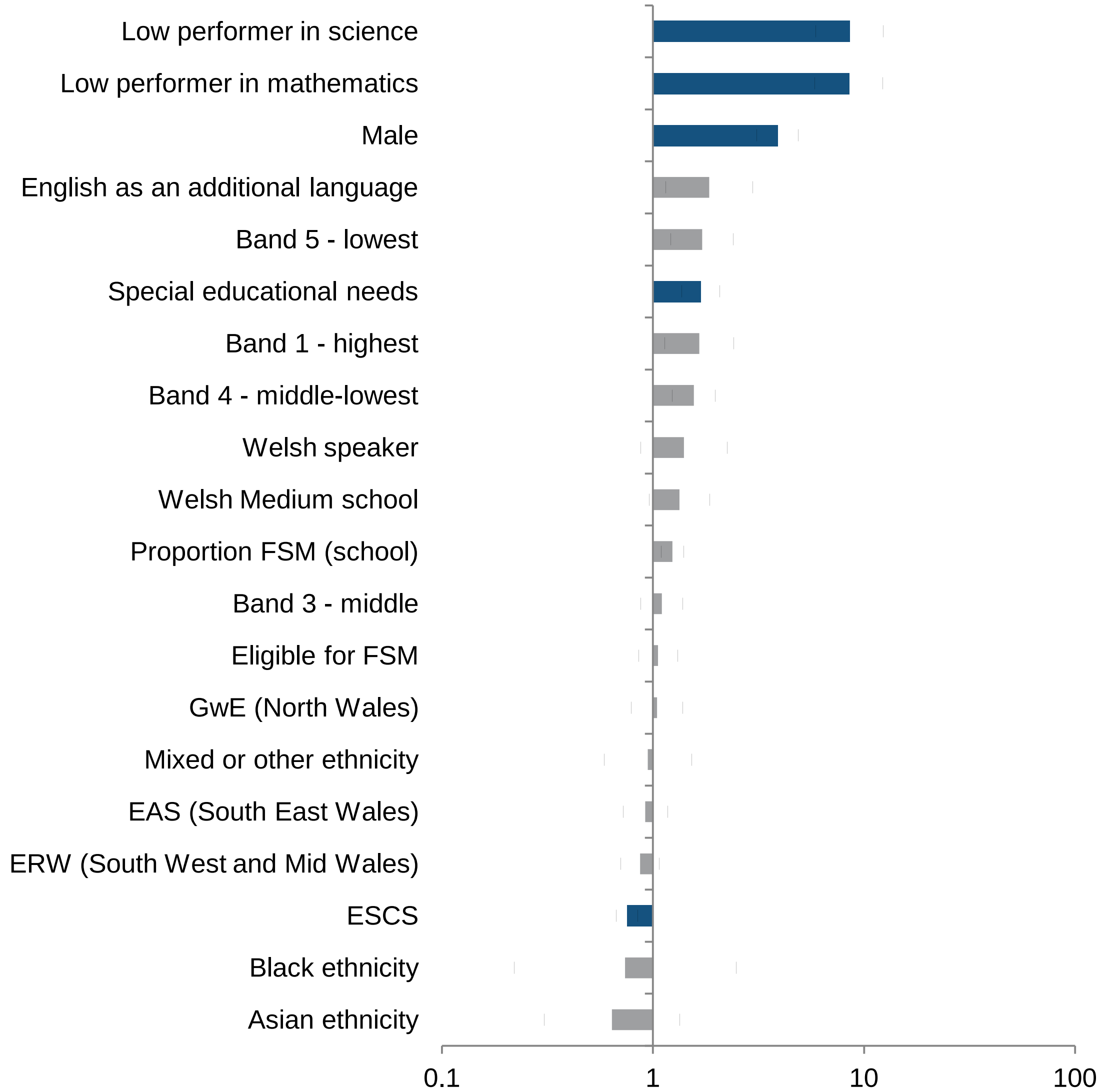
Note: Blue bars indicate a significant association

Figure A2: Characteristics associated with the likelihood (odds ratio) of being a low performer in science



Note: Blue bars indicate a significant association

Figure A3: Characteristics associated with the likelihood (odds ratio) of being a low performer in reading



Note: Blue bars indicate a significant association

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