Improving Learning

Within and Between School Variation in Achievement on the Programme for International Student Assessment (PISA) in Australia

PISA Australia Technical Paper

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Introduction

Australian secondary school students vary widely in their academic achievement. Using the scores from the Programme for International Student Achievement (PISA) in 2018, for example, the range from the 5th to the 95th percentile of student reading scores in Australia was 359 points compared to the OECD average of 327 points (OECD, 2019a; Thomson et al., 2019). This considerable range in achievement scores has been described as reflecting a long tail in the distribution of achievement.

In this paper, attention is focused on the variation in the achievement scores of 15-year-old students in Australia based on data from PISA 2018. It explores the extent to which the variation in achievement arises from variation among students *within* schools or variation in average achievement *between* schools.

The paper further explores the extent to which the variation in students' attitudes to aspects of schooling, and their socioeconomic backgrounds, arise from differences within or between schools. The focus on looking at within and between school patterns is important - the proportion of the variance in student achievement that occurs between schools can be interpreted as a measure of vertical or academic inclusion (Willms, 2010). At the same time, large variance within schools has important implications for approaches to teaching, specifically with relation to differentiation. Understanding the patterns thus illustrates themes of great salience for the Australian education system.

Context

In PISA 2018, the mean achievement in reading literacy for Australia was 503 points, which was similar to the mean for the United Kingdom and the United States, but significantly lower than that of a number of other countries, including Canada, Finland and Ireland. The variation among Australian 15-year-old students in reading and science achievement was greater than in most OECD countries and the variation in mathematics was similar to the average variation across the OECD. Details are provided in Table 1.

The standard deviation summarises the variation in performance across the entire distribution. The average standard deviation in reading achievement within OECD countries was 99 points. For Australia, the standard deviation of reading scores was 109 points – the second highest of OECD countries. In science in PISA 2018, the distribution of Australian scores – a standard deviation of 101 score points - was greater than the OECD average – 94 score points – and was the fifth largest in the OECD. The average score for Australia was 503 score points, compared to an OECD average of 489 score points.

In Australia, the range from the 5th to the 95th percentile of student reading scores was 330 score points compared to the OECD average of 306 score points (OECD, 2019a). The average difference between adjacent year levels was 33 score points (Thomson et al., 2019). In mathematics in PISA 2018, the distribution of Australian scores – a standard deviation of 92 score points - was similar to the OECD average – 91 score points. However, this still represents a wide range of achievement with the range from the 5th to the 95th percentile of student mathematics scores, being 302 score points compared to the OECD average of 297 score points (OECD, 2019; Thomson et al., 2019). The average difference between adjacent year levels in Australia was 28 score points.

The relatively large spread of PISA scores in Australia raises the question of whether the spread arises through differences among schools or through large variations within schools.

Table 1. Means and standard deviations for achievement in OECD countries in PISA 2018

	Reading		Mathematics		Science	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Australia	503 (1.6)	109 (0.9)	491 (1.9)	92 (1.2)	503 (1.8)	101 (1.1)
Austria	484 (2.7)	99 (1.2)	499 (3.0)	93 (1.5)	490 (2.8)	96 (1.2)
Belgium	493 (2.3)	103 (1.3)	508 (2.3)	95 (1.7)	499 (2.2)	99 (1.3)
Canada	520 (1.8)	100 (0.8)	512 (2.4)	92 (1.1)	518 (2.2)	96 (1.0)
Chile	452 (2.6)	92 (1.2)	417 (2.4)	85 (1.4)	444 (2.4)	83 (1.4)
Colombia	412 (3.3)	89 (1.5)	391 (3.0)	81 (2.0)	413 (3.1)	82 (1.4)
Czech Republic	490 (2.5)	97 (1.6)	499 (2.5)	93 (1.7)	497 (2.5)	94 (1.6)
Denmark	501 (1.8)	92 (1.2)	509 (1.7)	82 (1.0)	493 (1.9)	91 (1.3)
Estonia	523 (1.8)	93 (1.2)	523 (1.7)	82 (1.1)	530 (1.9)	88 (1.2)
Finland	520 (2.3)	100 (1.3)	507 (2.0)	82 (1.2)	522 (2.5)	96 (1.3)
France	493 (2.3)	101 (1.5)	495 (2.3)	93 (1.5)	493 (2.2)	96 (1.4)
Germany	498 (3.0)	106 (1.5)	500 (2.6)	95 (1.5)	503 (2.9)	103 (1.6)
Greece	457 (3.6)	97 (1.6)	451 (3.1)	89 (1.8)	452 (3.1)	86 (1.6)
Hungary	476 (2.3)	98 (1.3)	481 (2.3)	91 (1.6)	481 (2.3)	94 (1.4)
Iceland	474 (1.7)	105 (1.3)	495 (2.0)	90 (1.2)	475 (1.8)	91 (1.0)
Ireland	518 (2.2)	91 (1.0)	500 (2.2)	78 (1.0)	496 (2.2)	88 (1.2)
Israel	470 (3.7)	124 (1.9)	463 (3.5)	108 (1.9)	462 (3.6)	111 (1.9)
Italy	476 (2.4)	97 (1.7)	487 (2.8)	94 (1.8)	468 (2.4)	90 (1.7)
Japan	504 (2.7)	97 (1.7)	527 (2.5)	86 (1.6)	529 (2.6)	92 (1.6)
Korea	514 (2.9)	102 (1.7)	526 (3.1)	100 (2.0)	519 (2.8)	98 (1.7)
Latvia	479 (1.6)	90 (1.1)	496 (2.0)	80 (1.1)	487 (1.8)	84 (1.2)
Lithuania	476 (1.5)	94 (1.0)	481 (2.0)	91 (1.1)	482 (1.6)	90 (1.0)
Luxembourg	470 (1.1)	108 (1.0)	483 (1.1)	98 (1.3)	477 (1.2)	98 (1.2)
Mexico	420 (2.7)	84 (1.6)	409 (2.5)	78 (1.6)	419 (2.6)	74 (1.6)
Netherlands*	485 (2.7)	105 (1.7)	519 (2.6)	93 (1.8)	503 (2.8)	104 (1.9)
New Zealand	506 (2.0)	106 (1.3)	494 (1.7)	93 (1.1)	508 (2.1)	102 (1.4)
Norway	499 (2.2)	106 (1.3)	501 (2.2)	90 (1.3)	490 (2.3)	98 (1.2)
Poland	512 (2.7)	97 (1.4)	516 (2.6)	90 (1.7)	511 (2.6)	92 (1.4)
Portugal*	492 (2.4)	96 (1.2)	492 (2.7)	96 (1.3)	492 (2.8)	92 (1.3)
Slovak Republic	458 (2.2)	100 (1.4)	486 (2.6)	100 (1.7)	464 (2.3)	96 (1.5)
Slovenia	495 (1.2)	94 (1.2)	509 (1.4)	89 (1.4)	507 (1.3)	88 (1.1)
Spain	m m	m m	481 (1.5)	88 (1.0)	483 (1.6)	89 (0.8)
Sweden	506 (3.0)	108 (1.5)	502 (2.7)	91 (1.4)	499 (3.1)	98 (1.5)
Switzerland	484 (3.1)	103 (1.5)	515 (2.9)	94 (1.4)	495 (3.0)	97 (1.4)
Turkey	466 (2.2)	88 (1.6)	454 (2.3)	88 (1.8)	468 (2.0)	84 (1.6)
United Kingdom	504 (2.6)	100 (1.3)	502 (2.6)	93 (1.4)	505 (2.6)	99 (1.4)
United States*	505 (3.6)	108 (1.6)	478 (3.2)	92 (1.5)	502 (3.3)	99 (1.6)
OECD average	487 (0.4)	99 (0.2)	489 (0.4)	91 (0.2)	489 (0.4)	94 (0.2)
OECD total	485 (1.2)	105 (0.6)	478 (1.0)	97 (0.5)	486 (1.1)	99 (0.5)

Source: OECD (2019) PISA 2018 Results (Volume I) - Annex B1 Results for countries and economies

Notes:

Standard errors are shown in parentheses

** Data for the Netherlands, Portugal and United States did not meet the PISA technical standards but were accepted by the OECD as largely comparable.*

m *Data not available. Data were collected but subsequently removed for technical reasons.*

Approach

The extent of variation in reading, mathematics and science is typically indicated as the variance in achievement scores. Variance is a measure of dispersion calculated as the mean of the squared deviations of observed values from a group mean. The square root of the variance is the standard deviation.

Following standard practice for investigating variations in achievement, we partitioned the total variance in student achievement into the variance of student scores within schools and the variance between schools' mean scores.

The total variance indicates the extent to which students in a jurisdiction differ in achievement. The proportion of the total variance within schools provides an indication of the diversity that needs to be accommodated by teachers and schools in their approaches to teaching and learning. The proportion of the total variance that is between schools provides an indication of the extent to which schools are differentiated in their average achievement scores.

The variance decomposition was calculated for the Australian jurisdiction data using the MPLUS software, which was also used by ACER for the international calculations in PISA cycles 2006 to 2012. MPLUS allows for weighting at two levels (in this case, school and student level) which is theoretically desirable.

For the achievement scales, all available achievement plausible values were used (5 for each subject in PISA 2006 to 2012, and 10 for PISA 2015 and 2018). Stata was used by the Educational Testing Service (ETS) for PISA 2015 to 2018, but this similarly uses weights at both levels so differences between results from STATA and MPLUS are not large.

The proportion of total variance that is variance between schools is also 100 times the intra-class correlation coefficient and is represented by the statistic rho (ρ). In a group (or system) of schools where schools had the same average achievement but students within schools had varied achievement scores the value of rho would be zero. In a group (or system) of schools where all students within each school had the same achievement score but where schools differed in average achievement the value of rho would be one.

In other words, a low value of rho indicates high within school variation and low between school variation and a high value of rho indicates high between school variation and low within school variation.

Results

Interpreting differences among jurisdictions, or countries, in the values of rho (or the percentages of variance between and within schools) needs to recognise the importance of context. Differences in the values of rho reflect the effects of variations in factors such as inequalities in income or wealth, the relative distribution of students between metropolitan, regional and remote locations, demographic variations in populations, the proportions of students in government and non-government schools and whether school systems are comprehensive or selective. Differences are not necessarily an indication of the effects of school practices.

Table 2. Variance decomposition in Australia for achievement, socioeconomic background and selected attitudinal scales in PISA 2018

	N	Within-school variance	Between-school variance	Rho
Reading	14273	9606 (181)	2438 (225)	0.20 (0.013)
Science	14273	8023 (143)	2208 (203)	0.22 (0.012)
Mathematics	14273	6497 (139)	2052 (197)	0.24 (0.014)
Socioeconomic background (ESCS)	12813	0.64 (0.017)	0.19 (0.014)	0.23 (0.016)
Belonging to school	11917	0.90 (0.026)	0.03 (0.005)	0.03 (0.027)
Reading enjoyment	12509	1.36 (0.028)	0.04 (0.009)	0.03 (0.019)
Attitudes to school: learning activities	12170	1.05 (0.018)	0.01 (0.005)	0.01 (0.017)
Perceptions of reading competence	12264	1.03 (0.021)	0.02 (0.006)	0.02 (0.020)

Note: Standard errors are shown in parentheses. (OECD, 2019a; Avvisati, 2020*)*

National patterns

Table 2 shows the variance decomposition for the three achievement domains of reading, science and mathematics, student socioeconomic background (ESCS)[1] and four attitudinal scales: Belonging to school, reading enjoyment, attitudes to school learning activities, and perceptions of reading competence (OECD, 2019c).

It is evident that the values of rho (i.e. the proportion of variance that is between schools) are similar for all three achievement domains and for students' socioeconomic backgrounds. The difference between the values of rho for mathematics and reading is statistically significant, meaning that there are more differences between schools in mathematics performance than there are in reading performance.

It is also evident from Table 2 that the rho for each of the attitude domains are markedly smaller than the values of rho for achievement or socioeconomic background. Indeed, these values suggest that there are not substantial student differences between schools on these dimensions.

Jurisdictional differences

Table 3 records values of the proportion of variance that is between schools (rho) for each jurisdiction in PISA 2018 for reading, mathematics and science. Across all three achievement domains the only significant differences among jurisdictions involved New South Wales where the values of rho are either greater than, or not significantly different from, those of other jurisdictions. There were no significant differences among other jurisdictions.

The values of rho for New South Wales did not differ significantly from those for Western Australia or the Northern Territory (for which there are large standard errors) in any of the domains. However, the values of rho differed significantly from those for South Australia, Tasmania and the Australian Capital Territory on all three domains.

The values of rho were significantly lower for Victoria than New South Wales in reading and science but not in mathematics (although the tendency was for a lower value in Victoria). The values of rho were significantly lower for Queensland than New South Wales in mathematics and science but not in reading (although the tendency was for a lower value in Queensland).

[1] ESCS is the PISA index of economic, social and cultural status.

There are several possible explanations for the jurisdictional differences in the proportion of variance that is between schools. One of these relates to the extent to which there are differences in the provision of selective-entry government secondary schools.

In New South Wales there is a larger number of fully-selective or partially-selective government secondary schools than in other jurisdictions. There are 21 fully-selective high schools and 25 partially-selective high schools in New South Wales (New South Wales, 2021). Western Australia has one fully-selective high school, 15 partially-selective high schools as well as six schools which provide specialist visual and performing arts programs and two schools that provide specialist language programs (Western Australia, 2021).

Other jurisdictions have few selective-entry government schools with four fully-selective schools in Victoria, and three partially-selective and three fully-selective academies in Queensland. These differences appear to be partly associated with differences in the proportion of variance that is between schools (rho) across jurisdictions.

Another possible explanation could be differences in the percentages of junior secondary students in government, Catholic and independent schools. In 2018 across Australia 60 per cent of junior secondary students were enrolled in government schools, 22 per cent were enrolled in Catholic schools and 18 per cent were in independent schools (ACARA, 2021). These percentages varied across jurisdictions.

The percentage of junior secondary students in government schools ranged from 53 per cent (Australian Capital Territory) to 63 per cent (Queensland). The corresponding percentages in Catholic schools ranged from 16 per cent (Northern Territory) to 30 per cent (Australian Capital Territory) and in independent schools the percentages ranged from 15 per cent (Tasmania) to 21 per cent (Western Australia and South Australia).

Differences in the percentages of junior secondary students enrolled in government schools do not appear to be associated with differences in the percentage of between school variance in achievement for reading, mathematics or science.

There are other factors that could contribute to differences between jurisdictions in the proportion of variance that is between schools including variations in socioeconomic context, variations in the distribution of schools across location and, possibly, variations in school effects on student learning.

Table 3 Values of rho for PISA 2018 reading, mathematics and science by jurisdiction

Reading	Estimate	Mathematics	Estimate	Science	Estimate
Australia	0.20 (0.013)	Australia	0.24 (0.014)	Australia	0.22 (0.012)
New South Wales	0.25 (0.024)	New South Wales	0.29 (0.024)	New South Wales	0.28 (0.024)
Western Australia	0.19 (0.034)	Western Australia	0.24 (0.033)	Western Australia	0.24 (0.030)
Northern Territory	0.18 (0.082)	Northern Territory	0.24 (0.104)	Victoria	**0.19** (0.025)
Queensland	0.18 (0.031)	Victoria	0.23 (0.024)	Queensland	**0.18** (0.029)
Victoria	**0.18** (0.027)	Queensland	**0.19** (0.029)	South Australia	**0.17** (0.029)
South Australia	**0.15** (0.030)	Australian Capital Territory	**0.18** (0.037)	Northern Territory	0.16 (0.075)
Australian Capital Territory	**0.15** (0.040)	South Australia	**0.17** (0.034)	Australian Capital Territory	**0.15** (0.039)
Tasmania	**0.13** (0.045)	Tasmania	**0.16** (0.046)	Tasmania	**0.14** (0.050)

Notes:
Standard errors are shown in parentheses
Values of rho that differ significantly from the corresponding value for New South Wales are shown in bold

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Differences over time

Table 4 records values of rho for each domain on each PISA cycle since the domain was established. There does not appear to be any monotonic trend but it is of interest that the value of rho for reading appears to have increased from PISA 2000 to PISA 2009 and then declined from PISA 2009 to PISA 2018. This trend for the times when reading was a major domain follows an "inverted U" pattern and could reflect broad policy changes and targeted support based on assessment data following 2009 provided in a number of school systems. Similarly, the value of rho for mathematics appears to have increased from PISA 2003 to PISA 2012 and then declined from PISA 2012 to PISA 2018. It will be of interest to observe results for the next cycle of PISA, when mathematics will again be the major domain. In science, the value of rho increased between PISA 2006 to PISA 2015 but did not change between 2015 and 2018.

It seems possible that the decline in rho for reading between 2009 and 2018 may have been associated with declines in the average PISA scores for Catholic and independent schools (by 17 and 18 points respectively) but with no appreciable change for government schools. These differential declines resulted in smaller average achievement differences between government and non-government schools and therefore a reduction in the percentage of variance that was between schools. In mathematics there were declines in PISA scores between 2012 and 2018 in government (11 points), Catholic (15 points) and independent schools (16 points).

Table 4 Proportion of variance that is between schools (rho) for PISA scores for reading, mathematics and science over successive cycles from 2000 to 2018.

Domain	Year						
	2000	2003	2006	2009	2012	2015	2018
Reading	0.20	0.21	0.21	0.26	NA	0.22	0.20
Mathematics		0.22	0.21	NA	0.28	0.21	0.24
Science			0.18	NA	NA	0.22	0.22

Note: Calculation of values of rho was not possible for minor domains in 2009 and 2012. These are shown as NA.

International comparisons

Table 5 shows the extent to which the reading achievement of 15-year-olds varies between and within schools across OECD countries. In addition to recording the mean and total variance for each country, it shows the variance that is between schools, the variance that is within schools, the total variance as a multiple of the OECD average and the proportion of that variance that is contributed by differences among school means. It is important to note that the value recorded for Australia in reading in 2018 in the OECD is slightly different from the value that resulted from our calculations and recorded in Tables 2 through 4. This small difference may be due to the different software and analytic techniques used by the OECD. We were unable to check on the difference but believed that the discrepancy was small enough that the OECD international results still provided meaningful relative international comparisons.

The largest between-school proportions of variance are found in tracked education systems where entry to secondary school is based on measured performance (e.g. Germany, Italy, the Netherlands, Greece and Japan). The smallest between-school proportions of variance are found in comprehensive school systems (e.g. Finland, Canada and Denmark) (OECD, 2019b).

Table 5 Total variation in PISA 2018 reading performance and variation between and within schools

	Mean Reading score	Total variance	Between-school Variance	Within-school variance	Ratio of total variance to OECD average	Proportion of variance that is between schools
Finland	520 (2.3)	9902 (253)	652 (135)	9143 (223)	1.01	0.07
Iceland	473 (1.8)	10935 (278)	818 (153)	10280 (520)	1.12	0.07
Norway	499 (2.1)	11160 (267)	1033 (152)	10197 (239)	1.14	0.09
Canada	521 (1.8)	10049 (162)	1248 (109)	8808 (149)	1.03	0.12
Denmark	500 (1.8)	8354 (208)	1080 (115)	7251 (183)	0.86	0.13
Ireland	518 (2.2)	8227 (188)	1078 (149)	7106 (175)	0.84	0.13
New Zealand	506 (2.1)	11303 (285)	1598 (210)	9725 (230)	1.16	0.14
Sweden	504 (3.0)	11443 (304)	1706 (263)	9744 (259)	1.17	0.15
Portugal*	504 (2.6)	8307 (225)	1299 (197)	6910 (191)	0.85	0.16
United States*	505 (3.6)	11630 (340)	1919 (244)	9742 (256)	1.19	0.16
United Kingdom	504 (2.6)	10042 (255)	1788 (220)	8222 (177)	1.03	0.18
Poland	511 (2.7)	9343 (262)	1671 (235)	7639 (196)	0.96	0.18
Australia	502 (1.7)	11812 (197)	2140 (178)	9621 (156)	1.21	0.18
Estonia	523 (1.8)	8652 (222)	1634 (255)	6871 (177)	0.89	0.19
Latvia	479 (1.6)	8054 (188)	1810 (243)	6201 (158)	0.83	0.22
Korea	515 (3.4)	10504 (401)	2982 (404)	7503 (215)	1.08	0.28
Chile	456 (2.6)	8211 (217)	2396 (200)	5769 (133)	0.84	0.29
Luxembourg	470 (1.1)	11751 (216)	3563 (584)	8551 (560)	1.20	0.30
Mexico	434 (2.8)	6132 (231)	1870 (226)	4278 (101)	0.63	0.30
Greece	462 (3.7)	9037 (310)	2786 (351)	6220 (169)	0.93	0.31
Switzerland	470 (2.9)	10614 (328)	3588 (540)	7151 (229)	1.09	0.34
France	511 (2.7)	8644 (270)	2921 (325)	5685 (148)	0.89	0.34
Lithuania	476 (1.5)	8893 (189)	3073 (334)	5577 (139)	0.91	0.35
Colombia	412 (3.3)	7862 (274)	2894 (286)	4970 (106)	0.81	0.37
Japan	504 (2.7)	9433 (325)	3573 (319)	5839 (162)	0.97	0.38
Belgium	499 (2.3)	9857 (259)	3956 (296)	5881 (134)	1.01	0.40
Italy	477 (2.5)	9287 (334)	3998 (387)	5226 (131)	0.95	0.43
Slovenia	500 (1.1)	8382 (175)	3744 (384)	4600 (134)	0.86	0.45
Czech Republic	490 (2.5)	9473 (316)	4356 (369)	5032 (141)	0.97	0.46
Germany	499 (3.1)	11172 (323)	5229 (406)	5864 (148)	1.15	0.47
Slovak Republic	458 (2.2)	10067 (290)	4696 (380)	5260 (144)	1.03	0.47
Israel	470 (3.8)	15599 (477)	7374 (744)	8148 (240)	1.60	0.47
Hungary	486 (2.4)	8736 (277)	4492 (421)	4216 (116)	0.90	0.51
Netherlands*	484 (2.8)	10977 (363)	5800 (463)	5179 (165)	1.13	0.53
Turkey	466 (2.2)	7637 (293)	4238 (410)	3366 (92)	0.78	0.55
OECD average	489 (0.4)	9757 (47)	2829 (57)	6908 (36)	1.00	0.29

Source: OECD (2019) PISA 2018 Results (Volume II) - Annex B1 Table II B1.4.1 Total variation in reading performance, and variation between and within schools

Notes:

Standard errors are shown in parentheses

The total variation in student performance is calculated from the square of the standard deviation for all students. Due to the unbalanced, clustered nature of the data, the sum of the between- and within-school variation components, as an estimate from a sample, does not necessarily add up to the total.

Data for the Netherlands, Portugal and United States did not meet the PISA technical standards but were accepted by the OECD as largely comparable.

Australia sits in this table as having a between-school proportion of variance that is less than the OECD average and similar to that of United States, the United Kingdom, Poland and Estonia. However, Australia and the United States differ from the United Kingdom, Poland and Estonia in having a larger total variance than the OECD average. It is of interest that Canada has a smaller between-school proportion of variance and a smaller total variance than Australia, as well as a higher mean reading score.

It is also possible to link data reflecting the percentages of variance that are between schools in each country to measures of income inequality for each country. The Gini Coefficient is a well-established statistical measure of the degree of variation or inequality represented in a set of values that is used in analysing income inequality (OECD, 2015). Its values range from zero to 100.

Australia (34) and Canada (33) have similar values for the Gini coefficient but Australia has larger proportion of the variance in achievement that is between schools. Germany (33), like Belgium (29) and the Netherlands (27), has less income inequality than either Canada or Australia but a much larger proportion of variance that is between schools reflecting differences in the structure of its school system. The United States has a Gini coefficient of 48 reflecting considerable income inequality but a similar proportion of variance that is between schools to that in Australia.

Concluding comments

It is evident from the analyses presented in this paper that most of the variation in student achievement in PISA is variation among students within their schools. In PISA 2018 20 per cent of the variance reading achievement was between schools. In mathematics the percentage was a little greater at 24 per cent. This suggests that initiatives to reduce achievement inequalities among students will need to focus on differences within schools that accounted for 76 to 80 per cent of the variance. However, that does not imply that differences between schools are not important. By comparison, just 11 per cent of the variance in student reading achievement in Australia in PISA 2018 was “explained” by socioeconomic background (OECD, 2019b, Table II.B1.2.3). Masters (2016) observed one the major challenges for Australian education was to reduce the disparities in the schooling experiences of students in Australia’s most and least advantaged schools. He argued for monitoring the percentage of the total variance in student achievement attributable to between-school variance and implementing policies that reduced that percentage.

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