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Correlation between Scholar Achievements in Reading, Science, Physics and Mathematics

Abstract

With increasing technological capabilities, the importance of education in modern society has become essential. In particular, there is a growing demand for highly skilled workers for complex and better job opportunities. Therefore, the quality of education has become extremely relevant. The aim of this article is to identify and analyze students' educational achievements in reading, natural sciences, and mathematics in order to determine the correlation between students' performance in different areas. Specifically, the results of international organizations such as PISA, TIMSS, NAEP, which assess students' educational achievements, worldwide are examined in detail. The article also explores the influence of past educational achievements on future test results. Pearson correlation was used as a tool for analysis. The article also provides an overview of the consistency of results across different studies that examined interdisciplinary correlations in students' educational achievements.

Keywords: interdisciplinary correlation, Pearson correlation, quality of education, PISA test, reading, mathematics, natural sciences

Introduction

The importance of education in modern societies is increasing at a rapid pace with each year of technological progress. This is particularly true for the demand for highly qualified employees in more complicated and better workplaces. As a result, it is essential to analyze education in different countries, as each society searches for more efficient and successful educational approaches. The aim of this article is to find and analyze previously conducted assessments with the purpose of identifying correlations between student performance in different areas. The worldwide known Programme for International Student Assessment (PISA) provides data for more than 40 countries each assessment cycle (Official website of

Programme for International Student Assessment, 2023). It's reasonable to pay special attention to this test, making it a valuable resource for this research. Of course, we will also compare this test to other worldwide research studies such as Trends in International Mathematics and Science Study (TIMSS), the National Assessment of Educational Progress (NAEP), the Progress in International Reading Literacy Study (PIRLS), and other articles devoted to comparable topics. We will also consider smaller assessments that were conducted within a single school or university (Wolmarans a. oth., 2010; Chen a. oth., 2021; Pulkkinen, Rautopuro, 2022; Nyakyi, Mwenda, 2022).

The interests of this work include, but are not limited to, collecting and analyzing correlations between reading, science, physics, and mathematics, and finding different approaches to exploring their connections. We will also examine different age groups, countries, and the results of previous research studies. The difference between this study and others is that our aim is to check the alignment between different research studies on the same areas.

General information about the PISA test

One of the biggest and most well-known tests is the Programme for International Student Assessment (PISA), which involved 600,000 students from 79 countries in 2018 (OECD, OECD iLibrary, 2023). PISA was established in 1997 and "was first performed in 2000 and then repeated every three years. Its aim is to provide comparable data with a view to enabling countries to improve their education policies and outcomes. It measures problem-solving and cognition" (Berger, 2014). The main focus of the assessment lies in "measuring 15-year-olds' ability to use their reading, mathematics, and science knowledge and skills to meet real-life challenges" (PISA, 2023).

PISA is part of the Organization for Economic Co-operation and Development (OECD) — "an intergovernmental organization of industrialized countries, and is conducted in the United States by NCES" (NCES, Official website of The National Center for Education Statistics, 2023). In PISA, "the major domain of study rotates between reading, mathematics, and science in each cycle. PISA also includes measures of general or cross-curricular competencies, such as collaborative problem-solving. By design, PISA emphasizes functional skills that students have acquired as they near the end of compulsory schooling" (NCES, Official website of The National Center for Education Statistics, 2023). Until 2022, PISA had performed seven cycles of tests, but the test was postponed to 2023 due to post-COVID difficulties (PISA, 2023).

However, some articles point out flaws in the PISA testing and criticize its political and economic approach to children's education (Svein, 2017).

Evaluation methodology in PISA

From 2000 to 2012, the Rasch model and the partial credit model in PISA cycles were used to estimate item difficulty parameters and scale the items. The Rasch model is a mathematical model used to determine the probability that an individual will respond correctly to a particular item. In PISA 2015, a new modeling approach was introduced using a hybrid model that combines the Rasch and partial credit model with the two-parameter logistic or generalized partial credit model. As a result, the data from the prior cycles (2000–2012) had to be reanalyzed (OECD, PISA 2015 Technical Report, 2015). They reanalyzed data from assessments prior to 2015, enabling us to compare current measurements to those from previous years. It can be argued that PISA test results are related to IQ, as depicted in the figure below.

The evaluation of pupils is organized in such a way, that "in the first PISA survey in 2000, the OECD mean was set at 500 and the standard deviation in the OECD mean was set at 100" (Reiss a. oth., 2019) Also, the system is very convenient because, "Each proficiency level corresponds to a range of about

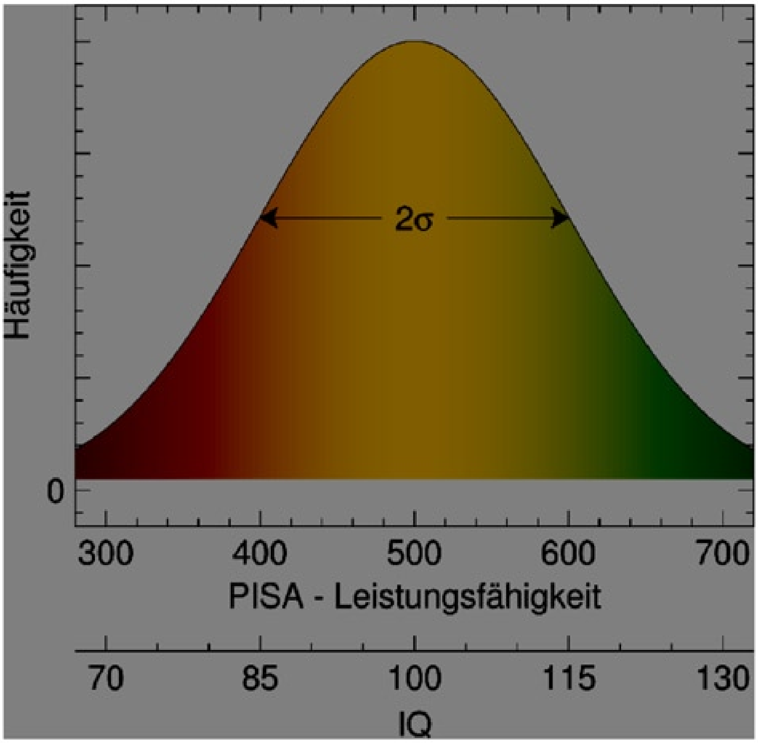

Fig. 1. Distribution of students' achievements in the PISA test on a mark scale (Wikipedia)

80 score points" (OECD, PISA 2018 Results, vol. I: *What Students Know and Can Do*, 2019). With these parameters, we can determine that approximately 68% of all students fall within the range of 400–600 score points, and 95% fall within the range of 300–700 score points. This information can later be used to interpret the success of educational systems in different countries.

Another important point to note is that the results we see in PISA research represent the relative achievements of students in a particular country (or a combination of countries) compared to the average score of all participants, which is approximately 500 marks, as mentioned before. Even though the PISA measurement data is based on the mean score of the respondents; it is still interesting to examine how specific countries have changed compared to the general tendencies across the board. Moreover, education is often compared between countries to identify the best practices and most efficient ways to teach children complex and constantly evolving ideas and approaches.

If we want to compare the results of pupils in different PISA tests, we should consider whether it is possible to do so and, if yes, what factors might influence the comparison. When comparing PISA data, we should take into account, that "comparisons between PISA 2018 scores and previous assessments can only be made to when the subject first became a major domain or later assessment cycles. As a result, comparisons of mathematics, and science performance between PISA 2000 and PISA 2018, for example, are not possible" (OECD, PISA 2018 Technical Report, 2018). This establishes time boundaries for the tests that can be compared or for which correlations can be calculated.

Another question is which subjects can be compared, as described in the report: "Some conditions have to be satisfied when different tests are used. Foremost, the data collected through these tests must be linked. Without any links, the data collected through two different tests cannot be reported on a single scale. Usually, tests are linked by having different students do common items or having the same students assessed with the different tests" (OECD, PISA Data Analysis Manual, 2009).

Another important factor to take into account is that "in later surveys, the OECD mean is no longer exactly 500, but has changed, for example, due to a different solution behavior of the participants or the increase in OECD countries" (Reiss a. oth., 2019).

Not only has the mean changed, but the standard deviation also shows a small fluctuations. For instance, the standard deviation for OECD average — 37 in reading performance was 95 in 2006 and 92 in 2012. (OECD, Table 1. B1.30 *Variation in science performance*, 2018, 2019) The changing standard deviation means that a flat change in evaluation of 4 points in different years can represent a different change in knowledge. This point applies not only to the comparison of reading scores from different years, but also to cross-disciplinary comparisons. One of the research aims is to adjust the PISA scale with a new approach (Weiss, 2009)

That being said, we can find a lot of articles that try to calculate the correlation between those measurements (Marchant, Finch, 2016; Pulkkinen, Rautopuro, 2022). Additionally, PISA has presented its own calculations on correlations, which are presented below.

As we can see, all the correlations calculated by PISA are positive and considered a strong positive association. There are some differences, ranging from the lowest of 0.64 to a maximum of 0.89, but all have a strong positive connection. Table 1 only presents 11 OECD countries out of the current 38 OECD countries. The other 16 countries for which data were provided are not OECD countries, but partners of the OECD. The reason that PISA mentions for this representation of countries is that "only the 27 countries and economies that conducted the global competence test are shown" (OECD, PISA 2018 Results, vol. VI: *Are Students Ready to Thrive in an Interconnected World?*, 2018), which "launch took place in Harvard on 12 December 2017." (OECD, PISA 2018 Global Competence) Based on this information, it's reasonable to assume that they are relying only on the results of the 2018 test.

Looking for more information on the topic, we found a correlation between PISA collaborative problem-solving scores and PISA science, reading, and mathematics literacy scores, by education system (NCES, Collaborative Problem-Solving: Correlations, 2015). Most OECD countries are presented separately, but correlations are presented only for collaborative problem-solving scores with other domains and not between the main ones such as "science," "mathematics," and "reading."

Calculation of correlations between domains in the PISA test

The questions raised a desire to understand the correlations between domains and particular countries, such as Germany, Poland, and other OECD countries, for which measurements could be found. One approach is to collect the mean scores for each country in each domain. For example, we can focus on reading measurements, initially and collect data from every year when reading evaluations were conducted, including in 2000, 2003, 2006, 2009, 2012, 2015, and 2018. Even though the PISA test in Mathematics was conducted in 2000, we can only use data starting in 2003. Similarly, for science, we can only use data starting in 2006. The reason for using only measurements in mathematics starting in 2003 and in physics starting in 2006 was described earlier in relation to the demand for "subject first became a major domain" (OECD, PISA 2018 Technical Report, 2018). So the test results became comparable in different years.

Table 1. Correlation between the four domains by PISA (OECD, PISA 2018 Results Vol. VI: *Are Students Ready to Thrive in an Interconnected World?*, 2018)

Correlation coefficient / OECD	between performance on the global competence cognitive test and...						between reading performance and...				between science performance and...	
	...reading performance		...science performance		...mathematics performance		...science performance		...mathematics performance		...mathematics performance	
	Corr.	S.E.	Corr.	S.E.	Corr.	S.E.	Corr.	S.E.	Corr.	S.E.	Corr.	S.E.
Canada	0.84	(0.00)	0.78	(0.01)	0.69	(0.01)	0.84	(0.01)	0.75	(0.01)	0.76	(0.01)
Chile	0.85	(0.01)	0.79	(0.01)	0.73	(0.01)	0.84	(0.01)	0.78	(0.01)	0.76	(0.01)
Colombia	0.87	(0.01)	0.81	(0.01)	0.74	(0.01)	0.86	(0.01)	0.80	(0.01)	0.77	(0.01)
Greece	0.86	(0.01)	0.78	(0.01)	0.73	(0.01)	0.85	(0.01)	0.77	(0.01)	0.76	(0.01)
Israel	0.88	(0.01)	0.85	(0.01)	0.81	(0.01)	0.89	(0.01)	0.83	(0.01)	0.83	(0.01)
Korea	0.84	(0.01)	0.85	(0.01)	0.81	(0.01)	0.84	(0.01)	0.78	(0.01)	0.84	(0.01)
Latvia	0.86	(0.01)	0.80	(0.01)	0.76	(0.01)	0.84	(0.01)	0.78	(0.01)	0.77	(0.01)
Lithuania	0.88	(0.00)	0.81	(0.01)	0.76	(0.01)	0.87	(0.01)	0.83	(0.01)	0.81	(0.01)
Scotland (United Kingdom)	0.78	(0.02)	0.68	(0.02)	0.64	(0.03)	0.80	(0.02)	0.71	(0.02)	0.68	(0.02)
Slovak Republic	0.82	(0.01)	0.77	(0.01)	0.72	(0.01)	0.85	(0.01)	0.80	(0.01)	0.81	(0.01)
Spain*	0.83	(0.01)	0.80	(0.01)	0.73	(0.01)	0.81	(0.01)	0.76	(0.01)	0.77	(0.01)

To proceed with our aim, we require a tool to quantify correlations. For this purpose, we will use "Descriptive statistics that express the degree of relation between two variables are called correlation coefficients. A commonly employed correlation *coefficient* is Pearson correlation, Kendall rank correlation and Spearman" (Zaid, 2015).

We would like to calculate Pearson's correlation. The formulas for calculating Person's correlation is presented below:

$$r_{xy} = \frac{\sum_{i=1}^{n} (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x})^2 \sum_{i=1}^{n} (y_i - \overline{y})^2}} \quad (1),$$

Where

— n is the sample size

— x_i, y_i are the individual sample points indexed with i

— $\overline{x}$ is the mean of the variable; $\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$, CITATION Cor \l 1033 (Zaid, 2015).

We will use the formulas from above to correlate the results of the mathematics and science assessments from the PISA test for Germany as an example. In order to calculate this correlation, we need to gather data that is comparable to each other. As mentioned, the results for mathematics are only comparable to 2003 onwards, and for science assessment, the data is comparable from 2006 onwards. Therefore, we will collect data only starting in 2006. We can obtain the mean achievements of Germany in the domains of mathematics and science for each year when the assessment was conducted, namely 2006, 2009, 2012, 2015, and 2018, from open sources. Additionally, as noted in the formula, we will need the mean results of all countries that participated in the test in that year. The results of this action might be presented in the following table.

In order to address the problem of different mean scores in the correlation data, we will establish a mean of 0 for all years and all PISA tests. This can be

Table 2. Germany's students assessment test results in Mathematics and Science according to PISA

	Mathematics Mean Score		Science Mean Score	
Year	Germany	all Countries	Germany	all Countries
2006	503.7	490.4	515.6	494.8
2009	512.7	491.7	520.4	497.7
2012	513.5	490.3	524.1	498.2
2015	505.9	487.1	509.1	490.6
2018	500.0	489.2	502.9	488.6

Table 3. Germany's students assessment test results in Mathematics and Science if themean were across all years of test

	Difference in mean assessment results between Germany and all participating countries	
Year	in mathematics	in Science
2006	13.4	20.8
2009	21.1	22.7
2012	23.2	25.9
2015	18.8	18.5
2018	10.8	14.3
Mean value	17.4	20.4

achieved by subtracting the average value from each country's indicator for the corresponding year and discipline. Namely, in the 2006 mathematics assessment, Germany achieved 503.7 points, while the average across all participating countries was 490.4. By subtracting these two values, we establish a mean value of 0, and now Germany will have an evaluation of 13.3 points in mathematics for the 2006 assessment. This approach not only eliminates errors related to different mean values for each year, but also provides clarity in interpretation, where a positive score indicates better than average and a negative score indicates a larger difference. The resulting table will be as follows:

Now that we have all the necessary information, we can use the previously mentioned formulas to calculate Pearson's correlation.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

$$r_{xy} = \frac{(13.4-17.4)(20.8-20.4)+(21.1-17.4)(22.7-20.4)+(23.2-17.4)(25.9-20.4)+(18.8-17.4)(18.5-20.4)+(10.8-17.4)(14.3-20.4)}{\sqrt{[(13.4-17.4)^2(21.1-17.4)^2(23.2-17.4)^2\,(18.8-17.4)^2(10.8-17.4)^2]\,[(20.8-20.4)^2+(22.7-20.4)^2+(25.9-20.4)^2+(18.5-20.4)^2+(14.3-20.4)^2}}$$

We have calculated the Pearson correlation between Physics and Mathematics achievements of Germany in the PISA test is $r_{s-m} = 0.83$. Since the values contain many digits after the decimal point, we approximated them in Tables 2 and 3 to avoid overloading the tables. The Pearson correlation coefficient represents the linear correlation between two variables, with a value ranging between –1 and 1. The table below shows the borders for strong and weak correlations.

By applying the same approach, we can now determine the correlation between Science and Mathematics for each country in our dataset. Table 5 presents the Pearson correlation coefficients for each country. For the "Selected countries and jurisdictions" category, we used data from all OECD countries available.

Table 4. Pearson's coefficient of power of correlation (Samuels, Gilchrist, 2014)

	Coefficient, *r*	
Strength of Association	Negative	Positive
Small	– 0.1 to – 0.3	0.1 to 0.3
Medium	– 0.3 to – 0.5	0.3 to 0.5
Large	– 0.5 to – 0.1	0.5 to 0.1

This allowed us to calculate correlations for a wider range of countries. As shown in the table, Germany exhibits a strong positive linear correlation between Science and Mathematics performance. The table also includes the cutoffs for interpreting the strength of correlation, ranging from weak to strong.

Not all 38 countries are presented in the table because some lacked assessment results for one year or more. Green marks were used to indicate a very strong positive correlation ($r > 0.90$), while red marks were used for negative correlation ($r < 0.0$). There is no strong or even medium negative association in this table, but the differences between countries appear to be significant. The PISA test also includes a reading assessment, so we can repeat the same calculations using reading and science as variables. The results are presented in the table below.

And also, we can calculate the correlation between the results in PISA tests in reading and mathematics using all the collected data.

Since our analysis is based on the evaluation of 15-year-old students in countries rather than individual test results, the correlations represent relationships at the country level rather than at the level of individual students' success. That will cause issues. The first change will be responsible for changing the subject matter indicated by the correlation: "When aggregated on the country level, the (average) test scores no longer represent any student's ability to solve specific kinds of math problems. Rather, the aggregated score is an indicator of a country's overall efficiency in promoting mathematical competence among its children and youth" (Klieme, 2016).

And the second issue is the influence on the precision of the results: "Measuring change in student achievement on the country level is less robust" (OECD, PISA Data Analysis Manual, 2009). It is important to understand the flaws and limitations of the calculated correlation in order to improve it in the future.

Keeping in mind the described limitations, let's look at the results of Germany, we observe a strong positive correlation between science and mathematics $r_{sm} = 0.83$ a non-significant negative correlation between reading and sci-

Table 5. Person's coefficient for variables science and mathematics assessment results

Country	Person's coefficient	Country	Person's coefficient
Selected countries and jurisdictions	0.95	Japan	0.99
Australia	0.99	Korea	0.64
Austria	0.89	Latvia	0.41
Belgium	0.49	Lithuania	– 0.23
Canada	0.56	Luxembourg	0.69
Chile	0.67	Mexico	– 0.04
Colombia	1.00	Netherlands	0.86
Czech Republic	0.95	New Zealand	0.96
Denmark	0.64	Norway	0.91
Estonia	0.92	Poland	0.89
Finland	0.98	Portugal	0.93
France	0.90	Slovak Republic	0.93
Germany	0.83	Slovenia	0.60
Greece	0.60	Spain	0.87
Hungary	0.82	Sweden	0.99
Iceland	0.98	Switzerland	0.98
Ireland	0.23	Turkey	0.98
Israel	0.97	United Kingdom	– 0.05
Italy	0.43	United States	0.19

ence $r_{rs} = -0.09$, and a strong positive correlation between reading and mathematics $r_{rm} = 0.72$.

In order to better understand the differences in the values of the correlation coefficient, and a histogram of frequencies is presented below.

Despite the overall positive correlation between all three domains of Physics, Reading, and Mathematics, there are some instances where the differences in correlations are quite significant. What could account for such large differences in these coefficients? First, PISA scores reflect a country's achievements compared to the mean results of all test participants. Thus, if your flat results remain the same as in the previous measurement, but another country improves its flat results from the previous measurement, then PISA measurements will show that your performance is lower this time. There is always the possibility of a situation

Table 6. Person's coefficient for variables reading and science assessment results

Country	Person's coefficient	Country	Person's coefficient
Selected countries and jurisdictions	0.94	Italy	0.89
Australia	0.91	Japan	0.82
Austria	0.87	Korea	0.10
Belgium	– 0.03	Latvia	0.38
Canada	0.96	Lithuania	0.16
Chile	0.82	Luxembourg	0.96
Colombia	0.89	Mexico	0.58
Czech Republic	0.39	Netherlands	0.89
Denmark	0.45	New Zealand	0.96
Estonia	0.81	Norway	0.96
Finland	0.89	Poland	0.52
France	0.15	Portugal	0.99
Germany	– 0.09	Slovak Republic	0.95
Greece	0.27	Slovenia	0.84
Hungary	0.87	Sweden	0.98
Iceland	0.86	Switzerland	0.83
Ireland	0.25	Turkey	0.77
Israel	0.62	United Kingdom	0.03

where the mean achievements of participants change due to external factors, such as the unequal impact of COVID-19 in every country or more local factors that affect one country, but are absent in others. Among other reasons, the switch from paper tasks to the online format in 2015 in some countries had an influence on the results, as mentioned in PISA (OECD, PISA 2018 Results, vol. I: *What Students Know and Can Do*). Other factors include demographic differences in the sample (the ratio of girls to boys), differences in the education system across different parts of a country, changes in the sample's mean and standard deviation through the years, and short-term changes in the education system. It should be noted that our analysis was performed at the country-wide level and did not consider individual student characteristics. Therefore, if one student prioritized mathematics over reading and another prioritized reading over mathematics, the overall results would not change. These factors may lead to certain differences in the results, which we hope to improve in the future.

Table 7. Person's coefficient for variables in reading and mathematics assessment results

Country	Person's coefficient	Country	Person's coefficient
Selected countries and jurisdictions	0.86	Japan	0.80
Australia	0.91	Korea	0.72
Austria	0.75	Latvia	– 0.56
Belgium	0.72	Luxembourg	0.78
Canada	0.58	Mexico	0.98
Czech Republic	0.36	Netherlands	0.59
Denmark	0.69	New Zealand	0.98
Finland	0.92	Norway	0.80
France	– 0.54	Poland	0.85
Germany	0.72	Portugal	0.95
Greece	0.36	Slovak Republic	0.97
Hungary	0.60	Sweden	0.98
Iceland	0.77	Switzerland	0.83
Ireland	0.94	Turkey	0.88
Italy	0.86	United Kingdom	0.99

Influence of previous results in discipline on following measurements

In the previous section, we compared the results across disciplines and arrived at the general conclusion of a positive correlation between Physics, Reading, and Mathematics. However, this dataset allows us to explore another intriguing aspect, namely, how and to what extent the previous test results influence the future results. For instance, we obtained reading achievement data for Austria spanning from 2000 to 2018, and we sought to determine the Pearson correlation between consecutive tests in the same domain. Specifically, we compared the 2000 results with those of 2003, 2003 with 2006, and so on, up to 2018. This approach is based on the assumption that previous test results have some inertia and continue to affect subsequent years.

Unfortunately, Pearson's correlation is a two-way correlation, meaning that in this case, it does not distinguish between the influence of 2000 on 2003 or 2003 on 2000. However, we can deduce that only the year 2000 can have an impact on 2003. Using the same formula (1) and the data we collected earlier, we obtained similar results for science assessments.

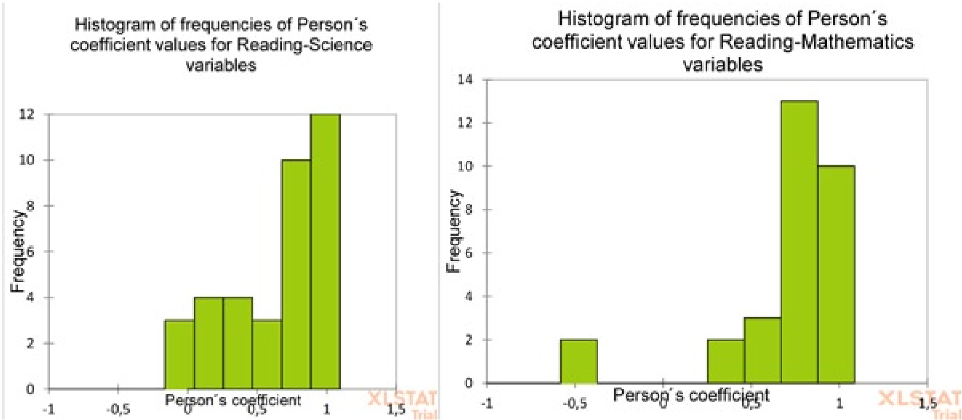

Fig 2. Histogram of frequencies of Person's coefficient values

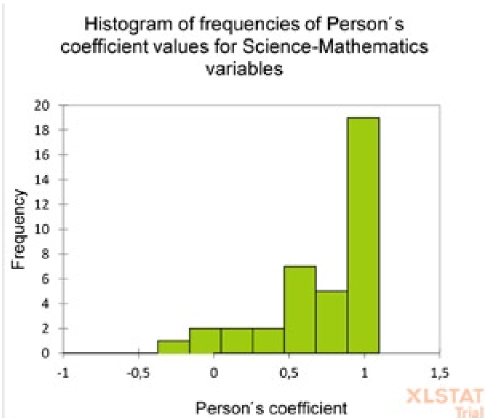

Fig 3. Histogram of frequencies of Person's coefficient values

Unlike in the previous table, in this part, we will highlight all correlations with a value of 0.5 or higher in green, and all correlations with a value of –0.5 or lower in red. The reason for this difference is that the variation in this sample is much higher. Although the Pearson's coefficient is very high (+0.96) when calculated for all countries, we can observe that many countries have a negative coefficient, and the number of countries with a coefficient greater than +0.90 is far fewer than in the previous calculations for the coefficient between domains. A similar trend can be seen when calculating Pearson's coefficient for mathematics results.

From the table, a general positive Pearson correlation is observed, with an overall $r = 0.96$, if calculated for all countries. However, there are significant negative values present, such as for Austria with $r\text{MM} = -0.88$.

Table 8. Person's coefficient for two consecutive test results in science

Country	Person's coefficient	Country	Person's coefficient
Selected countries and jurisdictions	0.96	Japan	0.16
Australia	0.97	Korea	– 0.14
Austria	– 0.90	Latvia	0.04
Belgium	– 0.22	Lithuania	– 0.45
Canada	– 0.48	Luxembourg	– 0.48
Chile	0.27	Mexico	0.76
Colombia	0.55	Netherlands	0.88
Czech Republic	– 0.85	New Zealand	0.36
Denmark	– 0.15	Norway	– 0.38
Estonia	0.13	Poland	– 0.24
Finland	1.00	Portugal	0.23
France	0.62	Slovak Republic	0.58
Germany	0.32	Slovenia	– 0.42
Greece	0.98	Spain	0.07
Hungary	0.70	Sweden	0.01
Iceland	0.26	Switzerland	0.76
Ireland	– 0.30	Turkey	– 0.60
Israel	0.60	United Kingdom	– 0.54
Italy	– 0.06	United States	0.27

We will apply the proposed approach to the reading results as well.

Again, a generally positive value of the Pearson correlation coefficient can be observed. Additionally, the data dispersion is not as significant as in Tables 8 and 9.

Some countries lacked data, such as the Netherlands' reading achievements in 2000, so correlations were calculated from 2003 to 2018 for a total of six measurements, and the same approach was used for other countries. The science-to-science domain had the least number of measurements, starting in 2006, so only four measurements were used for calculations. For mathematics-to-mathematics, there was one additional measurement in 2003, and for reading-to-reading, there were two more starting in 2000, resulting in a total of seven measurements. We did not expect such results, and it is possible that the Pearson's

Table 9. Person's coefficient for two consecutive test results in mathematics

Country	Person's coefficient	Country	Person's coefficient
Selected countries and jurisdictions	0.96	Japan	0.44
Australia	0.88	Korea	0.08
Austria	– 0.88	Latvia	– 0.06
Belgium	0.76	Lithuania	– 0.49
Canada	0.61	Luxembourg	– 0.48
Chile	0.15	Mexico	0.65
Colombia	0.50	Netherlands	0.59
Czech Republic	0.01	New Zealand	0.68
Denmark	– 0.18	Norway	0.26
Estonia	0.54	Poland	0.46
Finland	0.72	Portugal	0.88
France	– 0.15	Slovak Republic	0.26
Germany	0.37	Slovenia	0.28
Greece	– 0.25	Spain	0.45
Hungary	0.09	Sweden	0.10
Iceland	0.60	Switzerland	0.18
Ireland	– 0.16	Turkey	– 0.05
Israel	0.62	United Kingdom	0.17
Italy	0.82	United States	– 0.08

correlation, which measures linear association, may not be the most appropriate method for the second case, or that using only four measurements caused significant errors in the calculations. It is important to remember that correlation does not necessarily imply causation, and it's possible that other underlying factors or chance could explain the observed relationships. Therefore, additional analysis methods should be considered, and results should be interpreted with caution. Another major factor that can affect the results are link-errors, which were described in Annex A7 of the report. Comparing reading, mathematics and science performance across PISA cycles: "treated items that

Table 10. Person's coefficient for two consecutive test results in reading

Country	Person's coefficient	Country	Person's coefficient
Selected countries and jurisdictions	0.91	Korea	0.30
Australia	0.92	Latvia	– 0.43
Austria	– 0.44	Luxembourg	0.06
Belgium	0.63	Mexico	0.13
Canada	– 0.29	Netherlands	0.90
Czech Republic	– 0.31	New Zealand	0.55
Denmark	0.14	Norway	0.15
Finland	0.54	Poland	0.38
France	0.10	Portugal	0.75
Germany	0.73	Slovak Republic	0.34
Greece	0.04	Spain	0.22
Hungary	0.26	Sweden	0.35
Iceland	0.16	Switzerland	0.23
Ireland	– 0.41	Turkey	– 0.46
Italy	0.22	United Kingdom	0.37
Japan	0.21		

were left unanswered at the end of test forms as if they were not part of the test, rather than as incorrectly answered," "shifting emphasis of the test", and since we compare test from different years, the population sample shifts as well (OECD, PISA 2018 Results, vol. I: *What Students Know and Can Do*).

Other research studies that examine the relationships between physics, science, mathematics, or reading

Many articles examine the connections between Physics and Mathematics, as well as the correlation between student achievements in these two areas. Most of these studies find a positive correlation, but interestingly, the values vary. Of course, this may have obvious reasons, such as some topics having more intersections with each other and differences in studying these disciplines depending on the program. One research study conducted by Jihe Chen, Jerito Pereira, Ying Zhou, Xinxin Li, Maximus Tamur, and Syaharuddin in 2021 found a correlation scores between 0.57 and 0.65 "indicating a strong positive linear relationship between math and physics scores" in senior high school grade 12 (Chen a. oth., 2021).

Another study found significant differences in the achievements of students in Physics across Finland, Germany, and Switzerland. On the same scale, the difference in knowledge gained could be up to 25 times during the same period, with a sample size of more than 500 students from each country. The study also compared its results with PISA and demonstrated a strong similarity of outcomes (Geller a. oth., 2014).

Another study showed a high correlation with PISA and TIMSS (Trends in International Mathematics and Science Study), which is one of the largest international assessments with over 500,000 participating students. "There is a close alignment between country mean scores from both studies. The coefficient of correlation is .923, indicating that 85H of the between-country-variation in PISA Mathematics Literacy can be explained by TIMSS, and vice versa" (Klieme, 2016).

Conclusions

As expected, and as other studies have shown, there is a positive Pearson's correlation between all disciplines on average: Reading, Science, Mathematics. However, the aspect of regional and local peculiarities is important. According to our research, in rare cases, countries have a weak or even moderate negative association between disciplines. Despite the usual coherence and strong association with the PISA results, some articles in their own research also found strong differences between countries in interdisciplinary interconnections, showing negligible association. This aspect has been analyzed in the article.

A careful approach is required when computing and generalizing the results of similar studies. This is due to the numerous factors that have been identified to influence the results of such analyses, including the year of the test, which affects the demographic differences in the sample (the ratio of girls to boys), the country's economic status, the influence of global events that have varying effects on the levels of countries (wars, epidemics), changes in test conditions (changes in the sample's mean and standard deviation, transition from paper to electronic testing), possible short-term changes in the education system, a dependence on the region of the country where the testing was conducted. It is worth noting that the core calculations were made without individual results but with country summaries, which may lead to certain differences in the results, which we hope will be possible to improve in the future.

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