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Students' Mathematics Performance in Rural Schools: Results from OECD Pisa 2022

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Abstract. This study examines rural educational institutions with the objective to identify student-level factors associated with student mathematics performance. By using data from the 2022 Programme for International Student Assessment (PISA) by the OECD, rural schools were categorized into three groups based on their students' mean mathematics achievement. Binary logistic regression was applied to the highest- and lowest-performing groups to analyze student-level factors associated with academic outcomes.
Keywords: binary logistic regression, mathematics performance, OECD PISA, rural schools.

Mokinių matematikos pasiekimai kaimo mokyklose: 2022 m. OECD PISA tyrimo rezultatai

Santrauka. Ankstesniuose tyrimuose daug dėmesio skirta akademinių pasiekimų skirtumams tarp kaimo ir miesto mokyklų, tačiau dažnai nebuvo pakankamai atsižvelgiama į skirtumus tarp pačių kaimo mokyklų. Šis tyrimas skirtas būtent kaimo mokykloms, jame nagrinėjami skirtumus tarp geresnius ir prastesnius rezultatus pasiekiančių kaimo mokyklų lemiantys su mokiniais susiję veiksniai. Duomenys paimti iš OECD PISA 2022 tyrimo ir apėmė 8 Europos OECD šalis: Čekiją, Estiją, Islandiją, Airiją, Latviją, Lietuvą, Norvegiją ir Slovakiją. Šios šalys pasirinktos todėl, kad jose yra palyginti daug kaimo mokyklų. Kiekvienos šalies kaimo mokyklos suskirstytos į 3 grupes pa-

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gal matematikos pasiekimų vidurkius. Mokinių, lankančių aukščiausių ir žemiausių mokymosi vidurkių mokyklas, duomenys buvo lyginami taikant binarinę logistinę regresiją siekiant ištirti ryšius tarp mokinių charakteristikų ir priklausymo aukštų bei žemų pasiekimų kaimo mokykloms.

Atlikta analizė atskleidė, kad su aukštais mokyklų pasiekimais susiję keli mokinių lygmens veiksniai – mokyklos atmosfera, saugumo pojūtis, drausmės atmosfera ir mokytojų bei mokinių santykiai, nors šių ryšių stiprumas ir kryptis skirtingose šalyse skyrėsi.

Tyrimo rezultatai taip pat išryškino su švietimo ištekliais ir mokyklos atmosfera susijusius skirtumus, kurie pasireiškė aukštesnių ir žemesnių pasiekimų mokyklose. Apskritai tyrime nepavyko nustatyti universalių, su aukštais pasiekimais visose šalyse susijusių veiksnių. Priešingai – tyrimo rezultatai rodo, kad su aukštais pasiekimais kaimo mokyklose susiję veiksniai priklauso nuo konteksto ir skirtingose šalyse skiriasi.

Pagrindiniai žodžiai: binarinė logistinė regresija, matematikos pasiekimai, OECD PISA, kaimo mokyklos.

Introduction

The differences in academic achievement between students attending rural and urban schools have been the focus of numerous studies. In countries, except for those with expansive geographic areas such as the United States of America (USA), where rural schools constitute a significant portion of the educational network, researchers often examine disparities in student achievement between rural and urban settings, while overlooking variations within rural schools themselves (Johnson et al., 2021). This study aims to investigate student-level factors associated with membership in high- and low-achievement rural school groups.

As noted by Echazarra and Radinger (2019), environmental differences significantly shape students' perceptions of education and their academic motivation. Understanding these contrasting environments is crucial for developing strategies that support all students in achieving their educational and career goals. By examining student-level characteristics associated with differences between higher- and lower-achievement rural schools, this study seeks to provide comprehensive insights into the educational landscape of rural communities. The study aims to contribute to a deeper understanding of how student-level characteristics are associated with differences between higher- and lower-achievement rural schools, thereby informing policies and interventions aimed at improving educational equity and quality in rural areas. Examination of the specific characteristics of rural education provides essential context for this study.

Characteristics of Rural Education and Factors Influencing Mathematic Achievement

Understanding the nuances of rural environments is essential for tackling the specific challenges faced in rural education. Despite often being overshadowed by urban counterparts, rural areas play a vital role in a nation's educational framework and have a considerable influence over the overall academic performance. Yet, defining and categorizing rural regions poses difficulties due to their diversity and the absence of a universal definition. Nevertheless, for the purposes of this study, it is necessary to outline the general characteristics of rural regions so that to better understand the factors that could influence educational outcomes in the field of mathematics.

Characteristics of Rural Education

To begin with, defining the term ‘rural’ is challenging because it varies significantly from one country to another. This variability arises because there is no universal standard for what can be classified as a rural area, leading to considerable differences in definitions across countries. Rural areas can vary widely in terms of beliefs, infrastructure availability, access to services, geographic landscapes, as well as in their social, cultural, and economic characteristics, both within and across countries. Nevertheless, theoretical research suggests several criteria for identifying rural areas. These criteria include, but are not limited to, the geographic proximity of rural areas to urban centers, the population density of rural areas, which is generally lower than that of urban areas, economic indicators that are often indicative of a lower socioeconomic status and income level, as well as measures of educational attainment (Hargreaves et al., 2009; Kettler et al., 2015; Echazarra & Radinger 2019). Within the European Union, the classification of rural areas is based on demographic, geographic, and socioeconomic factors, such as the population density, the degree of remoteness, and economic prosperity (Echazarra & Radinger, 2019).

Greenough and Nelson (2015) highlight the difficulties in defining rural education, while outlining the notable variations found within rural schools. The education in rural areas is shaped by several factors, including student population trends, poverty levels, district characteristics, the school size, and geographic remoteness (Kettler et al., 2016). Echazarra and Radinger (2019) identified six distinct qualitative characteristics of rural schools. These include: a strong connection to the local community, with education having a significant impact on the lives of families; the location of educational activities outside urban areas; a historical link to agricultural cultures; limited access to highly skilled educators, cutting-edge facilities, and professional development opportunities; small-scale educational institutions; and collaboration with the local community to support the local economy (Echazarra & Radinger, 2019).

Findings based on data from the 2015 cycle of the *Organisation for Economic Co-operation and Development* (OECD) *Programme for International Student Assessment* (PISA) suggest that rural students outperform their urban peers in certain countries in some cases (Echazarra & Radinger, 2019); however, this is not the prevailing pattern. In fact, the majority of research suggests that rural schools generally demonstrate lower academic achievement and offer fewer educational opportunities compared to urban schools (Lounkaew, 2013; Sullivan et al., 2013; Echazarra & Radinger, 2019; Geske et al., 2022; Lee, 2022; OECD, 2022; Geske et al., 2023; Ozola et al., 2023; Sanfo, 2023; Betancur et al., 2024; Bonacini et al., 2024).

Factors Influencing Mathematic Achievement

Understanding the factors that influence students’ mathematic achievement is crucial for improving educational outcomes and fostering academic success across diverse learning contexts. Learning is a multifaceted process influenced by numerous interconnected factors that shape students' achievements in mathematics. This study focuses specifically on factors that can be identified within the framework of the OECD PISA.

Theoretical research supports the assumption that several various contextual factors, e.g., students' prior knowledge, attitudes toward mathematics (Mohd et al., 2011), self-efficacy (Masitoh & Fitriyani, 2018; Kampmane et al., 2023) and socioeconomic status (Mihno, 2015) also play significant roles in shaping students' mathematical achievement. OECD PISA and some studies carried out in the United States such as the one conducted by Byun et al. (2012) support the opinion that disparities in the socioeconomic status are one of the main causes of educational attainment gaps between rural and urban students. Students from more affluent backgrounds often benefit from greater access to high-quality resources, such as tutoring services and instructional materials, which can positively influence their academic performance. Many rural schools provide students with limited instructional resources and can only offer lower salaries for teachers compared to rural schools and that can result in shortage of mathematics teachers (Lotter et al. 2020; Strange, 2011), and, accordingly, result in a lower-level student mathematic performance.

It is evident that student achievement is influenced by a complex interplay of factors, extending beyond individual-level factors to include household, school, and societal contexts. One of the variations of societal contexts for rural schools are the variations in population density in rural areas, which contributes to another important aspect of rural schools: their size diversity. While some rural schools have student populations similar to those of urban and suburban schools, others are notably smaller (Greenough & Nelson, 2015). Furthermore, Greenough and Nelson (2015) note that the further a rural school physically is from an urban center, the more likely it is to experience a decline in enrolment, resulting in smaller school sizes. Notwithstanding Wang et al.'s (2023) mixed findings on the link between the school size and mathematics achievements in OECD PISA, this study seeks to explore the role of this factor in influencing the school climate. The size of a school is important for understanding its climate, as it may influence the aspects and dynamics of interpersonal relationships within it.

Compared to larger schools, in small schools, the relationships between students and teachers often tend to be more personal, thereby fostering a supportive and nurturing learning environment. These close relationships may have both positive and negative effects. From a positive standpoint, a smaller student number in the classroom and the closer overall relationships within the community provide teachers with greater opportunities to develop deeper connections with each student and to develop positive work environment characterized by strong relationships, collaboration, what increases the overall job satisfaction of teachers in rural schools (Berry & Gravelle, 2013). Students' mathematics proficiency and their overall mathematics performance can significantly benefit from effective teaching strategies and clear task instructions which are set by the teachers (Kampmane & Ozola, 2022). These positive relationships often extend beyond the classroom, and one may encounter them in various school and community settings, and this broader interaction allows teachers to develop a more comprehensive understanding of their students (Starrett et al., 2020).

Rural students are varied in many ways, including their socio-economic backgrounds, family structures, and cultural identities. Policymakers, school administrators, and educators must recognize these differences and develop strategies to address them. This study highlights a critical research gap in our understanding of rural learning environments and underscores the need for further research into the complex dynamics that drive variations in student achievement in rural educational settings.

This study aims to investigate student-level factors associated with membership in high- and low-achievement rural school groups in rural schools, while concentrating on educational establishments located communities with populations under 3,000.

The results may help guide future policy decisions and foster a more equitable education for students in small, rural communities. Ultimately, better awareness of the complex interactions between these factors could provide a more comprehensive and effective approach towards enhancing academic success in rural schools. The obtained results can be used for effective, evidence-based decisions in education policy.

Objective: To analyze mathematics performance in rural schools in OECD PISA 2022.

Research question: *Which student-level factors are associated with membership in high- versus low-achievement rural school groups in OECD PISA 2022?*

Research Methodology

The Programme for International Student Assessment, or PISA, is global research carried out by the OECD to appraise educational systems through the evaluation of students' performance in reading, science, and mathematics at the 15-year-old age. PISA aims to provide policymakers and educators with insights into the effectiveness of educational policies and practices across countries and regions. The assessment is conducted every three years, and it is considered one of the most comprehensive and influential international comparisons of educational achievement. PISA aims to provide policymakers and educators with insights into the effectiveness of educational policies and practices across countries and regions. It is regarded as one of the most thorough and significant worldwide comparisons of educational attainment.

Every three years, the OECD PISA tests how well 15-year-old students, who are about to finish compulsory middle school education, are prepared for the challenges of modern knowledge-based societies. The assessment focuses on how well students can use their knowledge and skills in real-life situations, rather than just their ability to understand the curriculum. Each test cycle concentrates on one main area – mathematics, reading, or science – thus providing detailed insights into students' abilities. The OECD PISA study includes standardized tests for students and extensive surveys for both students and school principals. The primary emphasis of the 2022 OECD PISA cycle on mathematics led the authors to restrict their data analysis to this specific domain. The OECD's official website (https://www.oecd.org/pisa/test) offers comprehensive information on the PISA assessment and related surveys, and the OECD PISA database for the year 2022 cycle (https://www.oecd.org/pisa/data/2022database) serves as a source of data for this study.

In the 2022 OECD PISA cycle, schools were selected from a nationwide list of all eligible schools based on rigorous sampling criteria. This ensured that the sample represented all types of schools from diverse geographic areas, including rural regions. Schools in areas with fewer than 3,000 residents were selected from among all those that participated in OECD PISA 2022 to identify rural educational institutions used in this study. School principals' evaluations of the settlement size in the school questionnaire were used to identify these specific schools. In the school survey, these areas were categorized as either 'small villages' or 'rural regions with populations of fewer than 3,000 residents'. The subsequent classification was further defined as 'small towns with 3,000 to 15,000 inhabitants', and schools from this and other categories were not included in our study.

To achieve the aim of the study, a quantitative descriptive research design was employed. The analysis was based on the OECD PISA 2022 database, focusing on European countries within the OECD. Notably, the PISA 2022 dataset exhibited variability in the number of rural schools represented, with some countries having limited samples (e.g., the Netherlands, with only three schools). Similarly, Sweden's questionnaire for school principals lacked data on the settlement size. To ensure sufficient data quality, this study included eight European countries with a minimum of 25 rural schools and at least 10% of students enrolled in rural educational institutions. Specifically, these countries were the Czech Republic (64 rural schools, 10% of all students), Estonia (54 schools, 20%), Iceland (51 schools, 14%), Ireland (26 schools, 16%), Latvia (65 schools, 17%), Lithuania (84 schools, 15%), Norway (48 schools, 13%), and the Slovak Republic (80 schools, 17%).

In OECD PISA, student achievement is determined by using a point-based system, where these points act as indicators of proficiency levels across different academic areas. In the year 2022 cycle, the average student performance in mathematics across the OECD countries stood at 472 points. This benchmark provides a valuable reference point for evaluating both national and international student performance. Additionally, the standard deviation of student achievement scores around this mean reveals the extent of variation within the dataset. In the case of PISA 2022 mathematics assessments, the average standard deviation among the OECD countries was 90 points.

The national average student achievements in rural areas showed variation. Estonia stood out with the highest score of 498 points, followed by Ireland (484 points), Norway (461 points), the Czech Republic (452 points), Iceland (451 points), Latvia (449 points), Lithuania (430 points), and the Slovak Republic (418 points). In four countries – the Czech Republic, Latvia, Lithuania, and the Slovak Republic – rural students' achievements were significantly lower than those in urban areas, with a gap of 39 to 55 points. In contrast, the gap was narrower in four other countries – specifically, Estonia, Iceland, Ireland, and Norway – ranging from 8 to 16 points (see Table 1). The corresponding mean values were computed from the student data file separately for each of the ten plausible values, and then averaged. All calculations were weighted by using the final trimmed nonresponse-adjusted student weight provided in the PISA 2022 database. When performing calculations, school averages were not calculated, whereas group averages were calculated directly from the student file.

Table 1. *Mean mathematics performance in different groups within the countries included in the study*

Groups	Countries							
	CZE	EST	ISL	IRL	LVA	LTU	NOR	SLK
Town or city	491	513	460	493	490	483	469	474
Rural	452	498	451	484	449	430	461	418
Difference	39	16	10	9	42	53	8	55
Highest average performance in rural schools	574	575	590	546	540	505	593	588
Lowest average performance in rural schools	358	389	340	438	382	334	392	268
Difference	216	186	250	108	158	171	201	320
Average of the group of rural schools with high achievements	503	532	492	511	479	460	508	508
Average of the group of rural schools with low achievements	395	455	416	453	414	388	429	340
Difference	108	77	76	58	65	72	79	168

Rural schools within each country exhibit significant disparities in achievement. For example, in Latvia, the lowest average score was 382 points, while the highest was 540 points, yielding a range of 158 points. In Estonia, the range was even wider, spanning from 389 to 575 points. The Slovak Republic showed the greatest variation, with scores ranging from 268 to 588 points, with a difference of 320 points.

The analysis aims to identify the key student-level factors that are associated with the likelihood of student membership in high- versus low-achieving rural school groups. To achieve this objective, for each school, while taking into account all 10 plausible values, the average mathematics achievements were calculated. This result was included in Latvia's PISA 2022 individual report to each school, which allows the mathematics achievements of school students to be compared with the achievements of students from other unnamed schools. Then, the authors divided schools in each country into three equal groups based on their average mathematics scores. Each group includes from 16 schools in Norway to 24 schools in Lithuania. This analysis was focusing on the two most contrasting groups – with higher and lower achievements. Binary Logistic Regression was used to analyze the data, considering covariates from the OECD PISA 2022 database that are likely to be associated with student achievement. This statistical method is well-suited for binary outcome variables, allowing researchers to understand how predictor variables are associated with a specific outcome. This allows to determine which student-level characteristics are significantly associated with a student's likelihood of belonging to the highest-performing school group versus the lowest-performing school group.

This study also utilizes OECD indices derived from student and principal questionnaires. Indices are composite variables combining multiple factors. These indices are created by aggregating questionnaire items to represent underlying constructs. These constructs cannot be directly measured; consequently, they are transformed or scaled by using specific procedures. The OECD's PISA indices are standardized to a mean of 0 and a standard deviation of 1, allowing for easy comparison across different studies. For more information on these indices, refer to the OECD PISA 2022 Technical Report, Section 19: "Scaling Procedures and Construct Validation of Context Questionnaire Data" (OECD, 2023).

For this study, the authors focused on rural schools within each country and classified them based on the average mathematics performance of their students, since mathematics was the main subject tested in OECD PISA 2022. It is important to note that, in the countries analyzed, there is a strong correlation between school average achievements in mathematics, science, and reading, ranging from 0.89 to 0.99. This means that if a school performs well in mathematics, it is likely that its students will also excel in science and reading. This suggests that mathematics achievement can serve as a reliable proxy for a school's overall performance.

In each country, the top and bottom one-third of schools in terms of mathematics performance were selected. The top third represented the highest-performing schools, while the bottom third represented the lowest-performing schools. As shown in Table 1, even in countries with relatively small achievement gaps between urban and rural schools, the gap between high- and low-achieving rural schools is comparatively large. Due to the fact that OECD PISA 2022 student samples are selected through a complex (non-simple random) design, and mathematics achievement is reported by using ten plausible values, standard errors were estimated by using *Balanced Repeated Replication* (BRR) with Fay's adjustment, applying the replicate weights provided in the PISA 2022 database; therefore, data processing required specialized software. Authors used the popular and proven *IEA IDB Analyzer* (Sandoval-Hernandez & Carrasco, 2020).

Research Results

The binary logistic regression models were built by using only student data files, which were not supplemented with information from school files. Such data pooling may unduly reduce model errors and lead to spurious statistically significant effects. School data in the model were used only for grouping: rural or urban schools, high- versus low-achieving schools. The results, as presented in Table 2, show that associations between student-level characteristics and membership in high- versus low-achievement rural school groups vary significantly across the countries.

A key factor in OECD PISA studies is the *Socio-Economic Status* (SES), typically measured by the "*Index of Economic, Social, and Cultural Status*" (OECD, 2023). Notably, the Slovak Republic exhibits the strongest association between student SES and membership in the high-achievement school group. This could be due to relatively small SES disparities among rural school students. Across the countries examined, the greatest SES differences between rural and urban students are seen in Latvia and Lithuania, with moderate differences being observed in Iceland and minimal differences in Norway (see Table 2 for details).

Table 2. *Odds ratios (ExpB) from binary logistic regression models for both higher- and lower-achievement school groups, along with Nagelkerke R-squared values for the models*

Index		**CZE**	**EST**	**ISL**	**IRL**	**LVA**	**LTU**	**NOR**	**SLK**
Index of economic, social and cultural status	ExpB	2.70	2.20	1.24	1.56	1.17	1.63	1.18	3.88
	Se ExpB	0.60	0.46	0.24	0.25	0.27	0.26	0.23	0.86
	95% CI LL	1.53	1.31	0.77	1.07	0.64	1.13	0.73	2.19
	95% CI UL	3.88	3.09	1.71	2.05	1.70	2.13	1.62	5.57
	Sig p	<0.001	<0.001	0.26	0.005	0.49	0.002	0.39	< 0.001
Quality of student-teacher relationships	ExpB	1.44	0.79	0.71	1.40	1.43	1.01	1.50	1.04
	Se ExpB	0.26	0.13	0.12	0.28	0.30	0.12	0.31	0.23
	95% CI LL	0.94	0.53	0.48	0.86	0.85	0.77	0.89	0.58
	95% CI UL	1.94	1.05	0.95	1.95	2.01	1.25	2.11	1.49
	Sig p	0.04	0.16	0.05	0.08	0.08	0.91	0.05	0.87
Disciplinary climate in mathematics	ExpB	1.41	1.85	1.00	1.25	1.29	1.24	1.90	1.56
	Se ExpB	0.31	0.44	0.17	0.19	0.27	0.21	0.44	0.27
	95% CI LL	0.80	0.99	0.66	0.87	0.76	0.82	1.04	1.03
	95% CI UL	2.02	2.70	1.34	1.63	1.82	1.66	2.76	2.10
	Sig p	0.11	0.01	0.98	0.16	0.23	0.20	0.004	0.01
Feeling safe	ExpB	1.07	1.16	1.16	1.05	1.31	0.82	1.18	1.19
	Se ExpB	0.18	0.15	0.12	0.14	0.15	0.06	0.19	0.17
	95% CIL L	0.72	0.86	0.92	0.78	1.01	0.70	0.82	0.86
	95% CI UL	1.42	1.46	1.40	1.32	1.61	0.94	1.55	1.53
	Sig p	0.67	0.25	0.17	0.73	0.02	0.01	0.28	0.22
Arriving late for school	ExpB	0.76	0.94	0.89	0.79	0.92	0.71	0.98	0.64
	Se ExpB	0.14	0.17	0.15	0.15	0.14	0.09	0.21	0.16
	95% CI LL	0.49	0.60	0.59	0.49	0.65	0.53	0.56	0.31
	95% CI UL	1.04	1.27	1.19	1.09	1.19	0.89	1.39	0.96
	Sig p	0.14	0.72	0.51	0.22	0.59	0.01	0.91	0.08
Sense of belonging	ExpB	0.86	1.06	1.12	1.04	1.18	1.36	0.97	0.85
	Se ExpB	0.14	0.23	0.22	0.16	0.18	0.17	0.11	0.14
	95% CI LL	0.59	0.61	0.70	0.73	0.83	1.03	0.75	0.57
	95% CI UL	1.13	1.52	1.54	1.35	1.52	1.69	1.19	1.13
	Sig p	0.34	0.77	0.55	0.81	0.27	0.01	0.78	0.33

Index		**CZE**	**EST**	**ISL**	**IRL**	**LVA**	**LTU**	**NOR**	**SLK**
Mathematics Anxiety	ExpB	0.95	0.93	1.17	0.89	0.93	0.86	1.05	0.99
	Se ExpB	0.13	0.12	0.18	0.06	0.11	0.06	0.17	0.10
	95% CI LL	0.70	0.69	0.82	0.77	0.71	0.74	0.71	0.79
	95% CI UL	1.20	1.17	1.52	1.00	1.15	0.99	1.38	1.19
	Sig p	0.72	0.58	0.28	0.08	0.54	0.04	0.78	0.92
Cognitive activation in mathematics	ExpB	0.98	1.44	1.17	1.14	1.09	1.15	1.01	1.07
	Se ExpB	0.14	0.25	0.18	0.15	0.18	0.16	0.17	0.16
	95% CI LL	0.72	0.96	0.82	0.85	0.73	0.84	0.67	0.77
	95% CI UL	1.25	1.93	1.53	1.44	1.46	1.47	1.35	1.38
	Sig p	0.91	0.03	0.29	0.30	0.60	0.30	0.95	0.62
Studying for school or homework before or after school	ExpB	1.08	0.99	0.89	1.06	0.96	1.02	0.85	0.91
	Se ExpB	0.07	0.05	0.06	0.06	0.05	0.04	0.08	0.05
	95% CI LL	0.95	0.90	0.78	0.95	0.86	0.95	0.70	0.82
	95% CI UL	1.21	1.08	1.00	1.17	1.07	1.10	1.00	1.01
	Sig p	0.19	0.82	0.06	0.29	0.48	0.53	0.08	0.08
Working in household/take care of family members before or after school	ExpB	0.93	0.95	1.13	0.99	0.95	0.95	1.01	0.96
	Se ExpB	0.05	0.04	0.06	0.03	0.04	0.05	0.06	0.05
	95% CI LL	0.83	0.88	1.01	0.93	0.87	0.86	0.90	0.86
	95%CI UL	1.02	1.02	1.25	1.05	1.02	1.05	1.11	1.06
	Sig p	0.14	0.18	0.03	0.86	0.18	0.35	0.92	0.43
Working for pay before or after school	ExpB	0.85	0.89	0.94	0.99	0.98	0.98	0.93	0.88
	Se ExpB	0.09	0.04	0.05	0.05	0.06	0.03	0.08	0.05
	95% CI LL	0.68	0.81	0.85	0.90	0.87	0.93	0.77	0.77
	95% CI UL	1.02	0.97	1.03	1.08	1.09	1.04	1.08	0.99
	Sig p	0.10	0.01	0.19	0.82	0.73	0.55	0.39	0.04
Nagelkerke R square for model		*0.34*	*0.31*	*0.13*	*0.16*	*0.19*	*0.20*	*0.21*	*0.47*

Note. Abbreviations in use: ExpB – odds ratios, Se ExpB – standard error, 95% CI LL – 95% Confidence Interval Lower Limit, 95% CI UL – 95% Confidence Interval Upper Limit, Sig p – significance *p*.

The socioeconomic status of students' families in the school's surrounding area is an important factor that cannot be influenced by the school itself. However, it can inform school strategies and guide the implementation of targeted measures. In contrast, interpersonal attitudes within the school play a crucial role in shaping the average mathematics achievements. These attitudes include teachers' relationships with students, students' relationships with teachers, and students' relationships with their peers. To improve mathematics outcomes in rural schools, it is essential to involve both school management and teachers in the process. Since rural schools tend to be small, they often foster very personal and sometimes non-neutral relationships, which, as mentioned in the theoretical research, can either hinder or facilitate learning.

The index "*Quality of student-teacher relationships*" is measured by students' evaluations, which involve rating eight statements on a scale. These statements assess various aspects of teacher-student relationships, including: The teachers at my school are respectful towards me; If I walked into my classes upset, my teachers would be concerned about me; If I came back to visit my school three years from now, my teachers would be excited to see me; I feel intimidated by the teachers at my school; When my teachers ask how I am doing, they are really interested in my answer; The teachers at my school are friendly towards me; The teachers at my school are interested in students' well-being; The teachers at my school are mean towards me. Each item on this scale has four response options: 'Strongly disagree', 'Disagree', 'Agree', and 'Strongly agree' (OECD, 2023a).

The "*Disciplinary Climate in Mathematics*" index assesses students' attitudes towards their mathematics teacher, indicating their willingness to cooperate during lessons. When students lack respect for their mathematics teacher, learning can be compromised. This index comprises a series of questions that ask students to report on the frequency of various scenarios that occur in their mathematics lessons, including: Students do not listen to what the teacher said; There is noise and disorder; The teacher has to wait a long time for students to quiet down; Students cannot work well; Students do not start working for a long time after the lesson begins; Students get distracted by using digital resources (e.g., smartphones, websites, apps); Students get distracted by other students who are using digital resources. Each scenario has a frequency response option, as reported in OECD (2023A).

The "*Feeling Safe"* index characterizes the relationships among students, reflecting their feelings of safety or insecurity at school and during their commute. In the context of rural schools, commuting is particularly important as it involves interactions among students from the same school. Feeling safe in this context refers to the students' sense of security and comfort in their physical and social environment. This index includes students' ratings of their agreement with four statements about their perceived safety: 'I feel safe on my way to school', 'I feel safe on my way home from school', 'I feel safe in my classrooms at school', and 'I feel safe in other places at school (e.g., hallways, cafeteria, restrooms)' (OECD, 2023a).

The "*Quality of student-teacher relationships*" is significantly and positively associated with the likelihood of individual students belonging to the high-achievement school group in the Czech Republic, and Norway. Also, in Ireland and Latvia, we can find a relatively large effect ($p=0.08$). Surprisingly, this relationship had a negative effect on student achievement in Iceland. This may be because teachers in Iceland establish positive relationships by lowering demands. Additionally, teachers might give more attention to students who struggle academically, resulting in lower-achieving students being more likely to develop strong relationships with their teachers.

Furthermore, the "*Disciplinary climate in mathematics*" lessons aspect is linked to the interpersonal dynamics between students and teachers, showing a statistically significant influence in Estonia, Norway, and the Slovak Republic. Higher levels of perceived safety are associated with a greater likelihood of belonging to a high-achievement school group.

The effect of the "*Sense of Belonging*" factor cannot be clearly characterized. In some countries (the Czech Republic, Norway, and the Slovak Republic), it shows a weak negative association with membership in the high-achievement school group, possibly because the schools in these regions do not emphasize high achievement. Higher values of this index also indicate mutual friendship and influence among students. The negative attitude of some students towards learning can decrease the desire of other students to learn.

Three indicators are directly related to learning mathematics: *Cognitive activation in mathematics*; *Mathematics anxiety*; and *Studying for school or homework*. Cognitive activation in mathematics shows a positive association with membership in the high-achievement school group, although statistical significance is observed only in one country – specifically, Estonia.

Unexpectedly, an increased frequency of homework correlates with higher student achievement in only three of the examined countries. This suggests that higher achievements in rural schools might be achieved by working more intensively during lessons.

It is worth noting that *Working for pay before or after school* is negatively associated with membership in the high-achievement school group, with statistically significant results in Estonia and the Slovak Republic. However, working in the household has an even smaller negative effect.

The model's performance varies significantly across the eight countries examined. The Nagelkerke R-squared values indicate that the model is able to explain a larger proportion of the variation in mathematics achievements in some countries than others. For example, the values are the highest in the Slovak Republic (0.47), the Czech Republic (0.34), and Estonia (0.31), suggesting that the model is more effective at capturing the factors that influence the student performance in these countries. In contrast, the values are lower in Iceland (0.13) and Ireland (0.16), implying that other factors not captured by the PISA 2022 student questionnaire may be driving the differences between schools with high and low achievements in these countries. Similarly, Latvia and Lithuania have relatively low coefficients, ranging from 0.19 to 0.21, indicating that additional factors are at play in these countries.

To provide an additional robustness check, the analysis was repeated for rural schools by stratifying achievement into two and four groups, comparing the upper and lower quartiles. The two-group models exhibited substantially poorer model performance: Nagelkerke R-squared values ranged from 0.07 to 0.15. Most coefficients that were statistically significant in the three-group models no longer met the significance threshold. For example, in the Czech Republic, the socioeconomic status coefficient Exp(B) decreased from 2.70 (p<0.001) to 1.24 (p=0.57), and student-teacher relationships Exp(B) declined from 1.44 (p=0.04) to 1.10 (p=0.59). Overall, these models did not provide additional information, and their use is therefore not warranted.

In the four-group stratification, comparing the highest- and lowest-achieving school groups, model performance increased for some countries; for instance, in the Czech Republic, Nagelkerke R-squared rose from 0.34 to 0.43. However, on average, the changes were smaller than one standard error (0.04–0.07). Overall, the models produced results similar to the original specification, with only minor changes in the Exp(B) values of the coefficients. Some differences were observed for the variable "*Working for pay before or after school*". Its coefficient changed slightly and became statistically significant for Ireland and Lithuania; meanwhile, in the Czech Republic, it remained unchanged but lost statistical significance. This may indicate a relatively low level of student participation in paid work. In sum, dividing schools into four achievement groups yields results comparable to the three-group classification, with no apparent inconsistencies; this model is equivalent to the one analyzed in the article.

The analysis also drew on the school principals' survey, which provides school-level information not available from the student questionnaire. As in the analysis of student data, we compare the top-performing third of schools with the bottom-performing third. Due to the fact that the number of schools in each group is very small, statistically significant effects can be identified only in rare cases; therefore, they are not reported here. Similar to the student-related indicators, only a few measures show a consistent pattern across all countries.

First, we consider the indicator "*Student-related factors affecting school climate*". This includes student factors affecting the teaching and learning process – truancy, alcohol and drug use, bullying, etc. In all countries examined, the principals of lower-performing schools describe these as a greater problem than principals of higher-performing schools. At the same time, "*Teacher-related factors affecting school climate*" and "*Shortage of educational staff*" affect lower-performing schools to a greater extent in some countries, but higher-performing schools in others. "*Negative school climate*" (including profanity, vandalism, theft, verbal abuse, and physical injury) is more prevalent in lower-performing schools in seven countries. "*Problems with schools' capacity to provide remote instruction*" were also more pronounced in lower-performing schools. In almost all countries – except for Latvia and Lithuania – lower-performing schools reported greater problems with instructional materials.

Notably, in all eight countries, lower-performing schools make greater efforts to involve students' parents in the learning process: their values on the indicator "*School encouragement of parent or guardian involvement*" are higher. This may represent one possible avenue for improving student achievement.

Discussion

In line with the Wang et al.'s (2023) overall findings for factors influencing students' mathematic achievement in OECD PISA studies, this study also found that there is no one-size-fits-all solution to ensuring high academic achievement among rural students worldwide. While no single factor guarantees success, certain elements emerged as particularly important for improving mathematic academic performance in rural schools. This is further supported by the finding that the statistical models explained different proportions of variance across countries (Nagelkerke R^2 ranging from 0.13 to 0.47), thus indicating that the strength and combination of influencing factors vary substantially depending on the national context. This also suggests that the explanatory power of the selected variables is moderate and context-dependent rather than universal. The findings on the influence of the disciplinary climate on students' academic achievement align with a study by Wang et al. (2023), which demonstrated a connection between student behavior and academic performance across five cycles of the OECD PISA, revealing a consistent negative association between the prevalence of student misbehavior and mathematic achievement. This is consistent with the study results, where the disciplinary climate showed statistically significant effects in several countries, including Estonia, Norway, and the Slovak Republic. However, the strength of this relationship varies across countries, indicating that the school climate interacts with other contextual factors.

As mentioned in Dai's (2024) study, a positive teacher-student relationship has a significant impact on the students' learning outcomes and processes as it can boost students' classroom participation, regulate their emotions, and cultivate their learning skills. In small schools, like those often found in rural areas, these relationships can develop more easily due to the close proximity and an increased individualized attention from teachers. In rural schools, teachers can assume roles as mentors and role models for their students more easily, further strengthening their bond and influence beyond the traditional classroom setting. This aligns with the empirical finding that student-teacher relationships were among the most frequently statistically significant student-level characteristics associated with membership in high-achievement school groups, and it highlights their importance as a key but complex predictor of academic achievement. This study revealed that stronger student-teacher relationships are not always associated with a greater likelihood of belonging to a high-achievement school group. In Iceland, these relationships are associated with a negative coefficient; however, this effect is not statistically significant. These results suggest that close student-teacher relationships do not uniformly translate into higher student achievement across all contexts.

One possible explanation for this phenomenon is that teachers may be unwilling to challenge students due to their personal relationships with them and their parents. In rural communities, teachers may feel pressure to maintain good relationships with parents and students so that to ensure social cohesion. As a result, they may struggle to set high expectations or provide constructive feedback, which would lead to weaker student outcomes. Furthermore, the close relationships between teachers and students in small schools can create challenges when it comes to maintaining professional boundaries. Teachers may find it difficult to evaluate or discipline students fairly, as they may be influenced by their personal feelings towards the students and their families. Accordingly, if teachers struggle to maintain professional boundaries, it can result in inconsistent treatment of students, which can ultimately hinder their academic progress.

Dai (2024) characterizes teacher-student relationship as a complex and dynamic process playing a significant role in shaping students' learning outcomes. As these relationships evolve over time through interactions, their dynamic nature might partly lead to the instability of the influence of this factor. This may also help explain why the statistical significance of this variable differs across countries.

Understanding the reasons behind the student-teacher relationship formation is essential. However, this study did not examine specific factors that would contribute to this process. Instead, the authors suggest that future research should investigate the underlying causes of these findings. Additionally, this study relied solely on OECD PISA 2022 quantitative questionnaire indices, which limits the ability to explain causal mechanisms behind observed relationships. This limitation highlights the need for mixed-method approaches in future research.

Nevertheless, cultivating a strong student-teacher relationship is vital, and educators can implement several strategies to achieve this. According to Dai (2024), firstly, they should actively listen to students' mental health concerns and proactively address emotional stressors. Secondly, teachers should provide structured guidance, by offering expertise and support to help students reach their objectives. Finally, educators can foster creativity by encouraging and supporting students' innovative endeavors (Dai, 2024). These strategies may be particularly relevant in rural contexts, where schools often play a central social role.

The quality of interactions between teachers and students can also depend on the teaching methods used in the classroom. The instructional approaches employed by teachers can greatly affect how student-teacher relationships develop, while shaping students' perceptions of and engagement with their instructors. E.g., Kampmane & Ozola's (2022) research has shown that effective teaching strategies and clear instructions can boost students' overall performance. A recent Wang et al.'s (2023) study results show that student-centered instruction tends to negatively impact mathematic achievement, while teacher-directed instruction has mixed results. The impact of cognitive activation on student achievement shows variations across different countries (e.g., in the framework of this study, cognitive activation is statistically significant only in Estonia). This finding aligns with mixed results from other studies, where cognitive activation was positively associated with mathematics achievements in the US, Spain, and Confucian regions but showed varied results in other countries depending on specific conditions and types of cognitive activities (Wang et al., 2023). There results indicate that while cognitive activation is crucial, its effectiveness may depend on the implementation context and the specific educational environment. This further supports the argument that instructional practices cannot be universally applied without considering contextual differences.

Mathematics anxiety is another significant concern, particularly in Ireland and Lithuania, where it shows a notable impact on rural students' mathematics achievements. However, it should be noted that mathematics anxiety showed statistically significant effects only in a limited number of countries, thus indicating that its impact is context-dependent rather than universal. A closer look at the relationship between homework frequency and achievement reveals an interesting finding: while more frequent homework is associated with better results in some countries, it is not a universal solution. Instead, the quality and nature of homework, as well as in-class instruction, appear to be more important factors than the sheer quantity of homework assigned. This study also is limited for the knowledge of the specifics and purposes of the homework and other related factors. Xu's (2020) study of mathematics homework states that mathematics homework assignments should be designed to cater to students' individual learning needs and interests. Moreover, teachers and parents should collaborate to help students understand the value of mathematics homework and encourage them to develop effective time management skills. These findings, again, emphasize that effective educational practices depend on the context rather than on single universal strategies.

Homework can be a valuable tool for reinforcing learning and improving academic achievement when used wisely and in moderation, as excessive homework can lead to stress and negative consequences. When assigning homework, it is important to acknowledge the disparities in the students' socio-economic backgrounds, as not all students have equal access to the resources needed to complete their homework effectively. This is particularly relevant in rural areas, where access to educational resources may be limited.

The socio-economic status continues to play a significant role in determining student achievement, as shown by theoretical research and the results of this study. This is also supported by the regression analysis, where SES showed the strongest association with membership in high-achievement school groups in several countries, particularly in the Slovak Republic (ExpB = 3.88), thus highlighting substantial inequality between high- and low-performing schools. However, the impact of SES varies across countries, with higher SES generally being associated with better academic outcomes.

The environment in which students grow up further shapes their educational and career trajectories. Urban areas often provide greater access to advanced educational opportunities, whereas rural areas typically offer fewer options. This disparity can contribute to differences in parental education levels, which, in turn, may affect parental involvement, which is an important factor in student achievement. Previous studies (Castro et al., 2015; Utami, 2022; Poudel & Subedi, 2024) emphasize the importance of strong parental engagement in supporting academic success.

A supportive home environment has been shown to play a protective role for students from disadvantaged backgrounds. Emotional support, encouragement, and guidance from parents can contribute to the development of resilience, confidence, and motivation, even when material resources are limited (Shapira-Lishchinsky & Zavelevsky, 2020). Additionally, low SES might lead to the need for working for pay before or after school, which might affect rural students' mathematics achievements. These results confirm SES as one of the most consistent predictors, while still highlighting cross-country variability.

As theoretical research suggests, the definition of rural schools can be quite varied, as the concept of 'rurality' encompasses a broad range of environments. In addition, the study has revealed substantial within-country variation among rural schools, with achievement gaps between the highest- and lowest-performing rural schools reaching up to 320 score points, which is considerably larger than the rural–urban differences in some cases. While some rural schools may be situated in small, safe communities with strong social bonds, others may be located in areas with limited resources and safety concerns. Meanwhile, the results of this study show that the sense of safety at school and during commutes positively affects student achievement in all countries except one (Lithuania).

This finding is particularly important in rural areas, where longer and more challenging commutes can exacerbate safety concerns, as safety is one of fundamental human needs according to Abraham Maslow's *Hierarchy of Needs* theory while the impact of belonging, which, in accordance to Maslow, is a more advanced need, has a more nuanced impact (Maslow, 1943). This further emphasizes that rural schools differ significantly in their conditions and cannot be treated as a uniform category.

A notable observation is that the variable "*Arriving late for school*" significantly impacts students' math achievement in only one country. This might suggest that, in many rural schools, students typically arrive by bus, thus making it unlikely for them to be late for individual classes. If they miss the bus, they often miss the entire school day. This highlights the importance of considering country-specific factors when interpreting the findings. Such results illustrate how structural and logistical factors can shape educational outcomes in rural contexts.

While this study provides valuable insights, it is not without its limitations. One major limitation is the small sample size of rural schools included in the OECD PISA 2022 dataset, which may limit the generalizability of our findings to all rural educational institutions. In addition, the use of cross-sectional data limits the ability to draw causal conclusions about the relationships between the analyzed factors and student outcomes. Accordingly, the reported odds ratios should be interpreted as associations between student-level characteristics and membership in high- versus low-achievement school groups rather than as school-level causal effects. Another limitation is the selection of factors examined in this study. Authors only considered variables that are available in the OECD PISA 2022 data. This means that other factors that could be influencing students' academic performance may have been overlooked. Furthermore, the analysis is based primarily on student-level indicators, and it does not explicitly incorporate school-level or system-level variables, which may limit the ability to fully explain differences in performance. Additionally, this research focuses specifically on mathematics, which provides a useful snapshot of rural students' abilities but may fail to fully reflect their overall academic performance. However, analysis does offer opportunities to identify the general trends and make predictions about the impact of these factors on other learning domains. Moreover, the variation in the model explanatory power across countries suggests that the selected factors do not equally explain student performance in all contexts, reinforcing the context-dependent nature of the findings.

Future research should also consider cross-level (multilevel) modelling approaches to better capture interactions between the student, school, and system-level factors. The influence of these factors should be examined across various academic domains. Furthermore, supplementing the quantitative data with qualitative data insights can provide a deeper understanding of the obtained results.

Conclusions

This study highlighted the challenges of defining and categorizing rural schools due to their diverse nature and explored various factors that could impact the mathematic performance of rural school students. Importantly, the findings demonstrate that rural schools are not a homogeneous group, as it has been demonstrated that substantial variation in student achievement exists not only between countries, but also the socioeconomic status has emerged as a significant predictor of membership in high- versus low-achievement rural school groups. However, the strength of this relationship varied across different countries. In some countries, such as Latvia, Iceland, and Norway, SES did not show statistically significant effects, thus indicating that other contextual or school-level factors may play a more prominent role in explaining the student performance. The study did not identify a single set of student-level characteristics consistently associated with membership in high-achievement rural school groups across all countries. Instead, it revealed the critical importance of positive interpersonal relationships in promoting students' academic success. The findings emphasize the need for supportive learning environments characterized by strong relationships among teachers, students, and peers. At the same time, the results suggest that the impact of these relationships is complex and context-dependent, as strong teacher-student relationships were not always associated with higher academic outcomes.

The findings highlight the potential importance of interpersonal relationships within schools; however, the present analysis does not permit conclusions about the causal role of school management practices. Improving school climate, reducing student-related behavioral problems, and ensuring access to educational resources may be particularly important for enhancing outcomes in lower-performing rural schools. Overall, the findings highlight that the factors influencing academic achievement in rural schools are context-specific, and their explanatory power varies across countries, as reflected in differences in the model strength. Therefore, policies aimed at improving rural education should be tailored to national and local contexts rather than be based on universal approaches. This study thus contributes to the understanding that effective educational strategies in rural settings require flexible, context-sensitive approaches rather than uniform solutions.

Author contributions:

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Rita Kiseļova: Conceptualization, funding acquisition, investigation, methodology, project administration, supervision, writing – original draft, writing – review and editing.

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