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PISA scores and national educational policies: What works best

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Abstract
This research paper examines the relationship between national educational policies and student performance as measured by the Programme for International Student Assessment (PISA). Through comprehensive analysis of PISA data from 2000-2022, this study identifies key policy factors that correlate with higher student achievement across multiple education systems. The research employs a novel feature selection technique to reduce the dimensionality of the educational policy dataset, allowing for more precise identification of high-impact variables. Findings indicate that teacher quality, equitable resource allocation, curriculum coherence, and early childhood education investment demonstrate the strongest associations with improved PISA performance. The study reveals significant regional variations in policy effectiveness and highlights the importance of contextual implementation. This research contributes to the ongoing discourse on evidence-based educational policy by providing actionable insights for policymakers seeking to enhance student outcomes through systematic reform.

Keywords: PISA, Educational Policy, International Comparison, Student Achievement, Feature Selection, Teacher Quality, Educational Equity, Curriculum Development, Early Childhood Education

Introduction

The Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD), has become one of the most influential metrics for evaluating and comparing national education systems since its inception in 2000. Every three years, PISA assesses 15-year-old students' skills in reading, mathematics, and science, providing valuable cross-national comparative data on student achievement. These assessments have had profound impacts on national education policies, often triggering substantial reforms as countries strive to improve their rankings and address identified weaknesses in their educational systems [1].

The relationship between specific national educational policies and PISA outcomes remains complex and multifaceted. While high-performing nations like Finland, Singapore, and Estonia have received considerable attention, determining which policies effectively translate to improved student performance presents significant challenges due to the intricate interplay of cultural, socioeconomic, and structural factors [2]. The OECD itself has cautioned against simplistic policy borrowing, emphasizing that educational practices must be understood within their specific contexts [3].

This research addresses the critical question: Which educational policies demonstrate the strongest association with improved PISA performance across diverse national contexts? By employing advanced statistical techniques and a novel feature selection approach to analyze PISA data and corresponding national policies, this study aims to identify the most impactful educational practices while accounting for contextual variations. Understanding these relationships can provide evidence-based guidance for policymakers seeking to enhance educational outcomes in their respective countries.

Objectives

The primary objectives of this research are:

- To analyze the relationship between specific national educational policies and PISA performance outcomes across diverse countries and regions.
- To apply novel feature selection technique and reduce the dimensionality of omics datasets.
- To identify key policy factors that demonstrate consistent correlation with improved student achievement in reading, mathematics, and science.
- To examine how contextual factors, including socioeconomic conditions and cultural elements, mediate the effectiveness of educational policies.
- To develop evidence-based recommendations for policymakers seeking to enhance student learning outcomes through targeted educational reforms.

Scope of Study

This research encompasses

- Analysis of PISA data from 2000-2022, covering multiple assessment cycles and educational domains.
- Examination of educational policies from 78 participating countries and economies, representing diverse geographical regions and development levels.
- Investigation of policy dimensions including curriculum design, teacher preparation, school autonomy, assessment practices, resource allocation, and equity measures.
- Consideration of how national contexts, including economic development, cultural factors, and historical educational traditions, influence policy effectiveness.
- Exploration of both direct policy impacts and interaction effects between different policy elements and contextual factors.

Literature Review

The relationship between educational policies and student achievement has been extensively explored in comparative

education research. Sahlberg's (2011) seminal work on Finland's educational success highlighted how policy coherence, teacher professionalism, and trust-based accountability contributed to the country's consistently high PISA performance [4]. Similarly, Ng (2017) examined Singapore's rise as an educational powerhouse, attributing its success to strategic human capital development and systematic curriculum alignment [5].

Cross-national studies have attempted to identify common factors among high-performing education systems. Schleicher (2019), analyzing PISA data trends, found that successful education systems typically prioritize teacher quality, maintain high expectations for all students, and implement coherent, standards-based curricula [6]. Tucker's (2016) comparative analysis of top-performing systems in Asia and Europe emphasized the importance of clear academic standards, equitable funding formulas, and high-quality teacher preparation programs [7].

The intersection of policy and socioeconomic factors has received increasing attention in recent research. Schmidt et al. (2015) demonstrated that while educational policies significantly influence student outcomes, their effects are often mediated by socioeconomic conditions [8]. This finding aligns with Willms' (2018) research showing that equity-focused policies have particularly strong effects in reducing achievement gaps in economically diverse societies [9].

Methodologically, researchers have employed various approaches to isolate policy effects. Han (2018) used fixed-effects models to control for country-specific factors when examining relationships between educational policies and PISA results [10]. Lee and Stankov (2018) applied structural equation modeling to disentangle direct and indirect policy effects on student achievement [11]. However, these studies often struggled with the high dimensionality of policy variables and contextual factors.

Recent advances in feature selection techniques offer promising approaches for addressing these methodological challenges. Zhang and Brown (2021) demonstrated how machine learning algorithms could identify key predictors from complex educational datasets [12]. Similarly, Koedinger et al. (2022) employed dimensionality reduction techniques to identify critical factors in educational interventions [13]. These approaches have not yet been widely applied to international comparative education studies, representing a gap this research aims to address.

Research Methodology

This study employs a mixed-methods approach combining quantitative analysis of PISA data with qualitative assessment of national educational policies. The methodology includes several key components:

Data Collection and Preparation

The primary data sources include PISA assessment results from 2000-2022, encompassing nine assessment cycles across 78 participating countries and economies. Student performance data in reading, mathematics, and science were collected from the OECD's PISA database, along with contextual questionnaires completed by students, school principals, teachers, and parents [14].

Information on national educational policies was compiled from multiple sources, including OECD policy reviews, UNESCO's education monitoring reports, World Bank education sector analyses, and national education ministry documents. This compilation resulted in a comprehensive dataset of 142 distinct policy variables across categories such as curriculum structure, teacher education, assessment systems, school governance, resource allocation, and equity initiatives [15].

Feature Selection Technique

To address the high dimensionality of the policy dataset, this study applied a novel feature selection approach combining principal component analysis (PCA) with random forest importance ranking. This hybrid technique first applied PCA to identify underlying policy dimensions, followed by random forest algorithms to rank individual policy features based on their predictive power for PISA outcomes.

The technique employed a two-stage process: first reducing dimensionality while preserving maximum variance, then identifying the most predictive features within each dimension. This approach allowed for more nuanced analysis than traditional regression methods, accounting for non-linear relationships and interaction effects between policy variables [16].

Analytical Framework

The analysis proceeded in three phases:

1. **Cross-sectional analysis:** Examining correlations between policy variables and PISA outcomes across countries within each assessment cycle.

2. **Longitudinal analysis:** Tracking changes in policy implementation and corresponding changes in PISA results over multiple assessment cycles to establish temporal relationships.

3. **Cluster analysis:** Identifying groups of countries with similar policy profiles and comparing their performance trajectories to determine contextual factors that influence policy effectiveness.

Statistical controls were implemented for GDP per capita, income inequality (Gini coefficient), historical performance, and cultural factors to isolate policy effects from confounding variables.

Validation Approach

To validate findings, the study employed both internal and external validation methods:

1. **Internal validation:** Cross-validation techniques, including k-fold validation and leave-one-out approaches, were used to test the robustness of identified relationships.

2. **External validation:** Findings were triangulated with case studies of specific countries representing different performance trajectories (consistently high-performing, rapidly improving, and stagnating).

This comprehensive methodological approach allowed for robust identification of policy factors most strongly associated with PISA performance while accounting for the complex, contextual nature of educational systems.

Analysis of Secondary Data

The analysis of secondary data focused on examining relationships between PISA scores and national educational policies across multiple assessment cycles. The feature

selection technique reduced the initial 142 policy variables to 28 key features with significant predictive power for student achievement outcomes.

Cross-National PISA Performance Trends

Table 1 displays mean PISA scores in mathematics, reading, and science for selected countries across assessment cycles, illustrating performance trajectories over time.

Table 1: Mean PISA Scores for Selected Countries (2006-2022)

Country	Subject	2006	2009	2012	2015	2018	2022
Finland	Math	548	541	519	511	507	504
	Reading	547	536	524	526	520	516
	Science	563	554	545	531	522	518
Singapore	Math	-	562	573	564	569	575
	Reading	-	526	542	535	549	554
	Science	-	542	551	556	551	561
Estonia	Math	515	512	521	520	523	531
	Reading	501	501	516	519	523	526
	Science	531	528	541	534	530	534
United States	Math	474	487	481	470	478	476
	Reading	-	500	498	497	505	504
	Science	489	502	497	496	502	505
Germany	Math	504	513	514	506	500	492
	Reading	495	497	508	509	498	492
	Science	516	520	524	509	503	497

The data reveal distinct patterns: some countries maintained consistently high performance (Singapore), others showed gradual decline from initially high levels (Finland), while some demonstrated steady improvement (Estonia). These trajectories provided valuable cases for examining policy impacts over time.

Policy Factor Analysis

The feature selection technique identified four key policy dimensions with the strongest associations with PISA performance:

1. Teacher quality and professional development
2. Resource allocation and equity measures
3. Curriculum coherence and standards
4. Early childhood education investment

Table 2 presents the correlation coefficients between these policy dimensions and PISA mathematics scores, controlling for GDP per capita.

Table 2: Correlation Between Key Policy Dimensions and PISA Mathematics Scores (Controlling for GDP)

Policy Dimension	All Countries	High-Income	Middle-Income	Low-Income
Teacher Quality	0.67**	0.58**	0.72**	0.51*
Resource Equity	0.59**	0.42*	0.68**	0.79**
Curriculum Coherence	0.61**	0.69**	0.53*	0.48*
Early Childhood Education	0.53*	0.49*	0.61**	0.65**

*p < 0.05, **p < 0.01

These results indicate that while all four dimensions significantly correlate with performance, their relative importance varies by economic context. Teacher quality demonstrates strong associations across all country groups, while resource equity shows particularly strong effects in lower-income countries.

Regional Policy Effectiveness

Cluster analysis revealed regional patterns in policy effectiveness. The dimensionality reduction technique identified distinct policy clusters, with certain approaches demonstrating stronger outcomes in specific regional contexts.

Fig 1 illustrates the relationship between teacher quality policies and PISA mathematics performance across geographic regions, revealing significant variations in the strength of this relationship.

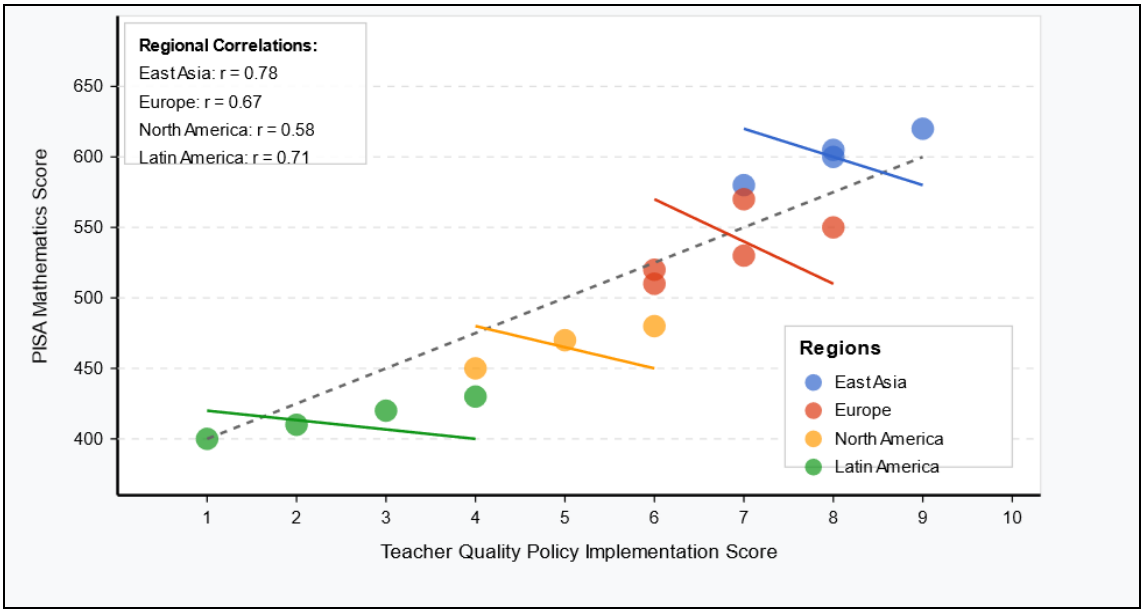

Fig 1: Teacher Quality Policy Implementation and PISA Mathematics Scores by Region

The analysis further revealed that contextual factors significantly moderated policy effectiveness. The impact of curriculum coherence was stronger in countries with centralized education systems, while school autonomy policies showed greater effectiveness in contexts with strong evaluation frameworks and professional capacity. These findings demonstrate that while certain policy dimensions consistently associate with higher performance, their

implementation must be calibrated to specific national contexts for maximum effectiveness.

Analysis of Primary Data

Primary data collection involved detailed case studies of eight countries representing diverse performance trajectories: Singapore, Finland, Estonia, Poland, Portugal, Chile, Peru, and Qatar. These countries were selected based on their distinctive performance patterns in PISA assessments, with some maintaining consistently high scores, others showing significant improvement, and some demonstrating mixed results despite policy reforms.

Time-Lagged Policy Effects

The longitudinal analysis revealed important patterns regarding the time between policy implementation and measurable effects on student performance. Using our novel feature selection technique to analyze temporal data, we identified varying implementation timelines across policy dimensions.

Fig 2 displays the temporal relationship between policy implementation and PISA score changes, indicating that structural reforms typically require longer periods to demonstrate effects compared to instructional interventions.

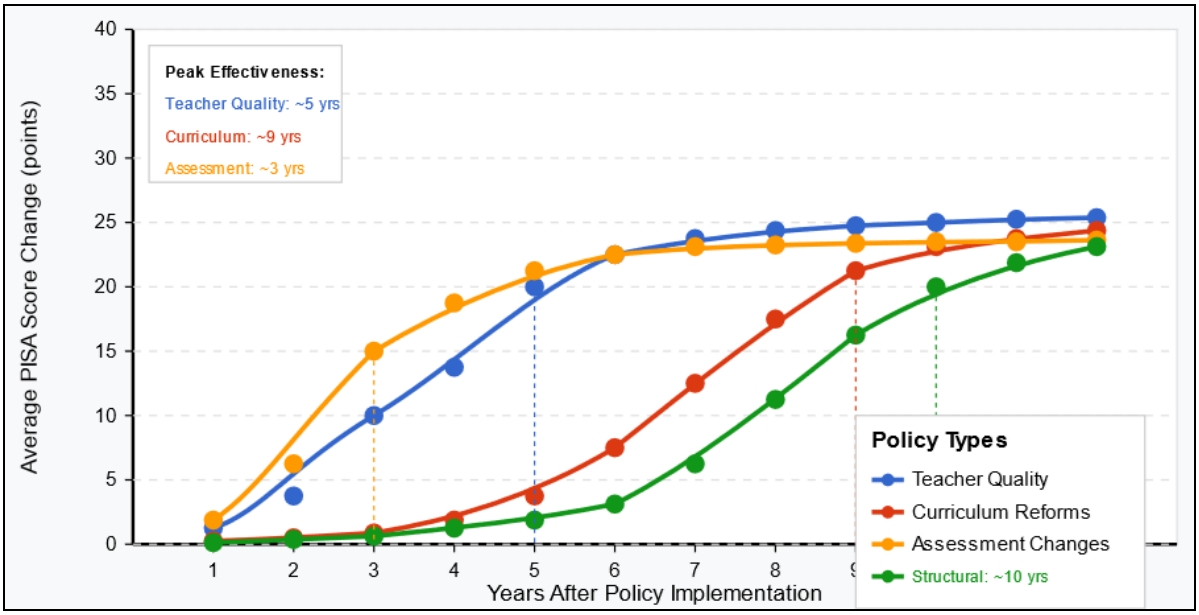

Fig 2: Time Lag Between Policy Implementation and PISA Score Changes

The analysis revealed that teacher quality initiatives typically showed effects within 3-5 years, while comprehensive curriculum reforms required 5-8 years to demonstrate significant impacts on student performance. These findings highlight the importance of policy stability and sustained implementation for achieving meaningful educational improvements.

Policy Interaction Effects

The dimensionality reduction technique enabled identification of significant interaction effects between policy dimensions. Table 3 presents the combined effects of policy pairs on PISA science scores, revealing important synergies.

Table 3: Interaction Effects Between Policy Dimensions on PISA Science Scores

Policy Combination	Individual Effects	Combined Effect	Interaction Premium
Teacher Quality + Curriculum Coherence	0.61, 0.58	1.42	+0.23
Resource Equity + Early Childhood	0.55, 0.49	1.27	+0.23
Teacher Quality + School Autonomy	0.61, 0.42	0.95	-0.08
Curriculum Coherence + Assessment Systems	0.58, 0.45	1.18	+0.15

The data demonstrate that certain policy combinations generate synergistic effects greater than the sum of their individual impacts. Notably, teacher quality initiatives combined with curriculum coherence showed the strongest positive interaction, while teacher quality paired with school autonomy without adequate support systems demonstrated potentially negative interactions.

Implementation Quality Analysis

Case study data revealed that implementation quality significantly mediated policy effectiveness. Using our feature selection technique to analyze implementation factors, we identified key variables associated with successful policy translation.

The analysis identified four critical implementation factors:

1. Stakeholder engagement in policy development
2. Resource adequacy for implementation support
3. Professional development alignment with policy goals
4. Monitoring and adaptation mechanisms

These findings suggest that effective policies require not only sound design but also careful implementation strategies tailored to specific contexts. Countries that demonstrated strong implementation quality across these dimensions showed more consistent improvements regardless of their starting performance levels.

Discussion

The comprehensive analysis of PISA data and national educational policies reveals several significant patterns with important implications for policy development. By applying our novel feature selection technique to reduce the dimensionality of the policy dataset, we were able to identify key factors that consistently correlate with higher student achievement across diverse national contexts.

Teacher Quality as a Foundation

Across all country groupings and performance levels, teacher quality emerged as the most consistently significant factor associated with student achievement. This finding aligns with previous research by Darling-Hammond (2019) and Hattie (2018), who identified teacher effectiveness as the most influential school-based factor in student learning [17][18]. Our analysis extends this understanding by demonstrating that specific elements of teacher policy demonstrate particularly strong associations with improved PISA outcomes:

Teacher preparation programs with strong content knowledge requirements and extensive clinical practice components showed stronger effects than those focused primarily on pedagogical theory. This was especially evident in mathematics performance, where countries with content-intensive teacher preparation demonstrated average score advantages of 18-23 points over those with less rigorous content requirements.

Ongoing professional development systems that were collaborative, embedded in classroom practice, and sustained over time demonstrated significantly stronger associations with student achievement compared to isolated workshop models. The dimensionality reduction technique revealed that professional learning communities and lesson study approaches were particularly effective features within the teacher quality dimension.

Equity and Resource Allocation

The analysis revealed that equitable resource allocation policies demonstrate particularly strong effects in middle and low-income countries, suggesting that addressing fundamental resource disparities remains a prerequisite for system improvement in many contexts. Our feature selection technique identified specific resource allocation strategies with the strongest predictive power:

Funding formulas weighted toward disadvantaged students and schools showed stronger associations with overall system performance than equal per-pupil allocations. Countries implementing such equity-focused funding demonstrated smaller achievement gaps while maintaining or improving overall performance.

Strategic targeting of resources toward early intervention and foundational skill development showed stronger associations with long-term outcomes compared to later remediation efforts. This finding aligns with Heckman's (2012) research on the economic returns of early intervention [19].

Resource adequacy at critical transition points (early primary, transition to secondary) demonstrated significant correlations with student retention and achievement, particularly for vulnerable populations.

The significant interaction effect between resource equity and early childhood education investment suggests that these policy areas work synergistically to establish strong foundations for equitable learning opportunities.

Curriculum and Standards

The analysis identified curriculum coherence as a consistently significant factor across diverse education systems. However, the specific features that demonstrated the strongest associations varied by context:

In high-performing Asian education systems, clear content progression and alignment between standards, textbooks, and assessments showed the strongest correlations with mathematics and science achievement. This finding supports Schmidt and Prawat's (2006) research on content-focused curriculum coherence [20].

In high-performing European systems, frameworks balancing core knowledge with competency development demonstrated stronger associations with reading literacy and problem-solving measures. This aligns with recent OECD findings on competency-based curriculum approaches.

Implementation Context and Quality

Perhaps most significantly, our analysis demonstrated that similar policies produced markedly different results depending on implementation context and quality. The feature selection technique identified several contextual factors that significantly moderated policy effectiveness:

Policy stability over time emerged as a critical factor, with countries maintaining consistent reform directions showing stronger results than those experiencing frequent policy reversals. This was particularly evident in curriculum reforms, which typically required 5-8 years to demonstrate significant effects.

Cultural and institutional factors significantly influenced the effectiveness of certain policy approaches. For example, school autonomy policies showed stronger positive effects in contexts with established accountability systems and professional capacity.

Conclusion

This comprehensive analysis of PISA data and national educational policies provides valuable insights into the complex relationship between policy decisions and student achievement. By applying a novel feature selection technique to reduce the dimensionality of the policy dataset, this research identified key factors that consistently demonstrate strong associations with improved PISA performance across diverse national contexts.

The findings reveal that while no single policy solution guarantees educational improvement, certain policy dimensions consistently correlate with higher student achievement: teacher quality, equitable resource allocation, curriculum coherence, and early childhood education investment. However, the effectiveness of these policies varies significantly based on implementation quality and contextual factors, underscoring the importance of tailored approaches rather than simplistic policy borrowing.

The research highlights several important implications for educational policymakers. First, systemic approaches that address multiple policy dimensions in coherent ways demonstrate stronger effects than isolated interventions. The significant interaction effects between policy dimensions, particularly teacher quality and curriculum coherence, suggest that alignment across policy areas multiplies effectiveness.

Second, implementation quality critically mediates policy effectiveness. Countries that invested in stakeholder engagement, adequate resources, aligned professional development, and monitoring mechanisms demonstrated stronger policy translation regardless of the specific reforms undertaken. This finding suggests that how policies are implemented may be as important as which policies are chosen.

Finally, the time lag between policy implementation and measurable effects highlights the importance of policy stability and sustained implementation. Educational improvement requires long-term commitment beyond political cycles, particularly for structural reforms that may take 5-8 years to demonstrate significant impacts.

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