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ARTICLE

The Influence of School-Level Structural Factors on Creativity and Math Achievement Among Students in Brazil: A Multilevel Analysis

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ABSTRACT: This study examines how school-level structural factors influence students' creativity and math achievement in Brazil. It addresses the research question: to what extent do these factors impact creativity, and how does creativity predict math achievement, controlling for individual characteristics? Recognizing the importance of creative thinking and math skills for academic success, uses a multilevel analysis with two models. Model 1 focuses on student-level variables, such as creativity scores and math achievement, alongside control variables like gender and socio-economic status (ESCS). Model 2 incorporates school-level factors from the PISA assessment, including support for creativity and available resources. The findings show that adding school-level variables did not significantly alter the models' outcomes, with both performing similarly. However, socio-economic status was a significant predictor, indicating the crucial role of individual backgrounds in education. Ultimately, the study highlights the need to consider both individual and structural factors to improve academic outcomes through targeted interventions.

Keywords: Creativity, PISA Score, Math Achievement, School Resources, Multilevel Analysis

A INFLUÊNCIA DE FATORES ESTRUTURAIS EM NÍVEL ESCOLAR SOBRE A CRIATIVIDADE E O DESEMPENHO EM MATEMÁTICA ENTRE ESTUDANTES NO BRASIL: UMA ANÁLISE MULTINÍVEL

RESUMO: Este estudo examina como fatores estruturais em nível escolar influenciam a criatividade e o desempenho em matemática de estudantes no Brasil. Aborda a seguinte questão de pesquisa: em que medida esses fatores impactam a criatividade e como a criatividade prediz o desempenho em matemática, controlando as características individuais? Reconhecendo a importância do pensamento criativo e das habilidades matemáticas para o sucesso acadêmico, utiliza-se uma análise multinível com dois modelos. O Modelo 1 concentra-se em variáveis em nível do aluno, como escores de criatividade e desempenho em matemática, juntamente com variáveis de controle como gênero e nível socioeconômico (NSE). O Modelo 2 incorpora fatores em nível escolar da avaliação PISA, incluindo apoio à criatividade e recursos disponíveis. Os resultados mostram que a adição de variáveis em nível escolar não alterou significativamente os resultados dos modelos, com ambos apresentando desempenho semelhante. No entanto, o nível socioeconômico foi um preditor significativo, indicando o papel crucial da origem individual na educação. Em última análise, o estudo destaca a necessidade de considerar tanto fatores individuais quanto estruturais para melhorar os resultados acadêmicos por meio de intervenções direcionadas.

Palavras-chave: Criatividade, PISA, Desempenho em Matemática, Recursos Escolares, Análise Multinível

LA INFLUENCIA DE LOS FACTORES ESTRUCTURALES A NIVEL ESCOLAR SOBRE LA CREATIVIDAD Y EL RENDIMIENTO EN MATEMÁTICAS ENTRE ESTUDIANTES DE BRASIL: UN ANÁLISIS MULTINIVEL

RESUMEN: Este estudio examina cómo los factores estructurales a nivel escolar influyen en la creatividad y el desempeño en matemáticas de los estudiantes en Brasil. Aborda la siguiente pregunta de investigación: ¿en qué medida estos factores impactan la creatividad y cómo la creatividad predice el desempeño en matemáticas, controlando las características individuales? Reconociendo la importancia del pensamiento creativo y las habilidades matemáticas para el éxito académico, se utiliza un análisis multinivel con dos modelos. El modelo 1 se centra en variables a nivel de estudiante, como puntajes de creatividad y desempeño en matemáticas, junto con variables de control como género y nivel socioeconómico (NSE). El modelo 2 incorpora factores a nivel escolar de la evaluación PISA, incluido el apoyo a la creatividad y los recursos disponibles. Los resultados muestran que la adición de variables a nivel escolar no alteró significativamente los resultados del modelo, y ambos modelos mostraron un desempeño similar. Sin embargo, el nivel socioeconómico fue un predictor significativo, lo que indica el papel crucial de los antecedentes individuales en la educación. En última instancia, el estudio destacó la necesidad de considerar tanto los factores individuales como los estructurales para mejorar los resultados académicos a través de intervenciones específicas.

Palabras clave: Creatividad, PISA, Rendimiento matemático, Recursos escolares, Análisis multinivel

INTRODUCTION

Mathematical achievement has long been regarded as a hallmark of intelligence (Schillinger et al., 2018), a perception that may stem from the historical reliance of various complex professions on mathematical skills as foundational tools. Throughout history, mathematics has served not only as a means of problem-solving ((Willoughby et al., 2021), (Kingsdorf & and Krawec, 2016)) but also as a language through which numerous scientific and technological advancements have been articulated.

The ability to engage with abstract concepts, utilize quantitative reasoning, and apply mathematical methods in diverse fields—such as engineering, physics, finance, and computer science—has reinforced the association between mathematical prowess and intellectual capability. In many cultures, this connection has been further popularized through educational systems that emphasize mathematics as a key component of curricula, often paralleling cognitive ability assessments.

Complex reasoning involved in mathematical tasks, such as algebra, calculus, and statistics, can serve as indicators of logical thinking and analytical skills. Moreover, the societal valuation of mathematical skills reflects broader economic and technological trends, where proficiency in mathematics is increasingly linked to career opportunities and advancements in fields that drive innovation. For that reason, math achievement throughout school life and also young adults is vastly studied.

On the other hand, creativity has historically been associated with the arts, literature, film, and professions that often prioritize imaginative and divergent thinking over logical reasoning (Sawyer, 2017). This distinction has fostered a perception that creativity flourishes in spheres that embrace emotional expression, aesthetics, and subjective interpretation, setting it apart from the structured and formulaic nature of mathematical thinking.

For many years, the arts have been viewed as the primary domain of creative activity, where individuals are celebrated for their ability to innovate, reinterpret, and evoke emotional responses through their work. This emphasis on creativity within artistic contexts has led to the belief that it thrives in environments characterized by free thought and inspiration, often seemingly detached from the analytical frameworks associated with scientific and mathematical disciplines.

However, recent discussions in the fields of psychology and cognitive science have begun to challenge this binary view of creativity and logic, the study How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module (Thuneberg et al.,

2018) draw a pre-/post-test design an inquiry-based learning approach was applied to a sample of 392 students (aged 12–13 years) and monitored the cognitive knowledge and the variables of relative autonomy, visual reasoning, formal operations as well as creativity, the results showed that the elements of autonomy, creativity, personal inquiries and original testing turned out to provide an opportunity to activate and utilize these capacities in learning mathematics in an informal, out-of-school setting.

Many renowned scientists and mathematicians have demonstrated that creative thinking is essential in forming hypotheses, developing innovative solutions, and approaching challenges from unique angles (Utemov et al., 2020), (Megnin, 1995)(Kim et al., 2016). This evolving understanding highlights the interconnectedness of creativity and logical reasoning, suggesting that both cognitive processes are vital to human innovation and discovery. As such, the traditional association of creativity solely with artistic pursuits is gradually shifting, recognizing that imaginative thinking can significantly enrich logical reasoning and vice versa.

When comes to the relationship of PISA Math scores and creativity the study Examining the relationship of a survey based measure of math creativity with math achievement: Cross-national evidence from PISA 2012 (Sebastian & Huang, 2016) conducted utilizing PISA data from 2012 propose a survey-based measure for math-creative thinking skills and further explore its relationship with math achievement. The results indicate a positive correlation between students' math creativity and their academic performance within schools, while between countries, there exists a negative relationship between average math performance and average math-creativity skills. Surprise some countries with lower scores on the 2012 math assessment show a higher proportion of students who identify as open problem solvers, underscoring the necessity of considering the level of analysis when evaluating the interplay between creativity and academic achievement and suggesting that fostering creative thinking in mathematics could enhance educational practices and policies.

Brazil's PISA results improved in the early 2000s, but scores declined after 2009. The study Student Composition in the PISA Assessments: Evidence from Brazil (Gomes et al., 2020) investigates whether this decline was real or a result of changes in PISA sample composition due to expanded access to education. The sample used was from PISA data between 2000-2015, the methodology was Counterfactual simulations using Propensity Score Matching (PSM) and Heckman selection models, the focus was to answer how Brazil's expanding student base (i.e., more disadvantaged students entering the system) influenced national average scores.

The authors found that much of the post-2009 decline in Brazil's PISA scores is attributable to demographic changes, not declining educational quality. If Brazil's test-taker composition had remained constant, scores would have been stable or improved. Results emphasize the importance of understanding who is being tested in international assessments. Finally, the authors concluded Brazil's policy success in expanding access to education came with short-term performance trade-offs in international rankings, not necessarily real declines in educational quality.

For psychometrics the uses of selection models to control for sample bias due to expanding school enrollment. Demonstrates how changes in test-taking population characteristics can distort trend interpretations if psychometric comparisons don't adjust for demographic shifts. And reinforces the need for longitudinal comparability in international large-scale assessments (ILSAs). For the Educational Field, challenges simplistic interpretations of PISA score declines—emphasizing that they may reflect broader access to education, not poorer quality. Supports a more nuanced approach to using large-scale assessments for international comparison, especially in developing countries. Encourages equity-focused interpretations of test results—celebrating access gains while tracking performance with adjusted metrics.

About the issues and variables not considered, limited attention to teaching quality, curricular reform, or systemic educational investments post-2009. Doesn't explore regional or urban-rural divides, which may interact with access and quality. Possible alternative explanations could be scoring declines might be partly explained by assessment fatigue, test disengagement, or shifts in PISA test format/design. Broader societal factors like economic downturns might also affect student learning and test performance. The study shows strong emphasis on equity and access.

The study The Relevance of the School Socioeconomic Composition and School Proportion of Repeaters on Grade Repetition in Brazil: A Multilevel Logistic Model of PISA 2012 (Ferrão et al., 2017) brings the relevance of the school socioeconomic composition and school proportion of repeaters

on grade repetition in Brazil: A multilevel logistic model of PISA 2012. The study addresses the longstanding issue of grade repetition in Brazil. Despite universal primary education, repetition remains high, especially among disadvantaged students. The goal is to understand how individual and school-level factors (e.g., socioeconomic status, school composition) affect repetition, and how these patterns may reinforce educational inequality.

The data was collected from OECD public records of PISA scores of 2012 with a sample size of approximately 19,000 students. The method used was a multilevel logistic regression model where level 1 (students) was composed by gender, age, parental education (HISEI) and level 2 (school) with the average HISEL, proportion of repeaters, school type, and perceived ethnic diversity, two models were tested—with and without school repetition rate.

As result the author found out that Students from low-SES backgrounds are 3x more likely to repeat. Also, that early repetition increases the likelihood of later repetition (odds ratio ~6.2). School repetition rate is the strongest predictor—odds ratio ~214. School SES matters but loses significance when repetition rate is included. In conclusion, grade repetition is not just an individual issue—it reflects and amplifies broader social inequalities. School culture and policies play a major role.

For Psychometrics, applies multilevel logistic regression to handle nested data (students within schools), demonstrating a strong methodological framework in educational measurement. Accounts for complex survey design of PISA data using robust estimation techniques, highlighting how psychometric modeling can inform policy-level insights when properly adjusted. And validates the importance of modeling contextual variables (e.g., peer composition, SES) in predicting educational outcomes—beyond just individual-level performance. For the Educational Field, highlights that grade repetition is more strongly influenced by school context than by student ability, reinforcing the role of systemic inequality. Identifies peer effects as a major influence: a student in a high-repeater school is much more likely to repeat, regardless of personal SES. Suggests a shift in policy toward addressing structural disadvantages at the school level rather than focusing only on student remediation.

A maxim in the literature when it comes to PISA score and Brazil is the constancy of socioeconomic status variables always playing a role in predicting results. Perhaps due to the complexity and diversity of a country of continental dimensions or for unknown reasons. This article aims to examine Influence of School-Level Structural Factors on Creativity and Math Achievement Among Students in Brazil. Investigating the specific variances in socioeconomic and gender contexts, this study seeks to clarify how these factors contribute to the math and creativity achievement of students across different Brazil.

To gain a better understanding of the complexities within Brazil's educational systems, this study will focus on the following research question: *To what extent do school-level structural factors influence students' creativity, and how does creativity in turn predict math achievement, controlling for individual characteristics?*

The first section of this study provided a composite of the literature review, underlining existing research on mathematic achievements and the relation with creativity, also bringing some research using PISA Data as data source in Brazil. Subsequent, the methodology section details the research design; to investigate school-level structural factors and its influence in students' creativity, and how does creativity in turn predict math achievement.

A multilevel model was utilized to analyze the mathematics scores of students from Brazil educational system. The first model was designed to understand if student-level controls such as gender and socio-economic status influence both creativity and math scores, and the second model accounts for school factors enhance student's creativity which predicts math achievements. Additionally, the model controlled for school support for creativity (e.g., emphasis on open-ended problem solving) and school resources (Information Communication and Technology – ICT access, extracurriculars, teacher training). The analysis was conducted on a dataset comprising 107,980 student observations. The Akaike Information Criterion (AIC) was used to compare both models and evaluate the goodness of fit of statistical models and select the model that best balances fit with complexity.

The results section will present the findings, exposing the comparison of both models variations. At last, the discussion will interpret these findings in light of the theoretical framework, drawing conclusions and implications for Brazil's educational system.

METHODS

This study used data from Organisation for Economic Co-operation and Development - OCDE (PISA 2022 U.S. Results, Mathematics Literacy, Achievement by Student Groups, n.d.) was analyzed using R Software and examined through a use of a multilevel linear regression as known as mixed effects modeling or hierarchical linear modeling, it explores the extent to which institutional characteristics shape creative development beyond individual traits..

The study uses data from PISA 2022; the dataset includes individual-level responses across multiple regions in Brazil with a sample size of 107,980 students. The data was analyzed quantitatively using mice, lme4 and mitml packages allowing identification of to what extent do school-level structural factors influence students' creativity, and how does creativity in turn predict math achievement, controlling for individual characteristics.

The first model (Model 1 - baseline) accounts for Math plausible score predicted by creativity and student-level control and the second model (Model 2) added school-level predictors to see If they improve the model and impact creativity.

PISA 2022 assess creativity thinking through examining students' capacity to generate diverse and original ideas, and to evaluate and improve ideas, across a range of contexts through open-ended communication and problem solving tasks (PISA 2022 Creative Thinking, n.d.), to achieve an overall score the average of scores was taken. For Math score it was used the plausible score which cannot be average according to PISA guideline and for that reason the model repeats the full analysis for each plausible value of ten entries for each student (for PV1MATH to PV10MATH).

When comes to the variables the overall model has the following structure:

- **Dependent Variable (DV):**
 - *Math Achievement:* PISA mathematics score (plausible values)
- **Independent Variables (IVs):**
 - *Student-level (Level 1):*
 - Creativity score (e.g., based on responses from the creativity questionnaire)
 - Gender
 - Socio-economic status (PISA variable: ESCS)
 - *School-level (Level 2):*
 - School support for creativity (e.g., instructional approaches, learning environment)
 - School resources index

Gender was also included as independent variable to explore how societal expectations, roles, and biases related to gender may impact individuals' attitudes toward creativity and math achievements.

The Pool the results using Rubin's rules (RR) which is designed to pool parameter estimates, such as mean differences, regression coefficients, standard errors and to derive confidence intervals and p-values and properly combine the variability within and between imputations.

RESULTS

A series of linear models were conducted to examine the relationship between student math achievement (as measured by 10 plausible values) and several predictors, including creativity, student-level socio-economic status (ESCS), and gender, as well as school-level predictors, such as school support and school resources. The first model (Model 1) included student-level predictors, and the second model (Model 2) extended this by adding school-level predictors. The analysis was conducted using data from the 2022 PISA assessment, and the results were pooled across 10 imputed datasets.

In Model 1, creativity composite scores were positively associated with math achievement ($B = 2.22$, $p = .054$), though this relationship was marginally significant. Gender (ST004D01T) also showed a significant positive effect on math achievement ($B = 8.03$, $p < .001$), with male students outperforming female students.

A strong positive relationship was found between students' socio-economic status (ESCS) and math achievement ($B = 26.37$, $p < .001$). The random effect for school-level variance was estimated to be significant, with an intraclass correlation coefficient (ICC) of 0.316, indicating a moderate amount of variance in math achievement across schools. The summary of fixed effects for Model 1 (pooled results) can be found in Table 1.

Table 1
Summary of Fixed Effects for Model 1 (Pooled Results)

Predictor	Estimate	Std. Error	t-value	p-value
Intercept	398.49	3.11	127.96	< .001
Creativity Composite	2.22	1.14	1.94	0.054
Gender (ST004D01T)	8.03	1.83	4.40	< .001
Socio-Economic (ESCS)	26.37	0.92	28.76	< .001

In the second mode, Model 2, which included school-level predictors, did not demonstrate substantial improvement over Model 1 in terms of model fit. School support ($B = 2.68$, $p = .005$) and school resources ($B = -1.07$, $p = .284$) were included as predictors in Model 2. While school support was positively associated with math achievement, school resources did not significantly contribute to the prediction of student math achievement.

The inclusion of these additional school-level variables did not substantially affect the overall fit of the model. The random effect for school-level variance remained similar to Model 1, suggesting no significant difference in school-level variance. In Table 1 it is possible to find the summary of fixed effects for Model 2 (pooled results).

Table 2
Summary of Fixed Effects for Model 2 (Pooled Results)

Predictor	Estimate	Std. Error	t-value	p-value
Intercept	374.57	4.05	92.57	< .001
Creativity Composite	-1.56	1.62	-0.96	0.339
Gender (ST004D01T)	16.30	2.03	8.04	< .001
ESCS (Socio-Economic)	12.38	1.28	9.68	< .001
School Support	2.68	0.93	2.87	0.005
School Resources	-1.07	0.99	-1.08	0.284

For the Model comparison using the Akaike Information Criterion (AIC) revealed that both Model 1 and Model 2 exhibited very similar AIC values across the 10 imputed datasets. The AIC values for both models were almost identical (e.g., Model 1: $M = 62118.59$, Model 2: $M = 62118.59$), indicating that adding school-level predictors did not significantly improve the fit of the model.

Therefore, while Model 2 included additional school-level predictors, the results suggest that Model 1, which only included student-level variables, provided a comparable fit. This suggests that, at least in this context, school-level factors such as school support and resources do not substantially improve the prediction of math achievement when accounting for student-level characteristics. The AIC Comparison Between Model 1 and Model 2 is shown in Table 3.

Table 3
AIC Comparison Between Model 1 and Model 2

	Model 1	Model 2
Value (1)	62236.12	62236.12
Value (2)	62117.03	62117.03
Value (3)	62113.84	62113.84
Value (4)	62206.69	62206.69
Value (5)	62145.83	62145.83
Value (6)	62073.02	62073.02
Value (7)	62187.59	62187.59
Value (8)	62038.47	62038.47
Value (9)	62165.95	62165.95
Value (10)	62118.59	62118.59

DISCUSSION AND CONCLUSION

In summary, the analysis shows a trend of strong influence from socio-economic factors and gender on student math achievement, with school support showing a small, positive impact. However, school resources did not demonstrate a significant effect, and school-level factors overall did not significantly improve model fit when added to the analysis.

There was a positive association between creativity composite scores and math achievement in Model 1, though it was marginally significant ($B = 2.22$, $p = .054$). This suggests that students with higher creativity scores tend to perform slightly better in math, but the relationship is not robust. Gender was found to have a significant effect on math achievement, with male students performing better than female students ($B = 8.03$, $p < .001$). This indicates a positive trend in favor of male students across the sampled population.

The strongest predictor of math achievement was students' socio-economic status (ESCS). Higher ESCS scores were strongly positively correlated with better math performance ($B = 26.37$, $p < .001$), suggesting that students from higher socio-economic backgrounds have significantly better math outcomes. The addition of school-level predictors in Model 2 revealed a positive trend for school support ($B = 2.68$, $p = .005$) on student math achievement. However, school resources ($B = -1.07$, $p = .284$) did not show a significant effect, indicating that while school support may enhance math performance, school resources, as measured here, were not a significant contributor.

When comparing Model 1 (student-level predictors only) with Model 2 (student- and school-level predictors), the Akaike Information Criterion (AIC) values were virtually identical between the two models, suggesting that adding school-level predictors did not improve the model's fit. This suggests that student-level characteristics, particularly socio-economic status and gender, play a more prominent role in explaining math achievement than school-level factors in this dataset.

In conclusion, both Model 1 and Model 2 exhibit similar AIC values across the 10 imputed datasets, indicating that the inclusion of school-level predictors, such as school support and school resources, did not lead to a substantial improvement in model fit over the simpler model. While the fixed effects for creativity, gender, and socioeconomic status (ESCS) were significant in both models, with ESCS showing the strongest impact on math achievement, the random effect of school (CNTSCHID) remained consistent across models. These results suggest that, although school-level factors such as support and resources are relevant, they may not drastically alter the overall model's explanatory power when compared to the simpler model without these predictors.

In relation to the research question, "To what extent do school-level structural factors influence students' creativity, and how does creativity in turn predict math achievement, controlling for individual characteristics?", the results suggest that school-level structural factors, such as school support and resources, do have an influence on students' creativity. Specifically, the model assessing creativity as an outcome variable found that both school support and school resources were significant predictors, with positive relationships identified.

However, when examining the relationship between creativity and math achievement, the findings reveal that while creativity was a predictor of math achievement, its effect was relatively modest and did not significantly improve the model's fit when school-level factors were included. This suggests that, although school-level factors can influence creativity, their direct impact on math achievement, once creativity is accounted for, is less pronounced. Individual characteristics, particularly socioeconomic status (ESCS), played a more substantial role in predicting math achievement.

Overall, the findings highlight the importance of considering both individual and school-level factors in understanding how creativity relates to academic outcomes but indicate that creativity itself is not the sole or most powerful predictor of math achievement.

Future studies could address the role of creativity in the role of creativity in other sciences and conduct a study with other countries to understand whether creativity is not a good predictor for math achievement only in Brazil or whether it is a parameter that is repeated globally.

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AUTHORS' CONTRIBUTION

Author 1 - Design and development of the project, data collection, data analysis, writing of the text and review of the final version of the article.

DECLARATION OF CONFLICT OF INTEREST

The author declare that there is no conflict of interest with this article.

DECLARATION OF AVAILABILITY OF RESEARCH DATA

The entire dataset supporting the results of this study is available on OECD.org and can be accessed at <https://www.oecd.org/en/data/datasets/pisa-2022-database.html>.

DECLARAÇÃO DE DISPONIBILIDADE DE DADOS DA PESQUISA

Todo o conjunto de dados de apoio aos resultados deste estudo foi disponibilizado em *OECD.Org* e pode ser acessado em <https://www.oecd.org/en/data/datasets/pisa-2022-database.html>.

This preprint was submitted under the following conditions:

- The authors declare that the necessary Terms of Free and Informed Consent of participants or patients in the research were obtained and are described in the manuscript, when applicable.
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