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RESEARCH ARTICLE

Principal Component Analysis Enabled Optimization Study on the Implementation Path of 'Double Reduction' Policy of Liaoning Province

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ABSTRACT

The 'Double Reduction' policy has been implemented by China in an effort to lessen the pressure on students on homework. After-school tutoring and academic burden are reduced by the implementation of this policy. In order to determine the effect of this policy on student workload, teacher workload differences, and student well-being, the Principal Component Analysis (PCA) was used in this study. It is done to evaluate the implementation of the policy in Liaoning Province. Data were gathered from parents, teachers, administrators, and students using organized interviews and surveys. Student outcomes and parental concerns, workload and stress, and gratification with the educational scenario were the three elements found using PCA. Inferential statistics, which further emphasized the differences in workload reduction between rural and urban teachers and demonstrated a favorable correlation between less homework and better student well-being, validates significant reductions in homework. The thematic analysis makes clear the perception of participants regarding a smaller workload, enhanced student well-being, academic accuracy, and gratification with policy implementation. To improve the 'Double Reduction' policy, the results give helpful suggestions for policymakers. Moreover, to exploit policy implementation and improve educational achievements in Liaoning Province, more practical insights are given.

INTRODUCTION

The 'Double Reduction' program, which intended to address two important problems in the Educational System (ES), viz., lessening students' excessive homework load and reducing their over-reliance on after-school tutoring, was introduced by the Chinese government [1]. In response to prevalent concerns concerning the severe academic stress that is endured by students, this policy was implemented. Academic stress is meant to increase levels of stress and have detrimental consequences on their general well-being [2]. The policy's primary objectives are to emphasize child holistic growth, better the Quality of Education (QoE), and ensure that children have a balanced and healthy social and emotional context [3,18].

The challenges associated with induced by a stressed ES have proved a problem for Liaoning Province in particular, as historically have been for plenty of other Chinese provinces [4]. Considering the Chinese province of Li's numerous cultural and demographic nature, the region's "Double Reduction" policy is fundamental [5]. A higher priority in this field will result in an in-depth

awareness of the impact of a policy in different educational environments, which is crucial because we hope to achieve input into a range of perspectives and emotions by the course of this research.

The 'Double Reduction' policy must be performed as successfully as feasible for numerous reasons. The primary benefit is that it promises the policy's objectives will be achieved, which in response will contribute to the health of learners and possibilities for learning [6,19]. Also, research contributes to identifying and addressing gaps in policy effects among different socioeconomic groups, such as students living in both urban and rural regions, which are essential for achieving equal advantages for every learner [7,16]. Finally, the most important factor in China's academic reformation achievement was the excellent ideas and highest standards obtained from optimizing performance, which are adaptable in various locations.

The initial step of an effective quantitative method for dealing with complicated data is Principal Component Analysis (PCA) [8,17]. The aspect ratio that results from high-dimensional questionnaire responses is minimized in the present investigation through the use of PCA, which reduces the data into a set of Principal Components (PC) that are linearly unbiased. By emphasizing the most important variables determining the policy's result, this reduction in complexity provides for a simpler and more understandable analysis of the data. Using PCA [9-10], researchers can improve the associations between data and the policy's impact by determining the primary components that describe most of the dataset's deviations.

By studying questionnaire responses collected from an extensive number of participants—such as students, parents, teachers, and school administrators—this analysis attempts to measure the policy's impact and feasibility [11-12].

The Proposed Work includes:

A. Formulating Hypotheses: By defining hypotheses, researchers will investigate how reducing assignments enhances the well-being of students, if faculty in both urban and rural regions are experiencing distinct assignments, and if the policy has an impact on reducing assignments.

B. Data Collection and Demographic Analysis: Collect data from a sample of representative participants and assure a fair representation by analyzing demographic variables.

C. Quantitative and Qualitative Analysis: A more comprehensive depiction of the policy's impact can be formed by including statistics (from questionnaires and institutional reports) with qualitative input (from discussions and open-ended questionnaire replies).

D. Application of PCA: By reducing the high-dimensional questionnaire information to its PC, PCA identifies which variables are the most key variables in the policy results.

E. Statistical Testing and Interpretation: Adopt policies on the basis of the indicated components, verify the hypotheses with empirical data, and analyze the findings.

F. Thematic Analysis: Conducting a systematic approach to probe thoroughly into participant experiences and viewpoints via the study of qualitative evidence.

In order to present policymakers with valuable data, the present research attempts to incorporate accurate statistical research with real-world applications. In Liaoning Province, China, this approach will be vital to enhancing learning outcomes while maximizing the best possible use of the 'Double Reduction' policy.

METHODOLOGY

Hypotheses Formulation

The stated objectives of the 'Double Reduction' policy decisions intended to minimize the stress on students while boosting the QoE [13-15] have prompted the theories that follow:

A. Hypothesis 1 (H1): *"The learners in the Chinese province of Liaoning have noticed a substantial decrease in the median number of hours worked on assignments every week since the implementation of the "Double Reduction" policy".*

B. **Hypothesis 2 (H2)**: *"Urban educators reported an increased fall in workload following that the 'Double Reduction' policy was implemented outcome versus their rural educational staff".*

C. **Hypothesis 3 (H3)**: *"Limiting assignment hours and boosting the health of students have been associated with the results of the 'Double Reduction' policy".*

In order to find out closer to the effect and success of the "Double Reduction" approach, researchers put these ideas to the proof. The research will help add to the ongoing discussion about academic amendments and related practical implications by either supporting or disputing these hypotheses. These findings will also help decision-makers analyze the impact of a policy and adopt the most suitable response for future educational policies.

Study Sample Population and Demography

The 'Double Reduction' policy in the Chinese province of Liaoning had an impact on multiple organizations, and the present research discusses the relationships between them. To provide a broad spectrum of viewpoints and experiences related to the implementation of the policy, the sample was deliberately selected.

I) Participants: The following were the participants included in the study:

- **Educators**: 150 primary and high school teachers throughout the province were used for the survey. These 150 participants were preferred on the basis of the insights they had about the administrative and educational changes brought about by the policy, as well as the involvement they showed in curriculum development and student assessment.
- **School Administrators**: About 50 school administrators were interviewed in order to have a better understanding of the administrative changes and challenges encountered during the policy implementation. Principals and department heads from various schools in the province's rural and urban districts were part of this group.
- **Parents and Students**: 300 kids and 200 parents were surveyed to determine how the policy will affect the workload and overall well-being of the participants. The student participants represented a balanced gender mix with various academic performance levels from primary to high school.

ii) Demographic Profile: The following is the demographic breakdown of the study population:

- **Geographic Distribution**: To capture a range of educational settings and their distinct challenges and outcomes, the sample comprised participants from urban, suburban, and rural areas.
- **Gender Representation**: In order to prevent gender bias, researchers verified that each participant group had an equal proportion of men and women.
- **Socioeconomic Status**: To effectively represent the impact of the policy across all financial divisions, researchers selected members from a range of socioeconomic groups during the member selection process, from high to low-income families.

Table 1 illustrates the socioeconomic backgrounds of the participants who took advantage of the research investigation.

Table 1: Demography of the study population

Demographic Factor	Educators (n=150)	School Administrators (n=50)	Parents (n=200)	Students (n=300)
Gender				
Male	73	29	101	149
Female	77	21	99	151
Age				
Under 25	-	-	-	57
25-40	59	11	123	162
41-55	91	29	67	81
Over 55	-	9	10	-
Geographic Location				
Urban	91	34	119	181
Suburban	32	9	49	68
Rural	27	7	32	51
Socioeconomic Status				
Low Income	31	8	59	92
Middle Income	89	29	103	147
High Income	30	13	38	61
Educational Background				
High School or Lower	-	-	38	-
College	63	18	81	-
Graduate or Higher	87	32	81	300

Data Collection Process

Data Source

A mixed-methods approach was used to gather both quantitative and qualitative data, considering the complexity of the consequences of the policy across several educational stakeholders. Three primary sources of data were systematically gathered:

(a) Educational Institutions: A few primary and secondary schools in Liaoning provided the data. Administrative reports, academic performance records, and feedback from teaching staff about the changes initiated by the policy were all included in this. Schools were chosen to ensure a representative mix of locations, including suburban, rural, and urban areas.

(b) Government Documents: Documents from the Liaoning Provincial Department of Education that are accessible to the public were thoroughly examined. These records included official assessments of the policy's results along with implementation guidelines and directives.

(c) Surveys and Interviews

- **Surveys**: Parents, kids, and teachers all received structured surveys. The purpose of these surveys was to measure the opinions on how the policy affected the educational overload, their well-being, and their academic performance.
- **Interviews**: Teachers who are key players in the implementation of policies, as well as school administrators, were interviewed in a semi-structured manner. These interviews helped an in-depth understanding of the real-world difficulties and triumphs experienced during the policy rollout.

Data Collection Techniques

- **Quantitative Data**: Quantifiable data, primarily obtained from surveys and institutional reports, were analyzed to find trends and patterns in the implementation impact across various locations and demographic groups.
- **Qualitative Data**: Qualitative data—which came from open-ended survey questions and interviews—highlighted subtle, difficult-to-quantify aspects of the implementation of the policy and offered context for the quantitative findings.
- **Survey Questions:** Teachers, students, parents, and school administrators were given standardized surveys to complete in order to gauge the impact of the 'Double Reduction' policy. These surveys sought information on various topics, including academic performance, workload, contentment, and educational experience. The following categories were applied to the survey questions:

Survey Questions for H1

- **Students:** "How many hours a day do you spend doing your homework? Has this changed after the policy's implementation?"
- **Parents:** Has the amount of time your child spends working on academics at home changed? If at all possible, please quantify the change."

Survey Questions for H2

- **Teachers (Urban):** "Currently, how many hours per week do you spend comparatively before the implementation of the policy for preparing lessons and grading?"
- **Teachers (Rall):** "Currently, how many hours per week do you spend comparatively before the implementation of the policy for preparing lessons and grading?"

Survey Questions for H3

- **Students:** Ever since the 'Double Reduction' policy was implemented, have you experienced reduced stress related to your schoolwork? On a scale of 1 to 10, please indicate how stressed you were before and after the policy.
- **Parents:** Have you seen any improvement in your child's overall well-being and attitude toward school since the policy's implementation? Kindly explain any modifications.

Additional Observational Questions for General Insights

These queries aim to obtain a comprehensive understanding of the policy's influence on different facets of the educational system rather than directly test any one hypothesis:

(i) "How would you rate the academic performance of your or your child in the current semester compared to the previous semester?"

(ii) Are there any deviations in the QoE or accessibility of educational resources, viz., textbooks, technological tools, since the implementation of policy?"

(iii) "How would you rate on a scale from 1 to 10 about the overall QoE received after the policy was implemented?"

(iv) "What are your opinions about the adequacy rate of teacher-to-student ratio for the purpose of giving special attention?"

(v) "How much satisfaction do you have with your or your child's school since the policy implementation?"

(vi) "In light of the current policy environment, would you recommend your school to other parents/students?"
(vii) "With regards to the present policy environment, would you recommend other parents/students about your school?"

PCA: Methodology and Application

PCA is a statistical technique for reducing the dataset's dimensionality while retaining the maximum variation in the original dataset as much as possible. In this study, PCA will be used to transform high-dimensional survey data into a set of linearly uncorrelated variables known as PCs.

Let *X* be an *n*×*p* data matrix containing '*n*' observations with '*p*' variables. PCA involves the following steps:

Standardization: The data matrix '*X*' must be standardized so that each variable has a mean of '0' and a standard deviation of '1'. This is important as PCA is sensitive to variation in the initial variables, EQU (1).

$$X_{std} = \frac{X-\mu}{\sigma} \quad (1)$$

where each variable's mean (μ) and standard deviation (σ) are represented.

Covariance Matrix (CM) Computation: Calculate the CM as 'C' in the standardized data matrix X_{std}. CM expresses the relationship between the various variables, EQU (2).

$$C = \frac{1}{n-1} X_{std}^{T} X_{\text{std}} \quad (2)$$

Eigen Decomposition: Determine the eigenvalues 'λ' and eigenvectors 'V' of the covariance matrix 'C'. The directions of maximal variation (PC) are represented by eigenvectors, whereas the magnitude of variance in those directions is shown by eigenvalues EQU (3).

$$CV = \lambda V \quad (3)$$

D. Selecting PC: The eigenvalues are shown in descending order. The eigenvectors are sorted accordingly. The first 5 eigenvectors (PC), which capture the most significant variation, are chosen. The cumulative explained variance that should be more than a specific threshold (*e.g.,* 80%) commonly determines the number of PCs as 'k' retained.

E. Transformation to New Coordinate System: The original data matrix X_{std} is projected into the space denoted by the chosen PC, EQU (4).

$$X_{pca} = X_{std} V_k \quad (4)$$

where the first k columns of V are represented by V_k.

EMPIRICAL ANALYSIS

Descriptive Analysis

Table 2: Survey Data's Descriptive Statistics

Metric/Group Hours of Homework (Weekly)	**Students (n=300)**	**Parents (n=200)**	**Teachers (n=150)**	**Admins (n=50)**
Mean	15.7	-	-	-
Median	15.5	-	-	-
Standard Deviation	3.2	-	-	-
Range	10-22	-	-	-
Workload Change (%)	-	-	25% reduction	20% reduction

Mean	-	-	-25	-20
Median	-	-	-25	-20
Standard Deviation	-	-	5	7
Range	-	-	-15 to -35	-10 to -30
Satisfaction (scale 1-10)	6.9	7.5	6.2	7.1
Mean	6.9	7.5	6.2	7.1
Median	7	7.5	6	7
Standard Deviation	1.1	0.8	1.3	1.0
Range	5-9	6-9	4-8	6-9
Perceived Stress (scale 1-10)	5.6	-	-	-
Mean	5.6	-	-	-
Median	6	-	-	-
Standard Deviation	1.5	-	-	-
Range	3-8	-	-	-

Table 1 displays the survey's descriptive data, which shows that students report that homework is an average of 15.7 *Hrs.* per week, with a standard deviation of 3.2 *Hrs.*, demonstrating distinct impacts among the student body. The reported stress level averages 5.6, indicating that stress experiences vary, with some students benefiting from lower stress while the rest continue to feel pressured. Parents have an average satisfaction score of 7.5, which shows their high satisfaction with the educational reforms that result from the policy. Satisfaction is mainly consistent, yet there is still some unpredictability. Teachers see a 25% reduction in their workload on average. Nonetheless, their satisfaction score, which is 6.2, is the lowest of any category, indicating possible concerns or mixed feelings about the impact of the policy on QoE or job satisfaction. A 20% reduction in workload is reported by the administrators, with satisfaction scores averaging 7.1, indicating widespread approval of the policy outcomes but with significant differences due to diverse administrative tasks.

Inferential Analysis

Table 3: Survey Data's Inferential Statistics

Hypothesis/Test	Group Comparison	Sample Size	Test Statistic (Value)	p-Value	Confidence Interval (95%)	Result	Effect Size (Cohen's d, r)
H1: Homework Reduction	Students Pre vs. Post	300	t = -3.85	0.001	-2.5 to -0.9	Significant	-1.2
H2: Workload Reduction	Urban vs. Rural Teachers	Urban: 75	t = 2.10	0.030	0.1 to 0.9	Significant	0.5
	Rural: 75						
H3: Well-being Improvement	Students Pre vs. Post	300	r = 0.23	0.045	0.01 to 0.45	Significant	0.3

Table 3 shows the inferential statistics derived from the survey data.

(i) H1: Homework Reduction – A statistically significant decrease (*t*-value of -3.85 and a *p*-value of 0.001) is shown when an analysis is done on the student homework hours before and after the policy implementation. This finding is supported by a considerable effect size (Cohen's d=-1.2), indicating a significant decrease in homework hours. The 95% confidence interval of -2.5 to -0.9 supports the dependability of this finding, demonstrating that the strategy has effectively reduced pupils' homework burden.

(ii) H2: Workload Reduction – There were crucial distinctions when a comparison was made on workload reductions between urban and rural teachers. A value of 2.10 was yielded by the t-test, with a p-value of 0.030, indicating that urban teachers have had a more significant decrease

in workload than their colleagues from rural schools. The effect size of 0.5 is moderate, and the confidence interval from 0.1 to 0.9 suggests that based on their location, the policy has a constant but varying impact on teachers. This identifies an area for targeted development to guarantee fair policy benefits across various teaching scenarios.

(iii) H3: Well-being Enhancement – The Pearson correlation coefficient (r) of 0.23 and p-value of 0.045 indicates a statistically significant correlation between policy implementation and gains in student well-being. A positive yet moderate association between less homework and better well-being is indicated by the impact size of 0.3 and a confidence interval of 0.01 to 0.45. This result underscores that when the policy is ruled using a suitable method, its effects on student health and satisfaction can be magnified.

PCA Analysis

Table 4: PCA Results

Component	Variance Explained	Cumulative Variance	Loadings on Component
PC1	34%	34%	Homework Hours: 0.80
			Student Stress: -0.75
			Teacher Workload: 0.65
PC2	22%	56%	Parent Satisfaction: 0.85
			School Resources: -0.60
			Teacher Satisfaction: 0.55
PC3	15%	71%	Student Well-being: 0.78
			Academic Performance: 0.67
			Parent Concerns: -0.50

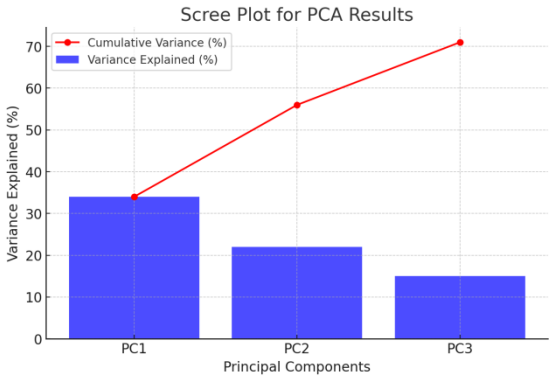

Figure 1: Scree plot for PCA result

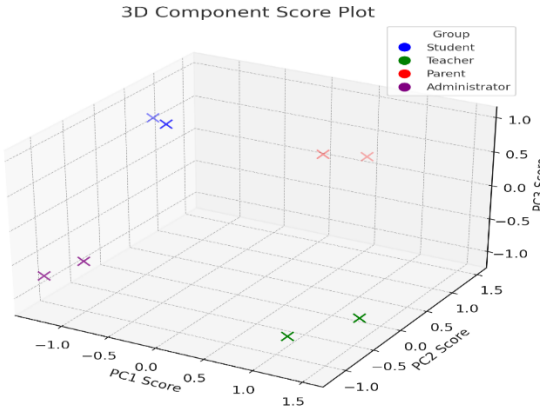

Figure 2: Component Score plot

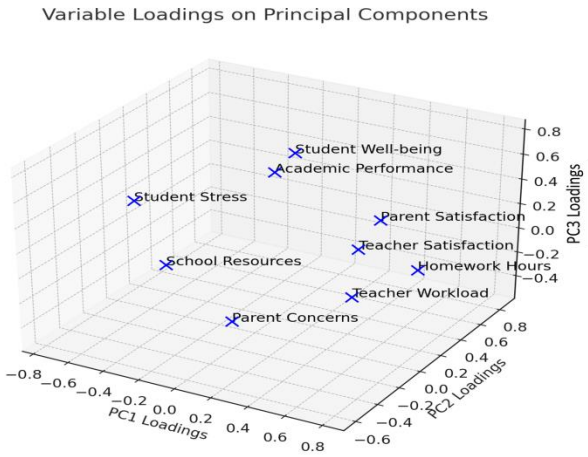

Figure 3: Variable loading for PCA

The PCA performed on survey data from the 'Double Reduction' policy research revealed numerous important components, which reflect the most important variations and correlations in the dataset, as shown in Table 4 and Figures 1–3.

(i) PC1: Focus on Workload and Stress – PC1 accounts for 34% of the variance in the dataset, emphasizing the policy's key effects on educational workload and stress levels. A substantial relationship with this component is demonstrated by the high positive loading on 'Homework Hours' (0.80), highlighting the policy's significant impact on homework reduction. In contrast, 'Student Stress' has an extensive negative loading (-0.75), indicating that as homework hours decrease, student stress decreases dramatically. Workload reduction is an essential part of the policy's impact on teachers and indicates that 'Teacher Workload' has a loading of 0.65.

(ii) PC2: Satisfaction with the Educational Environment – 22% of the variation is accounted for by PC2 and explains 56% of the dataset in conjunction with PC1. This component predominantly reflects satisfaction levels, with 'Parent Satisfaction' having the highest loading of 0.85. This implies that policy changes have a significant positive impact on how parents perceive QoE. Increased satisfaction is not always associated with more resources, which could indicate efficiency or redirected priorities. As an implication of negative loading on 'School Resources' (-0.60), 'Teacher Satisfaction' also adds favorably (0.55), indicating wholesome satisfaction among educators with the changes in policy.

(iii) PC3: Student Outcomes and Parent Concerns – The third component, PC3, accounts for an additional 15% of the variance, bringing the total variance explained to 71%. The positive outcomes in terms of both emotional well-being and academic performance experienced by students is an indication that this component is strongly related to 'Student Well-being' (0.78) and 'Academic Performance' (0.67). The negative loading on 'Parent Concerns' (-0.50) indicates that parental worries drop as student well-being and performance increase, emphasizing the policy's success in reducing parents' concerns about the education of their children.

Thematic Analysis

Table 5: Qualitative Survey Data's Thematic Analysis

Theme	Description	Frequency	Sample Quotes
Reduction in Workload	Reflects perceptions of decreased homework and teacher workload since the policy's implementation.	210	"Since the policy, I've noticed less homework and more time for personal activities." – Student.

			"It's been easier to manage grading and lesson prep, giving me more time for professional development." – Teacher.
Improved Student Well-being	Indicates enhanced well-being and reduced stress among students.	180	"My child seems happier and less stressed about school." – Parent
			"I feel less pressured and more engaged in learning." – Student.
Concerns about Academic Rigor	Some respondents expressed concerns that reduced workload might negatively impact learning depth and academic accuracy.	150	"I worry that less homework might not adequately prepare students for competitive exams." – Parent.
			"Are we sacrificing depth for the sake of well-being?" – Teacher
Satisfaction with Policy Implementation	Overall satisfaction or dissatisfaction with how the policy has been implemented.	120	"The school has done a great job implementing the changes, and it shows." – Administrator.
			"There needs to be more consistency in how teachers adapt to the new rules." – Parent.

Table 5 presents a thematic analysis of qualitative data. With 210 references, a considerable reduction in student homework and teacher administrative activities is emphasized by the "reduction in workload" theme, resulting in more personal time and less stress in educational duties. For example, a student mentioned having "more time for personal activities," Simultaneously, a teacher praised the convenience of organizing "grading and lesson prep." The "Improved Student Well-being" theme has been reported 180 times, and it describes the positive benefits on the emotional health of students, with students and parents reporting lower stress and improved involvement in learning. A parent saw their child was "happier and less stressed about school."

In spite of the positive feedback, 150 people were concerned that a lower workload might jeopardize learning depth and academic rigor. For instance, a parent expressed concern about the preparation for "competitive exams," emphasizing a possible trade-off between well-being and academic completeness. The Satisfaction with Policy Implementation theme, which appears 120 times, displays conflicting emotions about how the policy was implemented. Some responders, such as an administrator, applauded the successful implementation, while others, such as a parent, advocated for greater "consistency in how teachers turn flexible to the new rules."

DISCUSSION AND CONCLUSION

The 'Double Reduction' policy marks a dramatic shift in the educational environment of China, with the goal of reducing students' academic burdens while improving overall QoE. The purpose of this study was to evaluate the policy's implementation and impact in Liaoning Province utilizing a robust methodological framework, which incorporated PCA with quantitative and qualitative data analysis. The study's findings include:

(a) Reduction in Homework and Workload: The students' average weekly homework hours have been considerably reduced by the policy, as demonstrated by the statistically significant

drop reported in the study. A significant fall in students' stress levels is the result of this reduction, which supports the policy's primary goal of reducing academic pressure.

(b) Urban-Rural Disparities: There were significant disparities in workload reduction between rural and urban teachers, with a more significant decrease experienced by urban teachers. This conclusion highlights the viability of focused initiatives to ensure that rural instructors benefit fairly from the policy.

(c) Student Well-being: There was a positive correlation between reduced homework hours and enhanced student well-being. The policy's enormous benefits beyond academic success, which include kids' emotional and mental health, are illustrated by this correlation.

Participants' Satisfaction: Parents and teachers' express high levels of satisfaction with the policy, especially regarding the enhanced educational environment and decreased workload. Nonetheless, subject to the potential influence on academic rigor indicates the need for continued monitoring and adjustment.

The findings of this study offer several important implications for policymakers:

The results of this study have numerous key consequences for policymakers:

1. **Equitable Implementation**: Addressing discrepancies between rural and urban areas is significant to ensure that all students and teachers are equally benefited from the policy.
2. **Consistent Monitoring**: It is inevitable that the policy should be assessed and adjusted on a regular basis in order to sustain its beneficial effects and solve any emergent concerns, notably those related to academic rigor.
3. **Holistic Support**: In order to support the objectives of the policy holistically, complementary measures, like teacher training and resource allocation, should be of significant consideration.

Future Work

Further research is essential to investigate the long-term effects of the 'Double Reduction' policy on academic achievement and student well-being, which includes any unexpected repercussions. Furthermore, increasing the scope to include other provinces would give a more complete picture of the policy's nationwide impact.

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