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Technical Efficiency of Indonesia's Education Sector Before and During the COVID-19 Pandemic: A Data Envelopment Analysis (DEA) Application

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Abstract: The education sector is one of the areas impacted by the COVID-19 pandemic. Nevertheless, its management must continue to be implemented well and efficiently. The aim of this study is to examine the technical efficiency of the education field in Indonesia before and during the COVID-19 pandemic. The research period spans 4 years, from 2018 to 2021. This study focuses on the 33 provinces in Indonesia. The data analysis technique used is non-parametric efficiency analysis using Data Envelopment Analysis (DEA), and assumes Variable Return to Scale (VRS) and is output-oriented. Estimation results indicate that the majority of provinces (81%) experienced a decline in average efficiency scores during the pandemic. All of these provinces are located outside of Java Island. Furthermore, there are provinces that saw an increase in efficiency scores during the pandemic, namely East Java, Central Java, Lampung, Jambi, West Papua, and Yogyakarta. Meanwhile, provinces that did not experience a change in average efficiency scores before and during the pandemic are Riau, Jakarta, West Java, Banten, Bali, North Kalimantan, and Gorontalo.

Keywords: DEA, VRS, Output Oriented, Efficiency, Education Sector.

1. Introduction

The current economic development paradigm does not only emphasize increasing economic growth, but also improving the quality of human resources (Hibatulmedina & Rambe, 2022). Increasing economic growth and improving the social welfare of its citizens are things that absolutely need to be done by policy makers in bringing a country into a developed and globally competitive country (Afonso & Kazemi, 2016).

The wealth and competitiveness of a country in this era of globalization is determined by its ability to absorb and create knowledge. In the process, qualified human capital is needed in order to utilize the fast-growing technological developments to increase productivity. Therefore, the management and improvement of the national education system is very important to do (Aristovnik, 2012).

The COVID-19 pandemic that occurred in early 2020 had a huge impact. Lock downs carried out by various countries in the world have a direct impact on the global economy and disrupt various sectors including the education sector. In Indonesia, Large-Scale Social Restrictions (PSBB) carried out by the government disrupted the education process which was previously carried out offline or Face-to-Face Learning (PTM) to online or Distance Learning (PJJ).

The process of transforming the implementation of education with the use of technology certainly does not run smoothly, in practice there are various problems such as uneven

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infrastructure and different technological adaptability among education personnel. However, this transformation needs to be done considering the greater risk of doing PTM.

Based on the Regional Education Balance Sheet data in Table 1, it can be seen that most education indicators have increased and there are only two indicators that have decreased, namely the Primary School Pure Enrollment Rate (APM SD) from 91.287 to 91.132 and the High School Teacher Ratio from 0.074 to 0.049. Meanwhile, the allocation of education costs from both the State Budget (APBN) and the Regional Budget (APBD) has increased significantly. This shows that the education sector is seen as a very important sector.

Table 1. Regional Education Statistics

Variabels	Before the COVID-19 Pandemic	During the COVID-19 Pandemic
Literacy Rate	96.106	96.376
Expected Years of Schooling	13.091	13.175
APM Primary School	91.287	91.132
APM Junior High School	74.817	74.836
APM Senior High School	65.440	69.386
Primary school teacher ratio	0.060	0.065
Junior high school teacher ratio	0.068	0.071
Senior high school teacher ratio	0.074	0.049
APBD	10,817.651*	12,259.209*
APBN Education Fund	69.771*	138.834*
Percentage of Education Program Fund Allocation from APBD	0.147	0.226
Education Program Fund Allocation	1,682.381*	2,678.583*

Source: Regional Education Balance Sheet & BPS (processed)
**in billion Rupiah*

Given the important role of the education sector in the development of the economy and social life of the community (Gavurova et al., 2017), its management must remain equally good even in the conditions of the COVID-19 Pandemic. This is also inseparable from the amount of funds allocated in this sector, which reaches 20% of the APBN and APBD as mandated in Article 31 paragraph 4 of the 1945 Constitution, Fourth Amendment. To ensure that the resources invested in the education sector are well managed, their use must be regulated as efficiently as possible to get the greatest possible return (Gavurova et al., 2017; Haelermans & Ruggiero, 2013).

One of the ways to evaluate the performance and efficiency of education is the Data Envelopment Analysis (DEA) method introduced by Farrell in 1950. Efficiency measurement using DEA has been widely practiced in various fields such as economics, health and education. In the context of education, DEA helps measure technical efficiency, which, according to Mizala et al., (2002), refers to the ability of decision-making units (DMUs) to maximize output given a certain amount of input. Specifically, in the educational setting, output is typically measured by the results achieved, such as students' performance on standardized tests conducted nationwide.

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In the world of education, for example, research conducted by Aristovnik, (2012); Gavurova et al., (2017); Mou et al., (2019) examined the efficiency of the secondary school education system by comparing government spending in the education sector compared to educational achievements such as PISA (Program for International Student Assessment).

Meanwhile, several other researchers tried to measure government performance by comparing government spending with the impact of various socioeconomic indicators including education and health (Hibatulmedina & Rambe, 2022; Pula, 2022) economic performance, and economic (Baciu & Botezat, 2014).

Not only that, but some researchers also tried to measure the performance and efficiency of universities in various countries (Barra & Zotti, 2016; Martínez-Campillo & Fernández-Santos, 2020; Tran & Villano, 2018; Visbal-Cadavid et al., 2017). From the explanation above, the author tries to measure the performance of the education sector in Indonesia before and during the COVID-19 Pandemic. The author hopes that the results of this study can provide valuable input for related parties in order to advance education in Indonesia. Thus, the problem formulations in this research is How has the COVID-19 pandemic impacted the technical efficiency of Indonesia's education sector, and what are the implications for national education policies?

2. Research Method

2.1 Types and Sources of Data

The type of data used in this study is secondary data consisting of 33 provinces in Indonesia between 2018-2021. The data is obtained from various government institutions, namely the Regional Education Balance Sheet (NPD) data managed by the Ministry of Education and Culture and data from the Central Statistics Agency (BPS).

2.2 Research Variables

The DEA method is a method used to compare the Input and Output of the DMU to be analyzed. Therefore, the following are the Input and Output variables in this study:

2.2.1 Input Variables

The author uses four input variables in this study, namely the first, the total budget for the education sector, namely the total budget consisting of the APBN and APBD allocated by the government to finance the education sector in Indonesia. Some previous studies that used the total education sector budget input data include (Iskandar, 2021; Utami et al., 2021). Second, the ratio of elementary school teachers and students, Third, the ratio of junior high school teachers and students, and fourth, the ratio of high school teachers and students.

2.2.2 Output Variables

There are five output variables used in this study, namely the first literacy rate, namely the proportion of the population aged 15 years and over who have the ability to read and write Latin letters or other letters, several researchers who use this variable include (Rapiuddin & Rusydi, 2017; Trisyandi et al., 2016; and Utami et al., 2021);; Second, the expected number of years of

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schooling, which is a number that shows the expected length of schooling (in years) expected to be felt by children at a certain age in the future. Some researchers who use this variable include (Iskandar, 2021; Nuryadin et al., 2020; P et al., 2022); Third, the net primary enrollment rate, Fourth, the net junior high school enrollment rate, and Fifth, the net high school enrollment rate. Net enrollment rate is the proportion of school children in a certain age group who attend school at a level appropriate to their age group. Some researchers who use this variable include (Maududy & Aulia, 2018; and Rapiuddin & Rusydi, 2017).

2.2.3 Analysis Technique

DEA is a non-parametric mathematical programming for frontier estimation. In general, there are two approaches in DEA, namely the first CRS (Constant Return To Scale) developed by Charnes et al., (1978) and the second VRS (Variable Return to Scale) developed by Banker et al., (1984)

The DEA approach emphasizes a task-oriented approach and focuses more on an important task, namely evaluating the performance of decision making units (DMUs). The analysis is based on an evaluation of the relative efficiency of comparable DMUs. Furthermore, the efficient DMUs will form a frontier line. If the DMU is on the frontier line, then the DMU can be said to be relatively efficient compared to other DMUs in its peer group. In addition to producing the efficiency value of each DMU, DEA also shows units that become references for inefficient units (Rusydiana & Consulting, 2013).

$$Efficiency\ of\ DMU_0 = \frac{\sum_{k=1}^{P} \mu_k\, y_{ko}}{\sum_{i=1}^{m} v_i\, x_{io}} \qquad \text{.....(1)}$$

Source: (Rusydiana & Consulting, 2013)

Where, DMU = Decision Making Unit; n = DMU to be evaluated; m = different inputs; p = different outputs; xij = amount of input I consumed by DMUj; ykj = amount of output k produced by DMUj. Since the 1980s, this approach has been widely used to measure the efficiency level of the national banking industry. This DEA approach is a non-parametric approach. Therefore, it does not require any initial assumptions of the production function. However, the disadvantage of DEA is that it is very sensitive to extreme observations. The assumption used is that there is no random error, deviation from the frontier is indicated as inefficiency (Rusydiana, 2013). In DEA analysis there are two models commonly used, namely the CRS model and the VRS Model

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a) Constant Return to Scale (CRS)

The CRS model is a DEA model that was first developed by Chraner, Cooper, and Rhodes (CCR model) in 1978. This model assumes that the ratio between additional input and output is the same (constant return to scale). That is, if there is an additional input of x times, then the output will increase by x times as well. Another assumption used in this model is that each company or DMU operates at an optimal scale. The formula of constant return to scale can be written as follows:

$$Max_{\mu k,vi} \sum_{k=1}^{p} \mu_k y_{ko} - \mu_o \qquad \text{.....(2)}$$

$$s.t. \quad \sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{i=1}^{m} \mu_k y_{kj} - \sum_{i=1}^{m} v_i x_{ij} - u_o \leq 0 \quad j=1....,n$$

$$\mu_k \geq \varepsilon, v_i \geq \varepsilon$$

$$k=1,....,p$$

$$i=1,....,m$$

Source: (Rusydiana & Consulting, 2013)

where the above maximization is technical efficiency (CCR), xij is the number of inputs of the i-th type of the j-th DMU and ykj is the number of outputs of the k-th type of the j-th DMU. The efficiency value is always less than or equal to 1. DMU whose efficiency value is less than 1 means inefficiency while DMU whose efficiency value is equal to 1 means that the DMU is efficient.

b) Variable Return to Scale (VRS)

The VRS model was developed by Banker, Charnes, and Cooper (BCC model) in 1984 and is a development of the previous model, CRS. Firdaus & Hosen (2014) explain that in this model it is assumed that the conditions of all DMUs are not the same or it can be said that not all DMUs operate optimally. Imperfect competition, financial constraints and so on may cause a company not to operate at an optimal scale. The mathematical model with the VRS approach is obtained through modification of the model with the CRS approach and remains guided by the general mathematical model of DEA as an equation in measuring the level of technical efficiency. By adding the convexity constraint into the equation, the mathematical formula becomes:

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$$Max.\ h_s = \sum_{i=1}^{m} u_i y_{is} + U_o \qquad \text{.....(3)}$$

$$s.t. \qquad \sum_{i=1}^{m} u_i y_{jr} - \sum_{j=1}^{m} v_j x_{jr} \leq 0 \quad ;r=1,....,N$$

$$\sum_{j=1}^{m} v_j x_{js} = 1$$

$$u_i, v_j \geq 0$$

Source: (Firdaus & Hosen, 2014)

3. Results and Discussions

The results of the estimation of technical efficiency in the education sector before and during the pandemic in Indonesia are shown in Table 2. In this study, the author uses VRS assumptions with an output-oriented approach. This means that the resulting estimation results will be output oriented, which means that by maintaining the same input, it must be able to get the maximum output.

Based on Table 2, it can be seen that the average technical efficiency of the education sector in Indonesia during the study period fluctuated. The highest average efficiency occurred in 2018, which was around 0.919, and the lowest average efficiency was in 2021, which was 0.829.

There are three provinces that always get an efficiency score of 1 in each research period, namely Riau Islands, Banten, and Gorontalo. These three provinces always consistently reach the efficient scale and are not affected by the pandemic situation. This means that these three provinces can use their inputs well to produce optimal outputs.

Furthermore, there are two provinces that are directly affected by the pandemic situation where the provinces always consistently score 1 before the pandemic but are never efficient during the pandemic. The two provinces are West Sulawesi and North Maluku. This means that the pandemic situation has a significant impact on education management in these two provinces.

Then, there is also one province that never reached the efficient scale before the pandemic but during the pandemic actually managed to reach the efficient scale, namely Special Region Yogyakarta. This means that the pandemic situation is a momentum for Special Region Yogyakarta Province to achieve efficient management of the education sector.

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Table 2. VRS DEA Efficiency Estimation Results

No	Provinsi	2018	2019	2020	2021	Mean
1	Aceh	0.619	0.638	0.589	0.598	**0.611**
2	North Sumatra	1.000	0.811	0.917	0.799	**0.882**
3	West Sumatra	0.811	0.749	0.781	0.779	**0.780**
4	Riau	0.853	0.887	0.804	0.775	**0.830**
5	Jambi	0.855	0.993	0.901	0.798	**0.887**
6	South Sumatra	0.971	0.880	0.950	0.753	**0.889**
7	Bengkulu	0.926	0.970	0.912	0.840	**0.912**
8	Lampung	0.880	0.856	0.944	0.763	**0.861**
9	Riau	1.000	1.000	1.000	1.000	**1.000**
10	SCR Jakarta	1.000	0.855	1.000	0.965	**0.955**
11	West Java	1.000	1.000	1.000	0.862	**0.966**
12	Central Java	0.831	0.767	1.000	0.731	**0.832**
13	Special Region Yogyakarta	0.972	0.953	1.000	1.000	**0.981**
14	East Java	0.812	0.802	1.000	0.691	**0.826**
15	Banten	1.000	1.000	1.000	1.000	**1.000**
16	Bali	1.000	0.958	1.000	0.999	**0.989**
17	West Nusa Tenggara	0.863	0.777	0.823	0.743	**0.802**
18	East Nusa Tenggara	0.893	0.848	0.780	0.722	**0.811**
19	West Kalimantan	1.000	0.922	0.962	0.860	**0.936**
20	Central Kalimantan	0.881	0.881	0.818	0.702	**0.821**
21	South Kalimantan	0.874	0.812	0.790	0.759	**0.809**
22	East Kalimantan	0.986	0.975	0.953	0.840	**0.939**
23	North Kalimantan	1.000	1.000	1.000	0.977	**0.994**
24	North Sulawesi	0.894	0.816	0.855	0.701	**0.817**
25	Central Sulawesi	0.868	0.914	0.829	0.749	**0.840**
26	South Sulawesi	0.822	0.834	0.795	0.745	**0.799**
27	Southeast Sulawesi	0.877	0.908	0.807	0.744	**0.834**
28	Gorontalo	1.000	1.000	1.000	1.000	**1.000**
29	West Sulawesi	1.000	1.000	0.900	0.886	**0.947**
30	Maluku	0.881	0.876	0.850	0.773	**0.845**
31	North Maluku	1.000	1.000	0.816	0.839	**0.914**
32	West Papua	0.967	1.000	1.000	1.000	**0.992**
33	Papua	1.000	0.999	0.983	0.973	**0.989**
	Mean	**0.919**	**0.899**	**0.902**	**0.829**	

Source: DEA Estimation Results with Deap 2.1 (processed)

Meanwhile, most provinces have fluctuating efficiency scores. Out of 33 provinces, there were 17 provinces or more than half of them that never received a score of 1 or more efficient during the study period. This shows that the development and equity of education in Indonesia is still a real challenge for the government. Based on Table 2, it can be seen that the provinces that have never reached the efficient scale occur outside Java, namely Sumatra, Kalimantan, Sulawesi, West Nusa Tenggara and East Nusa Tenggara where the education infrastructure is not as good as Java.

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The situation faced by each province is certainly different so that achieving equitable distribution of education output is not an easy matter. This situation is very complex because it involves many aspects so that to achieve the goal of inclusion of education output requires adequate resource time, and the active role of the community in it.

Table 3. Classification of Technical Efficiency Results for the Education Sector

No	Criteria	Province
1	Always efficient during the study period	Riau Islands, Banten, and Gorontalo
2	Efficient during the pandemic	Special Region Yogyakarta
3	Inefficient during the pandemic	West Sulawesi and North Maluku
4	Fluctuating	North Sumatra, SCR Jakarta, West Java, Central Java, East Java, Bali, West Kalimantan, North Kalimantan, West Papua, and Papua.
5	Never efficient during the study period	Aceh, West Sumatra, Riau, Jambi, South Sumatra, Bengkulu, Lampung, West Nusa Tenggara, East Nusa Tenggara, Central Kalimantan, South Kalimantan, East Kalimantan, North Sulawesi, Central Sulawesi, South Sulawesi, Southeast Sulawesi, and Maluku.

Source: DEA Estimation Results with Deap 2.1 (processed)

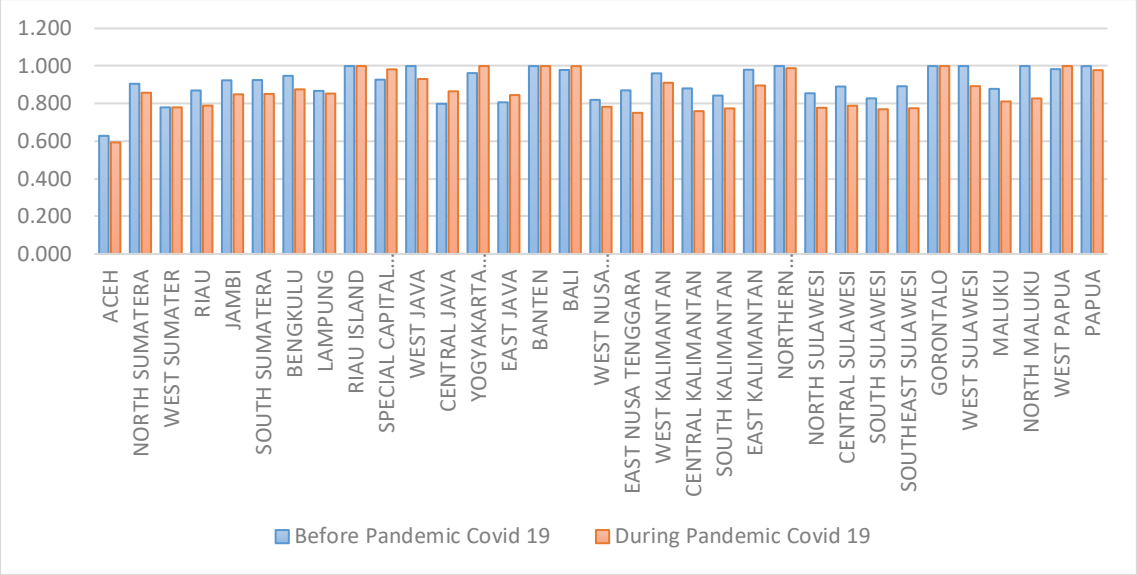

Figure 1. Average Technical Efficiency of the Education Sector Before and During the Pandemic

Based on Figure 1, it can be seen that in aggregate, 20 provinces (81%) experienced a decrease in the average efficiency score during the pandemic. These provinces are located outside Java Island. This shows that the pandemic situation has a significant impact on the management of the

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education system in Indonesia, especially provinces located outside Java Island which have limited facilities and infrastructure.

The sudden and massive emergence of the pandemic has caused diverse reactions, leading to distortions in various aspects including the world of education. In a relatively short time, teachers and other education personnel are required to adapt to the PSBB policy issued by the government to minimize the spread of the COVID-19 virus.

In practice, not all teachers and educational personnel can adapt well. (Anjelin & Purnomo, 2021; Astuti, 2021; Baety & Munandar, 2021) explain that online learning methods are still not effective. Furthermore (Astuti, 2021) explains that during the implementation of online learning in the COVID-19 pandemic era, some obstacles encountered include: teachers facing difficulties in effectively communicating with students, misunderstandings both between students and teachers and between parents and teachers, insufficient support equipment for online learning, unstable internet connectivity, and a decline in student motivation. Meanwhile, in rural and mountainous areas where there are many limitations in terms of facilities and quality of human resources, the situation is certainly even more difficult.

Table 4. Classification of average technical efficiency scores in education

No	Criteria	Province
1	Efficiency Score rises during COVID-19 Pandemic	East Java, Central Java, Lampung, Jambi, West Papua, Special Region Yogyakarta
2	Fixed Efficiency Score Before/During COVID-19 Pandemic	Riau, SCR Jakarta, West Java, Banten, Bali, North Kalimantan, Gorontalo
3	Efficiency Score drops during COVID-19 Pandemic	Bengkulu, Papua, South Sumatra, West Sumatra, Aceh, Maluku, East Kalimantan, West Kalimantan, North Sulawesi, Central Sulawesi, West Nusa Tenggara, Riau, Central Kalimantan, Southeast Sulawesi, North Sumatra, South Kalimantan, West Sulawesi, East Nusa Tenggara, North Maluku.

Source: DEA Estimation Results with Deap 2.1 (processed)

A total of 7 provinces received the same efficiency score before and during the pandemic. This means that the seven provinces were not affected by the pandemic situation and managed to adjust. Then, 6 provinces experienced an increase in efficiency scores during the pandemic. These provinces include East Java, Central Java, Lampung, Jambi, West Papua and Special Region Yogyakarta. This means that these six provinces can adjust well during the pandemic and successfully optimize their resources in the form of education budgets and student teacher ratios.

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The findings highlight significant disparities in education efficiency between Java and non-Java regions, emphasizing the need for targeted interventions. Improving digital infrastructure and equitable access to education in underdeveloped areas should be a priority, alongside teacher training to enhance adaptability to online learning systems. Provinces like Yogyakarta and East Java, which demonstrated improved efficiency during the pandemic, provide valuable best practices that can be adapted to other regions.

These measures are essential to ensure the education sector remains resilient, equitable, and continues to drive human capital development during crises. This study also has limitations. The analysis uses data from 33 provinces, which does not reflect recent changes in Indonesia's administrative divisions; future studies should update their scope to include the current number of provinces. Additionally, while DEA effectively measures efficiency, it does not account for qualitative aspects such as teaching quality or student engagement. Moreover, this study does not explore the causal factors behind efficiency changes, leaving opportunities for future research to identify drivers of efficiency and evaluate the effectiveness of specific policies. Addressing these gaps would provide more comprehensive insights into sustaining and enhancing efficiency in Indonesia's education sector.

4. Conclusions

The organization of the education sector must remain good and efficient even in pandemic conditions. This is because the education sector is a vital sector for the development of a country. Therefore, it is necessary to conduct an assessment to measure its performance and efficiency. Based on the results of the estimation of technical efficiency in the education sector using VRS assumptions and an output-oriented approach, the following conclusions are obtained:

a) The average technical efficiency of education sector in Indonesia during the research period shows fluctuating results. The highest average score occurred in 2018 which amounted to 0.919 and the lowest average efficiency score occurred in 2021 which amounted to 0.829.
b) There are provinces that always consistently get an efficiency score of 1 during the study, namely Riau Islands, Banten, and Gorontalo. Then, there are two provinces that were always efficient before the pandemic but never efficient during the pandemic, namely West Sulawesi and North Maluku. On the other hand, there is one province that was never efficient before the pandemic but was always efficient during the pandemic, namely Special Region Yogyakarta province.
c) Most provinces (81%) experienced a decrease in the average efficiency score during the pandemic. Most of these provinces are located outside Java Island where the facilities and infrastructure are not as good as in Java Island. However, there are also provinces that can adjust to the pandemic situation and even have better efficiency scores than before the pandemic, namely East Java, Central Java, Lampung, Jambi, West Papua and Special Region Yogyakarta.

d) Policymakers and stakeholders must recognize the importance of adopting region-specific strategies that address disparities in education efficiency, particularly by leveraging the lessons learned during the pandemic to create a more resilient and equitable education system.

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