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Research Article

Assessing the Impact of Mathematics on Human Capital Formation: A Comparative Study of Indian States

Dr. Srirupa Sinha[1], Dr. Sudip Mukherjee[2*], Dr. Anirban Sarkar[3]

[1]Assistant Professor, Department of Economics, Nagar College, Nagar, Murshidabad, West Bengal, India, sinhasrirupa14@gmail.com
[2*]Assistant Professor, Department of Economics, Dinabandhu Mahavidyalaya,Bongaon, West Bengal, India, bukanbabu@gmail.com, ORCID iD: https://orcid.org/0009-0009-0656-998X
[3]Professor and Head, Department of Management and Marketing, West Bengal State University, Barasat, West Bengal, India, anirban_sarkar77@wbsu.ac.in, ORCID iD: https://orcid.org/0000-0002-4691-5631

***Corresponding Author:** Dr. Sudip Mukherjee
*Assistant Professor, Department of Economics, Dinabandhu Mahavidyalaya,Bongaon, West Bengal, India, bukanbabu@gmail.com, ORCID iD: https://orcid.org/0009-0009-0656-998X

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ABSTRACT

This study examines how important mathematics education is for developing human capital and how it affects the standard of primary education in India.The study ranks 22 Indian states according to their mathematical learning outcomes for classes III, V, and VIII using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique. The results show that Punjab consistently ranks first in mathematics for all three classes, followed by Rajasthan. The study emphasizes the relevance of mathematics in strengthening the logical thinking, analytical, and problem-solving skills necessary for the creation of human capital and economic growth. The findings suggest that policymakers should focus on improving Mathematics education to enhance the quality of primary education and ultimately contribute to human capital development, economic growth, and sustainable development.

Keywords: Human capital formation, Indian states, Mathematics education, Primary education, TOPSIS method, Sustainable development.

1. Introduction

Education is the transformation of knowledge and the key to the success of human life. Education can be received formally and informally. When education happens within an institutional framework like a school, college, or educational institute, it is calle d a formal education system; when it occurs outside the formal education system, it is called an informal education system. The sources are daily experience, family, society, etc. Formal and informal education both teach so many things. In a formal educati on system, one can learn about many subjects. This paper tries to determine the impact of mathematics on all subjects and how it helps to enhance students' abilities. Students can apply Mathematics in formal and informal education systems. So, it is of great significance in education. Mathematics is a foundation of human thought, logic, and mental discipline. Mathematics is crucial in unders tanding other subjects like science, social studies, art, and music. Mathematical meaning is literally "things which c an be counted." Everyone today may think numbering is necessary in daily life. How could people rely on family, the number of children in a class, rupees in our pockets, runs in a cricket match, days in a week, months, or years if there was no such thing as mathematics?

You must be able to rely on addition, subtraction, multiplication, and division on a basic level.
(Algani, 2022). Creative thinking becomes a great thing in education. Creative thinking has increased as a result of recent developments in mathematics education.(Nasef2, 2021) . Moreover, it is a crucial factor to build up the human capital. This paper tries to find indicators that help to find the Learning Outcome Index based on Mathematics. This paper has six parts: 1. Introduction, 2. Objectives, 3. Mathematics and Human Capi tal, 4. Literature Review, 5. Methodology and Data Source, 6. Results and Discussion, 7. Conclusion.

2. Literature Review

Mathematics is vital for human life. Understanding Mathematics, the ability to calculate, and logical thinking help ensure a human's smooth running. Mathematics promotes a healthy brain and the skill to solve problems, enhancing creativity, analytical skills, and financial decision-making capacity. Mathematics makes a relation between human life and the rest of the world. School education is one of the best places to get equipped with Mathematics. Mathematical understanding is one of the scientific fields that has significantly advanced science and technology. Students must become proficient in mathematics at the elementary school level due to the significant role that mathematics has played in shaping human civilization (Kusmaryono, 2014). Mathematics is the branch of science that deals with shapes and numbers and is one of the subjects in the school curriculum. It has the most comprehensive application that cuts across many other disciplines. Any country's industrial and technological development depends on its ability to utilize knowledge of mathematics (Odiri, 2006). Mathematics is more than just a school topic; it is necessary for all daily duties.Math is a powerful tool with a universal language that has the same meaning everywhere, which is what makes it special. Languages separate us, but numbers bring us together. Working collaboratively on ideas and breakthroughs is made possible by math. Maths is essential for kids and adults. The quality of life for your family can be greatly enhanced by even the most fundamental math. (https://www.prodigygame.com/main-en/blog/why-is-math-important/, dated 15/01/2024).

That's why every student should have a sound knowledge of Mathematics. Underlying knowledge that contributes to the explanation of the world is revealed by mathematics. In addition to information, surveys, scientific observations, inference, reasoning, and evidence, mathematics has evolved into a broad field that includes numerical simulations of social systems, human behaviour, and natural phenomena. Counting, adding, subtracting, multiplying, and dividing are examples of basic math skills. (Yadav, S. 2019). In every sphere of life, Mathematics is needed. Mathematics can be applied in everyday life, workplace, and culture. In the twenty-first century, mathematics programs—especially those that focus on mental habits—are essential to teaching and learning. Given how crucial mathematics is to every aspect of daily life, students' abilities must be developed to maximize teaching and learning effectiveness and satisfy societal demands. (Elsayed, 2019). Mathematics, whose history is sometimes confused with philosophy, is important to our culture. NonEuclidean geometries have created new avenues for comprehending the universe, and mathematical logic theorems have exposed the limitations of the deductive method, just like cosmological and evolutionary theories have had a significant influence on how humans view themselves. Art also involves maths. The connection between mathematics and art has existed ever since the most well-known mathematician, Pythagoras, found numerical explanations in musical harmony. Because of these features, mathematics serves as a link between the natural sciences and the humanities, as well as between the two civilizations (Gupta, K. 2020).

Mathematics is necessary for human capital formation. Human capital means an individual's education, skill, experience, practice, and knowledge, making them potential and productive for the economy. Human capital is also an essential factor in economic development. The process of human capital formation can be initiated from the beginning by educating people. The subject of Mathematics helps to improve human capital. Mathematics aims to increase students' and employees' mathematical knowledge and skills. Mathematical knowledge enables human capital in businesses to make logical and reasonable decisions at all levels (Ukpata*, 2012). An exchange value is created from the individual's mathematical value. It measures an individual's human capital, which when added together, represents the human capital of an economy or system. Because of its market value, mathematics is a desirable commodity to buy, sell, and trade. These days, there may be a divisive rivalry amongst people over who can attend the most prominent math school to get a decent career and, consequently, a great future. The development of a political entity known as "the nation" and a political person known as "the citizen" are both impacted by mathematics education. (Tröhler, 2016). Therefore, as mathematics increases mental ability, helps to understand complicated calculations, and leads to analyses, the situation can be treated as an ingredient of human capital. Since proficiency in mathematics is crucial in assessing a country's degree in science and technology, which is a prerequisite for its advancement, it serves as the cornerstone for nation-building. Even if its influence is subtle and unseen, mathematics has a significant impact on science and society today. (JAYANTHI, 2019).

3. Objectives

This paper tries to find out the performance of different states in India in building up human capital by studying Mathematics in classes III, V, and VII, computing the rank of class III, class V, and class VIII for the subject Mathematics using the Topsis method for 22 different states of India. It will help to suggest some policy imperatives to improve the quality of primary education in India.

4. Methodology and Data Source

The learning outcomes of school education in several Indian states are analysed using data gathered from the secondary source National Achievement Survey (NAS) for the year 2021. Students in Class 3 are assessed on their learning outcomes in mathematics using twelve indicators. Class V and VIII mathematics learning results are measured using 15 and 20 indicators, respectively. The class-wise indicators are shown in Table 1.These factors aid in determining the pupils' learning outcome in mathematics.

Table 1: Indicators of Learning Outcome function of Mathematics for Class III, V, and VIII

Indicators of Learning Outcome function of Mathematics for class III	Indicators of Learning Outcome function of Mathematics for class V	Indicators of Learning Outcome function of Mathematics for class VIII
1.The ability to read and write numbers up to 999	1. Uses mathematical procedures in everyday contexts.	1. Uses the proper operations to solve problems involving huge numbers.
2. Uses place values to compare numbers up to 999.	3. Examines the area and perimeter of basic geometric shapes, such as squares, rectangles, and triangles, in relation to a particular shape as a unit.	2. Solves problems in daily life situations involving addition and subtraction of fractions/ decimals. (M606)
3. Uses addition and subtraction of three-digit int**e**gers, both with and without regrouping, to solve basic everyday problems.	3. Uses addition, subtraction, and forward or backward counting to determine the duration of familiar everyday activities. .	3. Determine the area or perimeter of rectangular objects in the surroundings, such as a chalk box's surfaces or the classroom floor.
4. . Creates and applies the multiplication facts (up to 10) in everyday contexts.	4 Use tables and bar graphs to display the gathered data and make deductions from it.	4. Create a table, pictograph, or bar graph with the information that has been provided or gathered, then analyse it.
5. Examines the circumstance or context and applies the proper number of procedures..	5. Recognises and writes numbers greater than 1000 that are used in their daily lives.	5. interprets fractional multiplication and division.
6. Using equal grouping and sharing, it explains the meaning of division facts and determines them through repetitive subtraction	6. Calculates and validates the sum, difference, product, and quotient of numbers using various techniques, such as traditional algorithms or breaking a number and then performing an operation	6. Solve problems related to daily life situations involving rational numbers.
7. Uses paper folding to recognise and create 2D shapes. Using straight lines, cutting paper on the dot grid, etc. .	7. Determine which part of a collection a given number corresponds to.	7. Simplifies issues involving the multiplication and division of large numbers by using an exponential representation of integers.
8. It uses a rule of a given shape to fill a specific region without any gaps.	8. Identifies and forms equivalent fractions of a given fraction.	8. Adds/subtracts algebraic expressions.
9. Determines relationships and uses conventional units, such as centimetres or meters, to estimate and measure length and distance.	9. Transforms fractions into decimals and the other way around.	9. Resolves issues with converting percentages to decimals and fractions.
10. Uses a clock or watch to accurately read the time to the hour	10. Angles are classified into right and obtuse angles, represented by drawing and tracing. (M509)	10. A unit square grid or graph sheet can be used to determine the approximate area of closed shapes.
11. Expands patterns in basic numbers and shapes. .	11. . Connects many commonly used weight, volume, and length units, and translates bigger units into smaller ones and vice versa.	11. Identifies different representative values, such as mean, median, and mode, for basic data from their everyday settings.

12. Uses drawings, tally marks, and visual representations to record data.	12. Calculates the volume of a solid object in units that are known.	12. Interpret data using bar graphs, such as the greater electricity consumption in winter than in summer.
	13. Solves questions involving money, length, mass, capacity, and time intervals using the four basic arithmetic operations	13. Extends the addition, subtraction, multiplication, and division properties of rational numbers by using patterns.
	14. Recognises the pattern in square and triangular numbers	14. Between two given rational numbers, find the other rational number.
	15. Gathers information on a range of everyday circumstances. Analyses it and delivers it in tabular and bar graph form.	15. The rules of divisibility 2, 3, 4, 5, 6, 9, and 11 are demonstrated.
		16. Find the squares, cubes, square roots, and cube roots of numbers using a variety of techniques.
		17. Solves everyday issues by applying a variety of algebraic identities.
		18. Verifies the parallelograms' characteristics and uses logic to determine their relationship.
		19. Determine the volume and surface area of cuboidal and cylindrical objects.
		20. Understands and creates pie and bar charts.

Source: NAS,2021

TOPSIS

For each criterion, the TOPSIS's function is to determine the separation between the positive ideal solution (PIS) and the negative ideal solution (NIS). The best option is determined by how near it is to the PIS. Nearest to the PIS and furthest from the NIS is the best option.

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The steps of TOPSIS analysis are given below:

The TOPSIS Algorithm

i. $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$ is the normalised decision matrix, which is created by dividing the raw criterion score (x_{ij}) by
the sum of the squared scores of all countries in a given category.

ii. Each element (r_{ij})of the normalised decision matrix is multiplied by its corresponding weight, w_j, to determine the weighted normalised decision matrix (T), which can be expressed as $(T) = [(t_{ij})_{n\times m}]$, where $t_{ij} = r_{ij} \times w_j; \sum w_j = 1$

iii. The subjective principle is used to calculate the weights. Weights are determined for each attribute by utilising the "entropy." The following are the stages involved in calculating weight:

a) The formula $a_{ij} = \frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}}$ is used to compute the normalised decision matrix.

b) The entropy value is then determined using the formula $e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} a_{ij} \ln a_{ij}$, $0 \le e_j \le 1$.

c) The average inherent information in each criterion's degree of divergence (d_j) is calculated as follows:

$(d_j = 1 - e_j)$

d) Each criterion's weights are determined using the formula $w_j \left(= \frac{d_j}{\sum_{k=1}^{m} d_k}\right)$

iv. The positive ideal solution (PS)$A^+$is determined by maximizing the benefit criteria and minimizing the cost criteria, i.e., $A^+ = \{t_1^+, t_2^+, t_3^+, .., t_m^+\}$, Where $t_j^+ = \{\max_i t_{ij}, j \in J : \min_i t_{ij}, j \in J'\}$; J is the set of benefit attributes and J' The set of cost attributes.The negative ideal solution (NS) $A^-$is determined by minimizing the benefit criteria and maximizing the cost criteria, i.e., $A^- = \{t_1^-, t_2^-, t_3^-, \ldots, t_m^-\}$, Where $t_j^- =$

$\{\max_i t_{ij}, j \in J' : \min_i t_{ij}, j \in J\}$; J is the set of benefit attributes and J' The set of cost attributes.

v. The L²-distance between criteria i and the worst condition A^- is calculated by

$d^- = \sqrt{\sum_{j=1}^{n} (t_{ij} - t^-)}$^2And the distance between the target criteria i and the best condition $A^+$is calculated by

$$d^+ = \sqrt{\sum_{j=1}^{n} (t_{ij} - t^+)}^2$$

vi. The "relative closeness" to the ideal solution (PS) is calculated as:

$C_i^+ = \frac{d_i^-}{d_i^+ + d_i^-}$; $0 \le C_i^+ \le 1$, $i = 1(1)n$

$\Rightarrow C_i^+ = 1$ If $t_i = A^+$ & $C_i^+ = 0$ if $t_i = A^-$

5. Result and Discussion

Using TOPSIS, the rank of different states of India is calculated for classes III, V, and VIII for Mathematics.

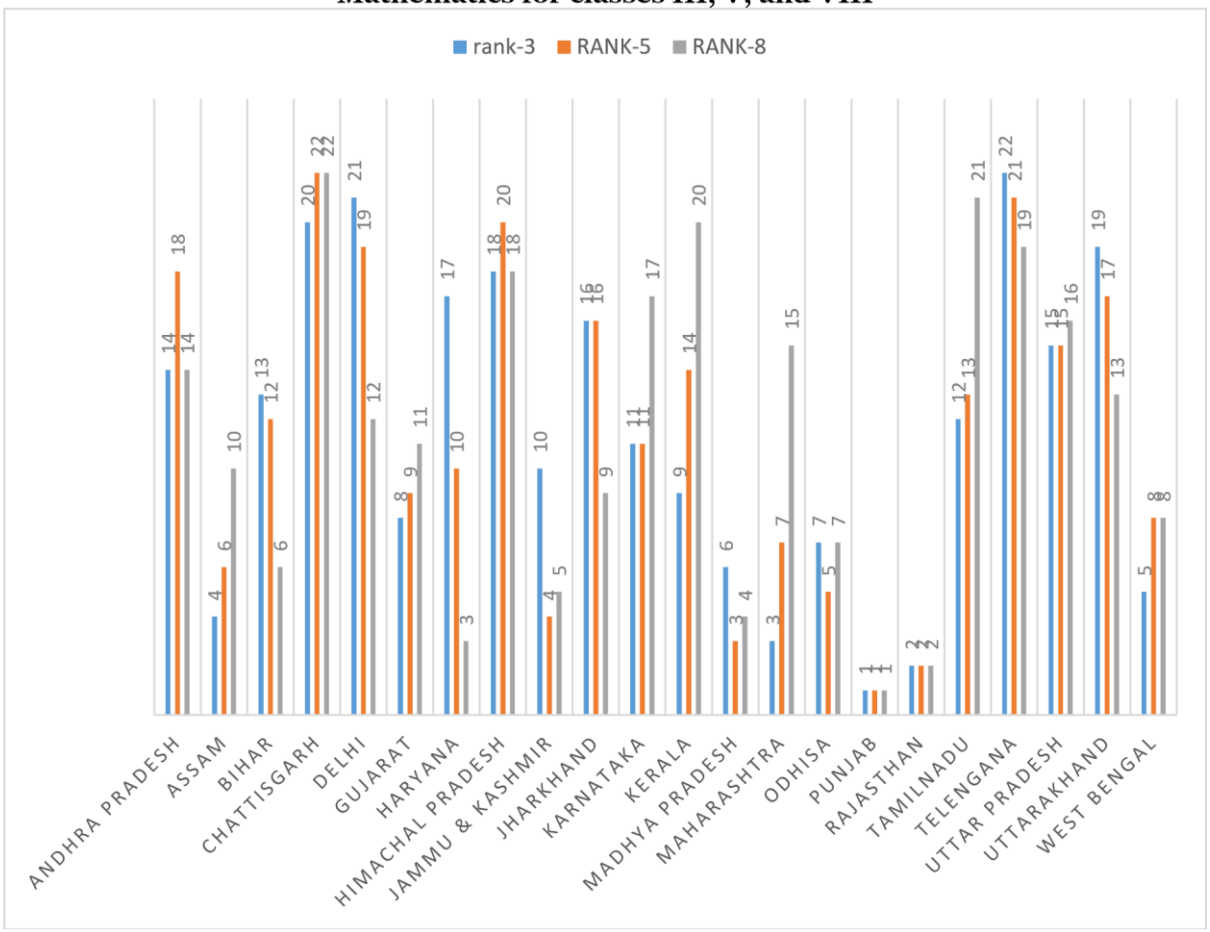
Table 2: Rank of different states of India based on the learning outcome of the subject Mathematics for classes III, V, and VIII

	Class-III		Class-V		Class-VIII	
States	**score**	**rank-3**	**score**	**rank-3**	**score**	**rank-3**
Andhra Pradesh	0.3982	14	0.2611	18	0.298467495	14
Assam	0.6229	4	0.5435	6	0.367345137	10
Bihar	0.4606	13	0.4143	12	0.478350647	6
Chhattisgarh	0.1131	20	0.0573	22	0.087111566	22
Delhi	0.1050	21	0.2384	19	0.353505688	12
Gujarat	0.5821	8	0.4651	9	0.367103952	11
Haryana	0.3499	17	0.4282	10	0.621287434	3
Himachal Pradesh	0.3212	18	0.1962	20	0.248477223	18
Jammu & Kashmir	0.5348	10	0.5849	4	0.500758518	5
Jharkhand	0.3529	16	0.2884	16	0.389733809	9
Karnataka	0.5108	11	0.4249	11	0.253446683	17
Kerala	0.5758	9	0.3268	14	0.15572913	20
Madhya Pradesh	0.6133	6	0.6216	3	0.58271564	4
Maharashtra	0.6659	3	0.5003	7	0.283131263	15
Odisha	0.6116	7	0.5486	5	0.446554981	7
Punjab	0.9591	1	0.9800	1	1	1
Rajasthan	0.7857	2	0.8049	2	0.815290075	2
Tamilnadu	0.4941	12	0.3341	13	0.101374359	21
Telangana	0.0832	22	0.0949	21	0.166137984	19
Uttar Pradesh	0.3747	15	0.3242	15	0.267315921	16
Uttarakhand	0.2426	19	0.2664	17	0.33079967	13
West Bengal	0.6229	5	0.4868	8	0.418334653	8

Source: Calculated by Authors

Punjab got 1st position in Mathematics for class III, followed by Rajasthan, Maharashtra, Assam, West Bengal, etc. Telangana got the last position among all 22 states in India.
It is also clear that Punjab got 1st position in Mathematics for class V, followed by Rajasthan, Madhya Pradesh, Jammu & Kashmir, Odisha, and so on. Chhattisgarh got the last position among all 22 states in India.
It is also clear that Punjab got 1st position in Mathematics for class VIII, followed by Rajasthan, Haryana, Madhya Pradesh, Jammu & Kashmir, and so on. Chhattisgarh got the last position among all 22 states in India.
The following diagram also represents the rank of states based on the learning outcome of mathematics for class III,V and VII.

Graph 1:Rank of different states of India based on the learning outcome of the subject Mathematics for classes III, V, and VIII



Source: Computed by Authors

From the above diagram, it is clear that Punjab consistently ranks in the 1st position in Mathematics for class III, class V, and class VIII. Rajasthan also has the consistency. It stands in 2nd position in Mathematics for classes III, V, and VIII.

6. Conclusion

In conclusion, this study demonstrates the crucial role of mathematics in human capital formation and its impact on the quality of primary education in India. The TOPSIS method provides a comprehensive ranking of Indian states based on their learning outcomes in mathematics, highlighting the strengths and weaknesses of each state. The results emphasize the need for policymakers to prioritize mathematics education to enhance the quality of primary education and ultimately contribute to human capital development. By improving mathematics education, India can foster a more skilled and productive workforce, driving economic growth and development.

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