Analyzing India's Science and Technology Policy – A Comparative Perspective

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Abstract
The Government of India has been formulating science policies since the 1950s, with the latest version of the policy formulated in 2020. The paper aims to understand the extent to which the 2020 Science Technology and Innovation Policy (STIP) addresses the critiques and limitations of its predecessor policy launched in 2013.Therefore, this paper compares the 2020 STIP document to the 2013 version across essential parameters such as the role of innovation and inclusivity, focus on informality, support for research and others. The paper also brings in global comparison by elaborating on science policies of Brazil and South Africa.

Keywords- Science, Technology, Comparative, Policy, Analysis, Innovation

Introduction

The former Prime minister of India, Jawaharlal Nehru, once said, 'It was science alone that could solve these problems of hunger and poverty, of insanitation and illiteracy, superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people'(Davar 2021).The global advancement in science and technology has proved effective, especially when it comes to facing the global pandemic due to the spread of COVID-19 in 2020.The development of vaccines, engagement of education digitally through online platforms, and the spread of information digitally are all made possible due to advances in communication and medical technology.

India has come a long way since the first science policy and has become far more advanced technologically to become one of the global competitors in the scientific world. The foresight of the Indian leadership that bringing overall development is possible only through advances in science and technology was clear since independence. Since the formulation of the first science policy in 1958, India has seen a considerable increase in research centers, science-oriented academic institutes, and advancements in atomic and space technology. The vast production of vaccines during the pandemic from India's Serum institute is evidence of progress in the field. While the advancement in science has borne fruits in terms of the country's development across vast areas, it has failed to eradicate root issues such as poverty and insanitation completely. There is a dire need to formulate a guiding science policy that is balanced in its approach and is deliberate in its effort to address the complex issues of our society. The need of the hour is to observe if the recently-formulated Science Technology and Innovation Policy of 2020 by the Department of Science and Technology, Government of India (GOI) attempts to address these pressing issues.

Therefore, the primary purpose of this paper is to see whether the Science Technology and Innovation Policy of 2020 addresses the complexity of various problems, be it research, socioeconomic, political, innovation, economic and societal issues, and provide some recommendations to better it. The paper starts by looking at the evolution of the science policies and then compares the 2013 STIP with the STIP 2020 through various themes. Subsequently, the paper elaborates the case studies of two developing nations—Brazil and South Africa—and evaluates their progress in science policy and discusses them with respect to the STIP 2020 document. Finally, the paper shares a few policy recommendations to augment the existing policy document.

Evolution of Science Policy in India

This section tracks the evolution of science policies in India from the first version in 1958 to the current version of 2020. The foundation for the first science policy in India was laid in 1958, following which there have been five such policies in the last six decades. The scientific policy resolution of 1958 set the pathway for scientific development in India, which led to technological advancement and development across various sectors. The key area of focus was the development of pure, applied, and educational science to develop the scientific temper of the country. Implementation of the policy led to the creation of many scientific labs and organizations such as ISRO (Indian Scientific and Research Organizations), new laboratories under DRDO (Defense Research and Development Organization),and expansion of the scientific community. However, the policy faced many hurdles in terms of social challenges, political will, and the exclusion of critical stakeholders such as the social-scientist in the decision-making of policy formulation and implementation(Sharma 1976). The policy aimed

to eradicate poverty, but it focused mainly on the development of urban areas and excluded rural areas, allowing deviation from its primary motivation(Ibid). The gap allowed for the formulation of the second Technology Policy Statement of 1983, which was driven by a motive to achieve self-reliance through the development of indigenous technologies. It recognized the role of technology in the betterment of people's living conditions. The policy brought science and technological development together under the same umbrella. It managed to gain an increase in funding to 0.7 percent of the country's GDP(Gross Domestic Product), and saw an increased publication from the R&D (Research and Development) community. The limitation towards the policy came in the form of the 1991 economic liberalization, which increased FDI (Foreign Direct Investment) and contradicted the ideology of self-reliance (Kaushik, Basha and Ganesan 2021).

The 1983 Technology Policy Statement was succeeded by the Science and Technology policy of 2003 that recognized the importance of funding in the research, development, and innovation to improve the scientific ecosystem and pushed for increased funding. It also mentions the need for the development of indigenous technology along with modern technology. The science technology and innovation policy implanted in 2013 emphasized the development of the science and technology-led innovation ecosystem. The policy was different in its motive to engage science and technology with innovation. It aimed to put India among the top five global scientific powers. However, the policy faced criticism in its approach to innovation and inclusion. The 2013 policy was finally succeeded by the STIP 2020, which aims to position India among the top three global scientific powers by doubling its GERD (Gross Expenditure of Research and Development) and increasing the GDP expenditure on research and development. The policy's implementation and impact will be seen in the upcoming years.

The STIP 2013 focused on the creation of an innovation-led scientific ecosystem. The policy document's primary feature was the incorporation of understanding of Innovation with the Science and Technology policy. It was driven with a significant aim to increase funding on R&D to 2 percent and increase the contribution of the private sector in it through various initiatives. The various stakeholders involved in the delivery of the policy are the concerned public and private bodies, the central ministries, the state government, the Research and Development body, the ministry of Science and Technology, and the NGOs (Non-Governmental Organizations) at the grassroot levels.

The policy received numerous criticisms such as the vagueness of the objectives regarding the ground reality (Mukhopadhyay 2015), lack of significant commitments from the public sector in research and development, and limited discussion on the National Innovation System in the policy document (Krishna 2013).The concept of innovation in the 2013 STIP has a linear approach(Sheikh 2014).The policy document has a narrow approach and fails to cover the complexity and nuances of India's developing economy(ibid) The one-pronged approach of considering innovation at par with R&D fails to consider the informal economy that plays a big part in the economy as a whole. The policy lacked the articulation of an inclusive innovation ecosystem (Joseph2013), the inclusion of innovation at the informal sector level (Sheikh 2014), and the lack of proper thought process in the implementation and the way forward, with no mention of the evaluatory bodies within the document (Mani 2013).

The next section elaborates the STIP 2020 policy document in detail.

Comparison of the STIP 2020 and STIP 2013 policie

The onset of the 2019 COVID-19pandemic brought global suffering, creating further economic, socioeconomic, health, and political challenges. The challenges also meant the showcasing of new opportunities for the scientific, academic, research, and industrial communities to link up and engage in new innovative measures to bring about a holistic solution to the complexity of the various problems faced by society at large. The 2020 STIP document is a re-visitation of the critiques and drawbacks of the 2013 STIP, and takes into consideration the above complex challenges at hand.

The STIP 2020 document is comprehensive document covering various issues across 11 chapters and discusses the aims, stakeholders, strategies, and mode of implementation. The driving force of the policy is the creation of a self-reliant, technologically-advanced nation that ranks among the top three scientific superpowers in the decade to come, and the doubling of spending and enrollment of full-time researchers every five years. It has a decentralized approach.

This section will particularly focus on the five essential themes of innovation, research and development (R&D), informality, inclusivity, and collaboration with stakeholders to compare the extent of changes brought about by the 2020 policy document. These themes are generally considered the primary components of any STIP policy.

a. Innovation

'Innovation is complex, uncertain, somewhat disorderly and subject to changes of many sorts' (Pinheiro 2015).

The 2013 document on Science and Technology was made unique from the predecessors of the policy through its focus on innovation. Its approach was to improve the research and the overall scientific temper of the country through innovation-led science policy. However, the detailing concerning innovation is very vague. The approach has been critiqued to be a linear process and fails to consider the overall complex nature of society (Sheikh 2014). The conceptualization of innovation is on par with research and development and does not include important ingredients such as the informal economy that is a significant part of innovation, especially in a country like India.

Compared to the 2013 policy document, innovation is dealt with as a separate chapter along with entrepreneurship in the STIP 2020 document. It is discussed in comparatively greater detail as to the importance, needs, and the implementation process. The 2020 STIP document tries to address the socioeconomic challenges and involves various stakeholders so that the policy is inclusive in nature. It aims to attain sustainable economic growth and higher global rankings in science and technology. The policy talks about increasing programs between academia and industry so that there is a mutual benefit and the development of the scientific temper of the country. Emphasis is given to promoting gender equity by encouraging women. Incentivized mission-oriented projects for addressing the regional issues through innovation clusters are discussed, which allows the realization of the SDGs (Sustainable Development Goals).

b. Research and Development (R&D)

The area of R&D has seen tremendous progress since the country's independence in 1947, leading to increased publishing of papers, new discoveries, and increased patents. As per the

National Science Foundation (NSF) Science and Engineering Indicators database 2018 ("S&E Indicators 2018 | NSF - National Science Foundation", 2022). India was globally ranked 3rd in scientific publication in 2018(White 2021). There has been a considerable jump in the number of higher education institutes and research organizations established in the country. However, to be among the top countries in R&D, there has to be backing from increased funding. There has been constant mention of the need to increase the funding towards research and development in order to take India to greater heights in terms of its contribution to global knowledge in the various predecessors of the science policy document. However, the percentage of spending has remained stagnant for a long time due to a lack of financial commitment.

The 2013 STIP document emphasizes the need to improve the GDP expenditure on research and development from 1 to 2 percent. However, it was observed that the spending for 2013 was just 0.74 percent (India, Technology & Infographic 2021).The goal to increase expenditure has failed to materialize due to a lack of commitments. The latest 2020 STIP also repeats the same need for improving funds from the GDP, but the spending has declined further from 0.74 to 0.65 percent (2018–2019). Regarding funding, the policy seems to be just a flashy one with big aims such as the previous one (ibid).

The STIP 2020 document is comprehensive in its goal setting and process of implementation. The policy specifies the areas of research topics to be engaging with that overall cover the spectrum from the rural to urban issues, climatic aspects, and indigenous issues to create a holistic knowledge system in R&D. The key area of focus is on the improvement of the foundational and translational research by taking up areas that will make India a leader in research, solving problems concerning rural communities, and issues that allow collaboration of industries and academia.

The policy brings about the concept of 'one nation, one subscription' wherein a single registration would suffice for a wide array of research papers would be accessible for free to researchers in India. It is inclusive in nature. This will increase the access to journals, domestic and international, for researchers and people who are interested in them. It removes the barrier of accessibility due to funding issues for researchers. The policy also mentions the formation of an online platform called INDSTA (Indian Science and Technology Archive of Research) that is STI regulated. It is an open book that shows the various outputs of research, provides notifications of opportunities in different research fields, and updates the vast science and technology community.

c. Focus on Informality

As per the Government of India report on Employment in Informal Sector and Conditions of Informal Employment (2013–2014), the informal economy contributes 50 percent of the GDP, and 90 percent of the total workforce are from this section of the economy (Ministry of Labor and Employment 2014). The role played by the informal sector in the economic growth of our nation is crucial. The 2013 STIP recognizes that the SME (Small and Medium Enterprises) has a meager presence in the Research and the Development area and highlights the need for some schemes to be instituted to encourage research in that area.

There is an interlinking of innovation with the informal sector in the 2020 STIP. This is done through incentivisation of private bodies and entrepreneurs who contribute towards innovation-based projects that are oriented towards finding solutions to social issues and challenges. The 2020 STIP document also recognizes the role of the informal sector but goes a step further. It draws out some mode of implementation at the ground level as well. It states

explicitly for reservation of part of the R&D fund towards MSME (Micro, Small, and Medium Enterprise) projects. It also clearly highlights the importance of the MSME in understanding the issues and challenges present at the ground level and their inter-linkage with academia and startups as a crucial mode to facilitate innovation.

d. Inclusivity

A national policy of any magnitude should be led by some inclusionary foresight. Inclusiveness brings in a holistic purview of things and ensures that decisions are taken in due consideration for the greater good of all.

The 2013 STIP mentions the Global Innovation System and highlights the need for the innovation system to be inclusive. It points to various instruments of STI for ensuring the inclusion of stakeholders. However, the approach towards inclusivity has been critiqued as not having a proper understanding of the various forms of exclusion while pushing for inclusive innovation.

The STIP 2020 document was published at the later stage of the first wave of the pandemic, when technology served as an essential tool be it in the form of information accessibility, discovering vaccines, or continuing with online education. The policy recognizes the importance of digitization and technology. It talks of expanding the online platforms of teaching and increasing the reach and the quality of education. Considering that a significant share of the country's population resides in the rural areas, it becomes crucial to first increase the reach of technology and electricity to the far corners of the country. The emphasis on indigenous technology and the policy's commitment towards developing and encouraging these forms through some entrepreneurial engagement contributes to the rural community development.

The document considers the varied forms of socioeconomic issues such as gender parity. It mentions the formulation of an E&I (Ethics and Inclusion) charter that will address issues related to socioeconomic disparity. Regarding the inclusion of women, it is mentioned that the representation of women is 30 percent in the evaluatory and the decision-making bodies. The document also talks about the inclusion of indigenous group representation. The policy aims to remove barriers to participation, promotion, and incentivization and ensure the recruitment, retention and effective engagements of excluded groups and marginalized communities (Ministry of Science and Technology, 2020)

e. Collaboration with Stakeholders

The major stakeholders in both the policies remain the same, involving the Central and State ministries, schools, higher education institutions, private and public organizations, MSMEs, NGOs, and the indigenous communities. However, the role and the mandate seem to change as the 2020 STIP document prepares for a more decentralized system as compared to its previous counterparts. Involvement in the grassroot and regional areas is considered as significant as involvement at the top level.

The formulation of the STIP 2020 document has been a bottom-up approach(Department of Science and Technology 2020). It has taken a four-track methodology wherein consultation with the public has been given major importance. This involved:

1. The drawing of ideas and perspectives from the stakeholders, i.e. public and experts
2. Categorisation of these ideas into various themes
3. Holding consultations with ministries and states and
4. An apex multi-stakeholder consultation.

The central and the state ministries contribute to allocating funds towards the development of science and technology. They strategize various schemes and regulate various institutions. Through the collaboration of multiple stakeholders, the centre and the states are expected to initiate different missions under the ADMIRE (Advance mission in Innovation, Research Ecosystem is a portfolio-based funding mechanism. It is a platform that supports innovation at the regional and national levels by funding projects that share the same motivation and goals as the STIP 2020) program that are innovation-oriented and contribute towards the scientific as well as holistic development of the community.

The 2020 STIP recommends the participation of people from the ministry of science and technology in revising the curriculum for the NEP (National Education Policy) 2020.This allows for the shaping of the science curriculum in alliance with the aims and motives of the STIP 2020. One of the primary motives of the STIP is the creation of a scientific ecosystem with a proper foundation.

The comparative analysis at the national level of the 2020 STIP with the 2013 STIP provides comprehensive insights on where the current STIP policy document stands with regards to its predecessor. To gain a holistic perspective and to bring in learning from the global implementation of such policy, case studies of science policies from two developing nations—Brazil and South Africa—have been elaborated upon in the next section.

Case study of science policies in Brazil and South Africa

The global development of science and technology has been unprecedented, and the policymaker's primary motive towards such progress is to resolve the many challenges faced by society such as poverty. The development and advancement of the science and technology of a nation are addressed through various indicators such as the R&D investment and innovation index among others. Innovation Index provides a ranking of countries based on a number of indicators to show where a country ranks globally in terms of innovation. Still, it does not necessarily cover the outcome of policy implementation. The Technology Achievement Index(TAI) is an indicator used globally, and through which a nation's actual progress in technological development can be monitored. It considers four parameters, i.e. creation of new technology, diffusion of new technology, diffusion of old technology, and increase in human skill(FAO 2002). India has a TAI score of 0.201 as per the 2001 UNDP report, thus ranking 63 out of the 72 countries (Desai, Fukuda-Parr, Johansson and Sagasti 2002).Developing countries such as Brazil and South Africa have a higher ranking of 43 and 39 respectively(Ibid).Brazil and South Africa, along with India, have a similar course of development in science and technology. Across other indicators such as publication, India does well but fails to perform well in the TAI rankings. This could be due to many reasons, but the most rational is the spread of technology to the rural community. A significant section of the global population resides in rural areas. Thus, the advancement of science should benefit not only the people in urban areas but also the rural community.

The paper will now look into the science policies of Brazil and South Africa as case studies, taking into consideration the evolution of the science and technology policy in the respective countries.

a. Brazil

Global industrialization led the development in science and technology during the 1930s in Brazil. With the establishment of educational institutes such as the University of Sao Paulo in 1934, there was a shift towards building a knowledge system that not only catered to 'applied research' but also 'basic research'.(Dias and Serafim 2011). Basic research allows for developing a knowledge system that leads to discovery and innovation. The 1950s saw a concentrated surge towards modernization and saw the institutionalization of the Science and Technology policy in Brazil. It led to the formation of two important institutes, the Campaign for Improving Higher Educational Institutes (CAPES) and the National Council for Scientific and Technological Development (CNPq), which served as funding agencies to develop the scientific temper of the nation. Through the CAPES and CNPq, thousands of students have graduated, contributing to the knowledge system(Dias and Serafim2011).The program initiated by them is hardly evaluated relative to other government-led programs. The government appears to strongly believe that ensuring autonomy and funding for these institutions will automatically result in the overall development. Proper evaluation strategy and monitoring is necessary to bring efficiency to the system. The policies focus on resolving issues related to social issues is significantly less. In 2008, only 1.1 percent of total spending from the S&T funding was used for research related to the redressal of social challenges (Thomas, Fressoli and Becerra 2012).

The period of inflation in the 1990s saw a reduction in the funding from government agencies, thus the science and research community had to greatly rely on collaboration with industries for funding(Reyes-Galindo, Monteiro and Macnaghten 2019). Based on the political scenario and the investments, there seems to be a continuous shift in the policy. Still, the primary motivation appears to remain unchanged because of the position enjoyed by the research community(Dias and Serafim 2011).

Considering the global initiation and work concerning climate change and ecological challenges, a group of scientists in Brazil came together independently to form the Brazilian Platform on Biodiversity and Ecosystem Services (BPBES) in 2015. Global strategy to tackle challenging issues such as climate change may not suit the implementation at the regional level, so the BPBES was roped in to develop reports based on regional contexts. Their work allows for the formation of networks with boundary organizations thus resulting in the formation of a boundary chain. Boundary organizations are various stakeholders that serve as a bridge of knowledge of science and policy. Their primary role is to create robust networks with various stakeholders of the science policy. BPBES develops an assessment report such as the Biodiversity on Climate Change special report, which is later shared with the concerned parties for re-evaluation to make the system efficient. The involvement of various stakeholders makes the assessment wholesome as does the bottom-up approach(Scarano et al. 2019).

Brazil's science and technology sector is performing well globally. Its ranking with regard to the Global Innovation Index stands at the 57th position in 2021(Innovation 2022). As per the Ministry of Science and Technology Brazil 2010 report, Brazil contributed to 50 percent of the overall scientific publications in Latin America (Thomas, Fressoli and Becerra 2012).

b. South Africa

A growing consensus on the need for a robust science policy in South Africa started to grow in the 1990s.The shift in the country's political scenario towards a democratic government led to some drastic changes. National level initiatives to construct a policy through public opinions and discussion were started in 1995, which led to the drafting of a white paper in 1997 that pointed out the flaws in the system and provided recommendations for the new science and

technology policy. The policy was developed under the framework of the National System of Innovation (NSI)(OECD2022). NSI rests its rationale in the variation of national institutions that shape the diffusion of technologies through the process of shared knowledge creation and the development of learning outcomes' (Lehmann and Schenkenhofer 2020). In 2002, the Department of Science and Technology (DST) was formed whose main aim was to transform South Africa from a 'resource-intensive to a knowledge-intensive' country(Swilling 2014). Later in 2007, the formulation of the ten year innovation plan was initiated by the Ministry of Science to fulfill the aim of the DST(Salami and Soltanzadeh 2012).

The work of implementation that resulted from the white paper is commendable. To enhance policymaking, the National Advisory Council of Innovation was formed in 1997.Its primary work was in guiding the various ministries concerned with science and technology development. Various such groups were formed to increase inclusivity and increase the involvement of different stakeholders in the policy processes. To train the unskilled and increase employability, the government has come up with a skills development act where they levy 1 percent of the staff payroll of all employers for training unskilled people. In relation to health care, the government is using its diplomacy tools to bring in Cuban doctors (OECD 2022).

The GERD spending has improved from 0.60 percent in the 1990s to 0.83 percent in 2017(World Bank 2017). The Global innovation index positions South Africa at 61st out of 132 countries(Office of Science and Innovation, Brazil 2022). South Africa is the leading country in terms of publication and research strength in the African continent but still falls behind the developing countries of India and Brazil in terms of global ranking such as the Innovation rankings.

Discussion

The STIP 2020 document is a comprehensive document attending to the major critiques of the STIP 2013 document. The STIP 2020 is a detailed and upgraded version of the 2013 document. Each chapter in the 2020 STIP document discusses various modes of guiding ideas and the key actors and how it plans to implement said ideas. There is an emphasis on evaluation and governance, which is very important for any policy.

Some goals of the STIP 2020 seem very ambitious and far-fetched, such as the doubling of full-time enrollment of researchers and Gross Expenditure on Research and Development (GERD).It also seeks to double the contribution of private sectors every five years and aims to position India among the top 3 global scientific powers which seems improbable.

One of the common things laid out in the policies is the increase in investment in science and technology. However, the GDP expenditure over the years either remains stagnant or decreases. Initiatives need to be taken to ensure contributions from the private sectors. The 'One nation One subscription' is an important scheme under the STIP 2020. It makes it unique in its effort to increase accessibility and its inclusive concept.

The growth of science and technology in developing countries such as Brazil, South Africa and India seems to be a favorable development. Considering that science and policy development primarily happened in the later phase of the 20th century, the contribution of these countries in terms of global scientific knowledge and discourse is commendable. India's STIP 2020 document coverage of the accessibility of academic resources through 'One nation one subscription' is a unique initiative considering the policies in place in the other two countries. The formulation of the STIP 2020 document, which involved discussion across stakeholders before the development of a national level policy, serves as an example of inclusivity. Brazil's

scientific community coming together and forming the BPBES could lead a way for scientific communities in other nations to innovate measures to raise concerns over ecological issues and other critical issues. The innovation funding and the formation of the National Advisory Council for Innovation is a crucial step towards achieving holistic science policy with a strong scientific and policymaking interface.

Policy Recommendations

The paper provides a thorough insight into the science and technology policy development in India along with developing countries such as Brazil and South Africa. A policy analysis paper without policy recommendations would not be able to provide learning for future policy reform. The following is a set of recommendations that might be beneficial for the betterment of science and policy development in the Indian context:

- The initial brains of the science-policy saw it as a tool to eradicate poverty, insanitation, and rural challenges. However, the Global Hunger Index released by Concern Worldwide and Welthungerhilfe ranked India at 101 out of 116 countries in the year 2021(Concern worldwide and welthungerhilfe 2021).While scientific developments have taken place, the majority of the country's population is still in the grip of poverty, hunger, and sanitation concerns. The rural community contributes towards approximately 65 percent of the population with agriculture as the major source of subsistence. Focusing on the use of technology in improving food production, its storage, and its marketing can help the farmers, the rural community, and the public. The science and technology policy should consult with departments such as the FICCI (Federation of Indian Chambers of Commerce and Industry) and the Ministry of Agriculture to engage in collaborative initiatives(FAO2002).Working in silos is not productive and inter-sector engagement should be pursued.
- Indigenous technology needs to be recognized in the legal and formal sectors. They serve as an important regional form of knowledge systems. The entrepreneurial engagements that the 2020 STIP policy mentions with regards to the promotion of indigenous knowledge systems and technologies should centralize the value of being human in their approach. They should strive to create livelihoods, empower the vulnerable to harness new technologies, and synergize economic, environmental, and social securities4.
- The assessment of the 2020 STIP policy in terms of its evaluation and implementation is very important and is rightfully given due importance in the policy document. There could be a specific independent body that communicates with the various stakeholders in preparing an assessment report. This has proved to be useful in the Brazilian context where the Brazilian Platform on Biodiversity and Ecosystem Services (BPBES) is an independent body that communicates with various stakeholders of the science policy and prepares an assessment report. It has prepared a few reports such as the Biodiversity and Climate Change special report. It has proven to be an important linkage between the various stakeholders(Scarano et al. 2019). Similar linkages could be forged in the Indian context to improve the evaluatory capacity of the body as well as collaboration among the stakeholders.
- The policy does not mention the pressing issue of brain drain where thousands of young students and scholars have approached foreign universities and settled abroad. There should be measures to engage in government-to-government agreements such

as the one in South Africa where they bring in Cuban doctors to improve their health systems. Initiatives should be taken by the government to reduce the human drain from our country (OECD n.d).

- The Indian scientific community could come up with metrics such as the TAI that measure the outcome of a policy. This could be done across different states and providing incentives for high-achieving states may in turn prove beneficial for the overall development of the state and the country.

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