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Trend and Development of School Science Education in India and China: A Comparative Study

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Abstract
Over the past few decades, the Asia-Pacific region especially the two most populated developing countries in the world, viz. China and India have made remarkable revolutions and developments in the School Science Education (SSE). The data available from international comparative studies like TIMSS and PISA revealed that Chinese-Taipei, Hong Kong (China), Shanghai (China), etc. provinces of China have outperformed in science competitions. This is a qualitative study, here the data are collected from various authentic sources and are analysed comparatively. In this study, the researcher will discuss how different educational policy reforms prioritized science education over the past few decades. This study also analyses the results from a few PISA science reports pointing out the major strengths and shortfalls of science education in areas like curriculum, pedagogy, examination system, and science teacher preparation in both countries that may be helpful for national educational policymakers, stakeholders or science education researchers to drive the School Science Education in a steady developed way under the 21st century learning. The authors sum up the article by pointing out the noteworthy policy reforms and changes. This comparative study is a valuable lesson for both the Chinese and Indian education systems as well as for the rest of the developing countries in the world.

Keywords
School Science Education (SSE), TIMSS, PISA, Policy reforms regarding SSE

1. Introduction
In an era of globalization, there are many factors such as the rapid flow of information exchange, innovations, and intelligence in Mathematics and Science that play a vital role in uplifting a nation's economy. There are many differences like socio-political-cultural systems, and educational structures exist between India and China. Both India and China have made notable improvements in science and technological education in the last few decades by modifying their educational policies, curricular goals and reforms, innovative pedagogies of science teaching-learning, etc. However, China has outperformed in primary and secondary education over India (Agarkar, 2017). The data available from international comparative studies in science like Trends in International Mathematics and Science Study (TIMSS, 2019) and Program for International Student Assessment (PISA) suggests that different provinces of China performed very well in science competitions in last few decades (OECD, 2010, 2013, 2016b, & 2019).

1.1 Importance of the Study
The present study focuses on the school science education (SSE) system at primary and secondary levels in India and China through a comparative approach. In the present era of globalization, every country tends to improve its different aspects of development including education by sharing the experiences of advanced countries. That is why various organizations are exercising and giving much attention to comparative studies.

- The present study focuses on the chronological development of SSE and highlights the contemporary features in India and China.
- Both China and India are the two most populated (Total population by countries, 2023) developing country in Asia and started their SSE reforms journey in the late 1940s.
- Over the past three decades China has reformed their school educational policies, science curricular goals, standards in a very planned and successful way (Asia Society, 2006).

- Students from different provinces of China consistently outperformed India in international science competitions like TIMSS, PISA (Table 1), and ISO. So, a comparative study is important.

1.2 Historical Overview of School Science Education in India and China

1.2.1 India

Since independence India has given importance to science education. After independence, the University Education Commission (1948) first emphasized the inclusion of general science as a course at the secondary level (p.108). In 1953, the Secondary Education Commission (1953) recommended that science teaching should be compulsory at both secondary and higher secondary levels. In 1958, the scientific policy of resolution stressed the development of science as well as scientific research to strengthen the nation based on science and technology. The National Council of Educational Research and Training (NCERT, founded in 1961) has a separate department for science education to look after the healthy progress of SSE. Education Commission (1964-1966) (1966) advocated for the integration of science education starting from the primary level as Environmental Science. According to NPE-1968, "Science Education should be an integral part of general education till the end of the school stage". NPE-1986 addressed as "Science Education for All". NCERT published five different National Curriculum Frameworks (NCFs) in the years 1975, 1998, 2000, 2005, and 2023 (NCERT, 1975, 1988, 2000, 2005, 2023). NCF-2005 (2005) provided the framework for present school education programs like making syllabi, textbooks, and teaching practices in Indian schools.

The latest policy document was produced by the Ministry of Human Resource Development (MHRD) as National Educational Policy 2020 (NEP-2020). NEP-2020 recommended reshaping science education according to global standards in the context of learning outcomes, pedagogical innovations, and curriculum with a flexible approach and focused on creativity and innovation.

The government of India very recently published the draft of the National Curriculum Framework- 2023 (NCERT, 2023). The new textbooks and curriculum will be published following NCF-2023 and taught very soon in Indian schools.

1.2.2 China

In 1915, the first science society was established by a group of Chinese researchers studying science and technology at U.S. Universities (Wang, 2002). Over the time period 1949-1978, in the People's Republic of China (PRC) science was integrated into Chinese culture. After 1949 there was a rapid change in science education access from the elite class to all (Ren, Yen, & Li, 2012).

In 1958, the China Association for Science and Technology (CAST) was established by merging two organizations viz., the All-China Federation of Natural Science Societies and the All-China Association for Science Popularization. At that time 'science popularization model' in China became famous. CAST helped in accelerating scientific literacy and technological development throughout the country (CAST, 1958).

However, in the period 1966-1976 almost a decade-long 'cultural revolution' (Li, 2001) caused a daunting period in the Chinese Education system. For example, several important components of secondary science content (like the steam-operated engine, the engine runs by internal combustion, and the motor runs by electricity, etc.) were reduced from the syllabus in most regions of China. After that in 1978, several policies of reforms were introduced by the Communist Party of China (CPC) in mainland China. CPC again introduced Russian theories of pedagogy along with Education Science from North America and further Pedagogies of Europe and its' reflection was evident as "pedagogy-didactics" in the disciplines of Physics, Chemistry, and Biology textbooks that were used for science teachers (both preservice and in-service) preparation system (Bangping, 2015).

From the 1980s to 1999 Chinese SSE went through a remarkable change in syllabus in primary science and Physics, Chemistry, and Biology at lower secondary (grades 7-9) as well as in upper secondary level (grades 10-12). At the beginning of the new millennium in 2001 Ministry of Education (MOE, 2001) published a leading plan entitled "Framework for Basic (i.e., primary and secondary) Education Curriculum Reform". In 2002, a new curriculum standard for primary science (grades 3-6), for junior high school integrated science (grades 7-9) also for Junior high school science (where Physics, Chemistry, and Biology were taught separately) were published. Senior high schools (grades 10-12) Physics, Chemistry, and Biology curriculum standards were published by MOE in 2003 (Bangping, 2015).

To maintain global science education standards China implemented different policies like the "National Science Literacy Action Plan" (also known as the 2049 plan), "Guidelines for National Science Literacy Action Plan (2006-2010-2020)", "Implementation of National Science Literacy Action Plan (2016-2020)", and keeping in mind to enhance and inculcate scientific literacy among Chinese citizens, K-12 children and beyond (Liu et al., 2017).

Chinese Ministry of Education (MOE) published a curriculum program and curriculum standard for compulsory education in April 2022 (MOE, 2022). The new ninth curriculum reform pointed out the backlogs of the previous eighth curriculum reform of 2001 and prescribed several remedies and changes required according to the demands of the present society. The new curriculum reform suggested for implementing the curriculum program in such a way that the localities and schools should have more power and autonomy. This approach of curriculum implementation leads to multiple modes of development at the national as well as the provincial level instead of "three dimensional goals" as mentioned in 2001 curriculum reform (Luo, 2023).

2. Research Gap

In the last few decades looking into China's very impressive progression many comparative studies have been performed with China. But till now no comparative study is reported between India and China in the context of school science education.

3. Motivation

To fill the research gap, we initiate to present a comparative study between India and China in the context of school science education.

4. Objectives

The major objectives of this study are-

- To investigate the evolution and reform of policies related to science education at the school level in India and China and to make a comparative study.
- To analyse the structure and important features of science education at the primary and secondary levels of India and China.

5. Materials and Methodology

Comparative research designs for qualitative studies are described as follows:
Few-country (two) comparison" (Lor, P. (2018), p.35), Case-oriented studies, Document analysis, and Content analysis.

a) General methodology: *Qualitative study,*
b) Methodology: *Few-country comparison,*
c) Comparative method: *Document analysis, Content analysis.*
d) Research materials: *Government documents, books, edited books, conference papers, peer reviewed journals.*
e) Data collection process: *Multiple procedures consisting of studying journals (print and online), books, book chapters, policy documents, and reports of the commissions were used.*
f) Data analysis: *The study employed a current document-based analytical approach. For Analysing the collected data historical and sociological strategies were adopted.*

6. Major Findings

6.1 Contrasting school education systems of India and China

6.1.1 Standards and Alignment of SSE

China has a national standard for science education at three levels of schooling viz. primary, lower secondary, and senior secondary level. Those standards were revised and enriched from time to time and subsequently taught at school to master the topic (Wang, 2002).

In India, there is also a standard published by NCERT as "National Curriculum Framework 2005 (NCF-2005)". All the educational boards (both central and state-run) strictly follow the science curricula at different levels of school education as recommended by NCF-2005.

6.1.1a Science Curricula at Different Stages in China

The following curriculum guidelines and structures were regulated by the Chinese Govt. till June 2019. The Chinese SSE was divided into five levels for the science curriculum (Chiu, 2007).
Level 1 (Grades 1-2): 'Life curriculum' including social studies and science.
Level 2 (Grades 3-4): Integrated science
Level 3 (Grades 5-6): Integrated science
Level 4 (Grades7-9): Integrated science but most of the schools in China prefer to teach physics, chemistry, and biology separately.
Level 5 (Grades 10-12): Individual disciplines viz., Physics, Chemistry, Biology, and Earth Sciences.

MOE presented a revised new curriculum reform and standard for elementary education to provide a guideline for developing its quality in a balanced manner. According to the new reform science will be taught as early as grade 1, and interdisciplinary contents will be added more in the curriculum with a proper design how to achieve depth in a subject within a specific time period (MOE, 2022).

6.1.1b School Science Curriculum in India

Primary stage (classes 1-5): As per the recommendations of NCF-2005 science and social science were integrated as 'Environmental Studies' along with health as an important component.

Upper primary stage (classes 6-8): NCF-2005 recommended that the children at this stage should learn the principles of science by doing hands-on experiments; here integrated science approach is also taken.

Secondary stage (classes 9-10): According to NCF-2005 science at this stage is taught as a composite discipline. NCERT made a sincere effort to make syllabi, and textbooks for science in an integrated manner i.e., Physics, Chemistry, and Biology altogether.

Higher secondary stage (classes 10-12): Science subjects are taught separately and emphasis is given on experiments and the problem-solving approach. In the present scenario, the syllabus gap between the secondary and higher secondary stage is minimized. In each discipline, core topics with in-depth concepts are included and at the same time burden of inclusion of the huge number of topics has been avoided.

In the NCF 2023 draft, it is recommended that there will be no hard separation between science arts and commerce; students can choose science subjects with arts or commerce at the higher secondary level.

6.1.1c Curricular Goals of Science Education at the School Level in China

The goal of the science curriculum at primary and secondary levels is mainly to develop scientific and technological literacy for all students. Eight competence indicators for students in grades 1-9 were mentioned in the curriculum guidelines (MOE, 2001).

(i) Knowing and understanding scientific and technological phenomena.
(ii) To develop process skills scientifically.
(iii) Understanding the nature of science.
(iv) Making able to apply scientific knowledge and methods in daily life situations.
(v) To develop thinking and problem-solving approaches scientifically.
(vi) To make a design according to people's needs and produce the required product accordingly.
(vii) Understanding the development of science as well as technology and the relationship of science & technology with society.
(viii) To develop a scientific attitude.

In 2017, MOE published the curriculum reform guideline for setting up the standard of elementary science education. The main focus of this curricular guideline was to develop scientific literacy and the formation of a strong base of science learning with an everlasting approach among elementary school children. This curricular goal will be helpful for students competent enough when enter into workforce (Pei, 2019).

For grades 10-12 i.e., at the senior secondary level priority is given as core competencies. So, mastering each science discipline becomes the vital goal of this stage because, after graduation from the senior secondary stage, the students have to clear the entrance examination to get admitted to higher education seeking science as a major.

6.1.1d Curricular Goals of School Science Education in India

According to NCF 2005 the aims of science education are as follows:

- To nurture the curiosity of the child around his surroundings and the world.
- To engage them in the exploration of phenomena and hands-on activities to improve their cognitive and psychomotor skills.
- Basic language skills i.e., speaking, reading, and writing skills can be achieved not only for science but also through science in the primary stage of education.
- To make students understand scientific concepts by varieties of activities and experiments.
- To encourage group activities like a discussion with peers and teachers, surveys, and organizations of data displaying those through exhibitions.
- To make learners understand the historical and developmental perspective of science so that the learner should consider science as a social enterprise.
- To acquire the necessary theoretical knowledge with practical skills that will be helpful for taking entry into the world of work.
- To nurture the inherent curiosity, aesthetic and creative sense in science and technology.
- To inculcate the moral aspect of life like honesty, cooperation, and integrity through learning science.
- To develop 'scientific-temper' objectivity, and critical thinking aptitude of the child through science learning.

The latest NCF 2023 also stated the aims of science education having some common aims with NCF 2005. NCF 2023 suggested that science education will be helpful for students

- ✓ To develop their understanding of scientific knowledge i.e., theories, laws, principles and concepts of science.
- ✓ How to use scientific methods.
- ✓ To understand the historical and developmental evolution of science and scientific methods.
- ✓ To think and link science with other disciplines.
- ✓ To develop an understanding of the relationship between science technology and society.
- ✓ To develop a scientific temper.

6.1.2 Recent Reforms of the School Examination System

6.1.2a Current examination system in India

The Central Board of Secondary Education (CBSE) continuously looks after matters related to the changes, innovations, and reforms needed in the examination system. Right to Free and Compulsory Education Act 2009 (RTE Act 2009, section 16) (GOI, 2009) stated that there should be no detention in Elementary education. Continuous Comprehensive

Evaluation (CCE) and Summative Evaluation are running presently and there is no detention up to class 8. NCF 2005 recommendations regarding assessment systems in examination systems related to science subjects are as follows:

- For science experiments, learning activities, and technological modules, internal assessment must be done for school as well as secondary and higher secondary board examinations.
- The theoretical questions should be set in such a way that will be helpful to judge the critical understanding, practical skills, and problem-solving competencies of the students.

One of the most interesting changes in the examination system is the introduction of the semester system in grades 11 & and 12 (NCF draft, 2023).

6.1.2b Current examination system in China

After completion of 9 years of compulsory/basic education, students have to take 'Zhongka' (senior high school entrance examination). Zhongka, is also the Summative Assessment of 9years of compulsory education in China. Obtaining high marks in Zhongka ensures to take admission to the top high school of students' choice with cheaper fees also.

After graduation from senior high school, students who are willing to get admitted to colleges have to sit in 'Gaokao' (national college entrance examination). Gaokao is a very important and tough exam also for higher education-seeking students. English, Mathematics and Chinese are compulsory for Gaokao, so these are taught very seriously along with science major subjects.

The curriculum reform-2001, after nationwide implementation, focused on reducing the burden of the school students by changing the exam-centric evaluation system. For this, the state council officially published guidelines for reshaping the 'gaokao' system. In this guideline the high importance of standardized testing was reduced and instead of the former system a modern examination system was set up by comprising of standardized tests, extensive evaluation and specific admission criteria. This new system was not only helpful for the students to grow their self-confidence but also helpful for the teachers to improve their teaching skills (OECD, 2016a).

The report published by the 20th National Congress of CPC (Communist Party of China) advocated for "advancing educational digitization". In the current scenario all the central and local governments as well as schools giving importance on integrating curricular activities with digital resources and achieved a lot of success. Some schools utilize 5G, AI and other advanced technologies for evaluation classroom teaching learning and thus reducing the subjectivity in evaluation and increasing the objectivity with scientific acceptability (Li et al., 2023).

6.1.3 Science Teacher Education and Preparation

6.1.3a India: In India, teacher education programs are level specific and regulated by the National Council of Teacher Education (NCTE).

(I) Primary Teacher Education or Diploma in Elementary Education (D. El. Ed): [*Qualification-class 10+2 passed, duration 2years*]

- Curriculum and Pedagogy are included in this course so as to acquire the skill and competencies to become a trained elementary teacher.
- There is no specialization for science subjects teaching.

(II) Bachelor of Education (B.Ed.): [*Qualification-Graduation, Duration-2 years*]

- Only one method subject is provided for practice teaching.
- Future science teachers are trained and oriented in such a way that their skills and competencies of secondary science teaching ability are developed properly.

6.1.3b China: In 1994, after the implementation of the Teacher Education Law all the colleges and universities have the authority to train teachers from Kindergarten to High school level.

- China appoints specialist science teachers in grade 3.
- China has given rigorous effort in science teacher preparation in addition to the continuous professional development of science teachers.

MOE issued a detailed guideline for local governments to run huge science courses at middle schools. MOE instructed the schools how to emphasize on experimental teaching, ensuring hand on activities through experimentation by students with the help of teacher's regular guidance and supervision. It was also suggested by MOE for proper utilization of digital resources by increasing teaching learning timing, sharing enriched resources, and improving teaching skills, evaluation techniques, etc. (MOE, 2023).

6.2 PISA 2009, 2012, 2015 & 2018 Science Results in Focus

The Program for International Student Assessment (PISA) is conducted by Organization for Economic Co-operation and Development (OECD) and focuses on 15 years old young children's ability to use their knowledge and skills to face real-life challenges. Since PISA started in 2000(and is repeated every three years), India being a non-member OECD country participated in PISA-2009 (see Table 1) and ranked 73rd among 74 participating countries/ provinces.

Whereas Shanghai, Hong Kong, Chinese Taipei and Macao provinces of China performed very well and ranked 1st, 4th, 12th, and 15th respectively in the PISA-2009 Science test (OECD, 2010). China even after 2009 outperformed in

the consecutive PISA tests (OECD, 2013, 2016b, 2019) but India after the worst result in 2009 did not participate in the consecutive PISA tests.

Pramanik and Guha (2019), and Pramanik (2019) showed that China and the USA performed better in mathematics in the International Mathematical Olympiad, and PISA tests whereas India remained far behind.

Table 1 Comparison of results of PISA-2009 and onwards between India and China

	2009 (rank)	2012 (rank)	2015 (rank)	2018 (rank)	2022***
*B-S-J-Z(China)			518 (10th)	590 (1st)	'Not published yet'
Shanghai(China)	575 (1st)	580 (1st)			
Hong-Kong, China	549 (4th)	555 (3rd)	523 (9th)	517 (9th)	
Macao-China	511 (15th)	541 (6th)	529 (6th)	544 (3rd)	
Tamil Nadu (India)	348 (72nd)	**NP	NP	NP	
Himachal Pradesh(India)	325 (74th)	NP	NP	NP	
OECD average score	501	501	493	489	

N.B.*B-S-J-Z represents Beijing, Shanghai, Jiangsu, and Zhejiang provinces of China collectively.
** NP means not participated.
*** The last cycle of PISA was held in 2022 but PISA 2022 results have not been published to date.

6.2 Comparative analysis of science education between India and China

The comparison between school science education between India and China is shown in Table 2.

Table 2 Comparative analysis

	INDIA	CHINA
Years of Schooling	The current school education system according to NPE 1986 recommendation (p. 6) comprises 5 years of primary education, 3 years of upper primary education, 2 years of secondary education, and 2 years of higher secondary education i.e., 5+3+2+2 structure of school education (which was previously suggested by NPE 1968 as 10+2 system then also accepted by NPE- 1986 (1986). According to NEP-2020 the new curricular and pedagogical structure is (5+3+3+4) and a few states of India already implemented 5+3+3+4 structures of NPE-2020 (2020).	The **6+3+3** pattern is followed from primary to senior secondary level of school education.
Science education at the Primary stage or elementary science education	**Classes 1-5**: Primary stage Science and social sciences are integrated into 'Environmental Studies **Classes 6-8**: Upper primary stage, science contents are cross-disciplinary concerning NCF-2005. • Free and compulsory. • No detention as a whole so as in science also.	**Grades 1-6**: primary education. For grades1-2: Life curriculum. **Grades 3-6**: Integrated Science or General Studies (GS). After being revised in 2002 and enriched in 2011 GS became interdisciplinary comprising personal, social, and humanities education, science education, and technology education. • Primary and lower secondary education (grades1-9) is compulsory including science education. In 2017, MOE took four key strategies for developing elementary science education viz., increasing the teaching learning time of science education, inclusion of topics related to engineering and technology into science subject, formulation of stage wise design on the basis of learning difficulty level, and teaching science subjects with the help of advanced level understanding of a specific science content (Pei, 2019).

Secondary Education	**Classes 9-10**: general secondary stage. • Science is taught as a composite discipline comprising of physics, chemistry, and biology. • Science education is compulsory for all students at this stage. **Classes11-12**: Higher secondary stage. This stage is purely discipline-based. Science subjects (Physics, Chemistry, and Biology) containing in-depth concepts of the themes/topics without burdening of excessive topics. Higher secondary science is not compulsory. The secondary & higher secondary (classes 9-12) stage has detention policy. **NEP-2020 recommendations (MHRD, 2020)** for school science education reforms: • Empowering students through choosing subjects of their own interest from sciences, arts, humanities, languages, sports and vocational subjects. • Restructuring school curriculum and pedagogy in accordance with the 21st century learning skill: holistic, integrated, enjoyable and engaging approach. • Necessary steps will be taken to prepare enriched bi-lingual science textbooks and teaching-learning materials.	**Grades 7-9:** lower secondary stage. • Science is taught either as 'integrated science' or as discipline-based subjects viz. physics, chemistry and biology. **Grades 10-12**: senior secondary stage. • Science curriculum maintains the objectives 'literacy in science', 'inquiry-based teaching and learning of science' and 'nature of science' which were originally taken from "project 2061" which was in American science education reform documents (**AAAS 1989**). • Science subjects are taught separately to develop the core competencies of the student.
Initiatives for nurturing science talents and promoting competencies in international science competitions.	There are many schemes like the National Talent Search Scheme (NTSS), National Talent Search Examination (NTSE), Innovation in Science Pursuit for Inspired Research (INSPIRE), etc., a scheme to nurture and inspire young science talents by helping them financially. Homi Bhabha Center for Science Education (HBCSE) has taken the initiative of identifying and preparing extraordinary science talents for International Science Olympiads in different subjects. But India after failing to shine in PISA- 2009 is less interested in taking part or no such notable steps have been taken to promote the competencies of children in international science competitions. The Ministry of Education had decided to take part in PISA 2021 cycle (which was held in 2022), but due to the learning gap during the COVID-19 pandemic and post-COVID-19 scenarios, the Indian Government decided not to participate in PISA 2021 as well as even in next cycle of PISA 2025 (Mohanty, 2023**)**.	Taiwan International Large Scale Study Centre (TILSSC) providing funding since 2016 to coordinate and utilize the results of TIMSS, PISA, etc. international science examinations in order to reform their curriculum accordingly. Different provinces of China have been doing exceptionally well in the last three decades in the international science competition.

7. Conclusion

China faced many ups and downs over the past century. It can be pointed out that since the past few decades, China's trends of educational policy reforms including science education has emphasized globalization in a localized way i.e., although the main framework and objectives of science education imported from the West, they have institutionalized

these features sincerely maintaining their own culture and national pride. As a result, China is now on the frontline of global science education standards as well as a forerunner in the global economy. This is reflected in the excellent results in international science competitions like TIMSS, PISA, etc. These results in these tests help science educators, policymakers, and the Ministry of Education to revise curriculum, innovate pedagogy, etc. In the present scenario, China's policy reforms and developments influence other countries to a large extent and it will be very interesting to watch how the rest of the world follows and learn from China's experiences (Mahbubani, 2015; Hayhoe, 2017).

On the contrary, India being a developing highly economic emerging country is far behind China with reference to the international science competitions. There are many reasons behind this like lack of government initiatives, deficiency of curriculum standards as compared to high-performing countries like China, Japan, Singapore, etc., less infrastructural provision of doing hands-on experiments of scientific theoretical principles for better understanding of science concepts, lack of specialized teacher specially in the primary section, etc. initiatives like Taiwan International Large Scale Study Center (TILSSC) should be taken by Indian Govt. or private organizations to nurture and promote science talents and offer them orientation towards international science competitions.

In 2020, India launched a New Education Policy 2020 (MHRD-2020). NEP-2020 mentioned the pivotal role of an updated science curriculum to face the upcoming 21st-century challenges to the new world. Hope the huge changes (see Table 2) recommended by NEP-2020 will lead Indian science education to the frontline position in the world. States of India viz., Karnataka, Madhya Pradesh, and Assam have already implemented NEP-2020 and other states are also in the way of implementation.

In the future, a comparative study on the philosophy of science education between India and China can be carried out.

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